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GUEST EDITORIAL

Will agri-environment schemes deliver substantial biodiversity gain, and if not why not?

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Summary

1. One of the main aims of agri-environment schemes (AES) is to increase biodiversity on farmland. Common conservation practice is to identify areas containing valuable resources (e.g. habitats, ecosystems and species) and then to protect them: 'protected area' schemes. AES differ from typical protected area schemes because they are often applied to small patches of land, such as field boundaries, and are sometimes located in areas where the target species does not occur.
2. AES require an enormous amount of funding and they have been applied across a large geographical area, i.e. the European Union. However, recent evidence suggests mixed results regarding the effects of AES on biodiversity.
3. It is hard to predict the consequences of AES on biodiversity because a number of factors are seldom accounted for explicitly. For example: (i) the occurrence of target species will vary between patches; (ii) there will be variation in habitat preference by species in different geographical areas; (iii) both optimal foraging theory and metapopulation theory predict that the distance from breeding individuals is likely to determine patch use; (iv) if resources are widely spread then the home ranges of some species may need to increase to encompass the multiple resources needed for breeding. The potential for these factors to affect the outcome of AES on biodiversity is discussed.
4. *Synthesis and applications*. AES are likely to increase biodiversity if a lower number of larger resource patches are provided, in contrast to current practice that promotes many small fragmented areas of environmental resource. One way of achieving this may be to run these schemes more like traditional protected area schemes, with farms or groups of farms managed using extensive farming methods. Such an approach negates some of the problems of current AES and may help to address a wider range of concerns held by different countryside stakeholders.

Key-words: agro-ecology, biodiversity conservation, Common Agricultural Policy, farmland birds, integrated farming systems, spatial ecology, wildlife and farmland

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Introduction

The role that agri-environment schemes (AES) can play in improving biodiversity on farmland appears with increasing frequency within the scientific literature (Fig. 1). AES have other aims, including the maintenance and enhancement of landscapes, protection of the historic environment, protection of natural resources and promoting public access to the countryside (http://www.defra.gov.uk/erdp/schemes/es/default.htm); however, benefiting biodiversity gain is a major goal of these schemes. It has recently been highlighted that, overall, progress towards achieving the European Union (EU)'s target of halting biodiversity loss on farmland by 2010 is not visible and the target is unlikely to be reached without additional integrated policy efforts (EEA 2006). This editorial discusses why these schemes

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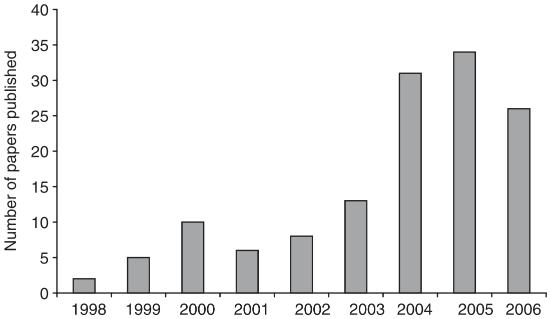

Fig. 1. A graph showing the increase in numbers of journal articles about agri-environment schemes. These papers were those listed in Web of Science using the term 'agri-environment schemes' in a search carried out on 18 October 2006. The *Journal of Applied Ecology* published more papers than any other journal (23 out of 136; 17%), with a total of 39 journals publishing one or more papers. *Journal of Applied Ecology* papers together accounted for 36% (434/1202) of the citations. Note that the papers listed under 2006 are only those listed up until 18 October 2006 and are thus only around three-quarters of those likely to be published by the year end.

Fig. 2. A fictitious example of a future 'protected' farmland area (in which the entire area shaded in grey is managed sympathetically for wildlife, i.e. a 'protected area' approach) and an AES in which small parts of a farm are managed for wildlife (the boundaries marked in black are managed for wildlife by planting grass margins, increasing hedge height and width). The protected area approach outlined in the text lessens the problems associated with distance from nearest colonizing source and multiple resource provision because (i) the area is much larger and (ii) entry is restricted to landowners with existing 'healthy' wildlife populations.

provide particular challenges to biodiversity conservation within farmland ecosystems. It is not intended as an exhaustive (systematic) review of the literature on AES but as an overview, to place the papers within this Special Profile issue of *Journal of Applied Ecology* in context and to suggest directions for future research.

A common approach to conservation is to identify areas containing valuable resources (e.g. habitats, ecosystems and species) and then protect them. Conservation schemes designed for these 'protected areas' have been categorized into five groups by the IUCN (1994) (listed in Pullin 2002): (i) 'strict' nature reserves, which usually contain high-priority species, habitats or ecosystems; (ii) wilderness areas, unmodified or only slightly modified land designated with the aim of preserving its natural condition; (iii) national parks, mainly used to protect ecosystems and land used for recreation; (iv) natural monuments, used for the conservation of specific natural features; and (v) habitat or species management areas, which involve management intervention to aid specific habitats or species. The rationale underpinning groups (i–iv) is relatively simple: identify an important area and protect it.

The habitat or species management area classification (group v) incorporates a range of different conservation approaches. Most are aimed at networks of sites, such as special protection areas (SPA), under the Birds Directive, and special areas of conservation (SAC), under the Habitats and Species Directive, both of which are European designations aimed at minimizing developments and protecting what is on the site by encouraging favourable management within the designated area. AES also fall under this category. However, two properties of AES set them apart from typical protected area schemes: (i) they are often applied to very small patches of land, such as a field boundary or an individual field, and thus they create at larger scales (such as the farm scale or larger) a complex mosaic of differing habitat quality (Fig. 2); (ii) they are sometimes placed in areas where the target species is absent, with the intent of improving conditions necessary for the return of the target species.

HAVE AES BENEFITED BIODIVERSITY?

Although boosting populations of wildlife is a major aim of AES, the evidence regarding their effects on biodiversity is mixed. A recent review by Kleijn & Sutherland (2003) reported that the research designs of most AES are inadequate for assessing the reliability of the schemes. Of 19 bird studies providing results, four yielded positive increases in species richness or abundance, two gave negative results and 11 showed results in both directions. Of 20 arthropod studies, 11 yielded an increase in species richness or abundance and three showed mixed results but none showed a decrease. Of 14 plant studies, six showed increases in species richness or abundance and two showed decreases. More recent studies have added to our knowledge of how AES affect biodiversity, for example Kleijn *et al.* (2006) found that AES in five European countries have performed poorly for a range of taxa that were considered either uncommon or listed in Red Data Books, whereas poor to moderate effects were reported across a range of

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more abundant and widespread taxa, including vascular plants, birds, bees, grasshoppers and crickets and spiders.

AES require an enormous amount of money (24 billion euros were spent by the EU between 1992 and 2003 on these schemes; Kleijn & Sutherland 2003) and they have been applied across a large geographical area: the EU. Given the importance of this topic it is not surprising that the efficacy of these schemes is of great interest to scientists, policy-makers and the general public. For example, *what lessons can be learned from AES to optimize their biodiversity gain and ecological benefit* has recently been identified by policy-makers and scientists as one of the key policy-relevant ecological questions in the UK (Sutherland *et al*. 2006). Optimizing the use of available measures (such as AES) under the reformed Common Agricultural Policy is seen by the European Commission (CEC 2006) as a major part of the European strategy to halt biodiversity loss on farmland by 2010. Recent studies have begun to question whether the current approach is optimal and to suggest changes. Three areas of particular concern are explored below.

Why might AES fail to benefit biodiversity substantially?

Clearly AES need to provide 'good-quality' habitats (e.g. by providing preferred food, improving access to food or minimizing predation risk) and research is still on-going to quantify optimal environmental resources in farmland systems. Papers in this Special Profile illustrate this, for example bumblebees *Bombus* spp. make extensive use of the legume-based 'pollen and nectar flower mix' as prescribed under an English AES but this type of resource is short-lived and alternatives are needed (Carvell *et al*. 2007). Both cutting regime and fertilizer input affect beetles on grass margins, with no fertilizer input being particularly beneficial to a range of beetle species (Woodcock *et al*. 2007). Grassland restoration is a complex issue and there is a range of practical options that can be used to provide both very high-quality habitat (as source populations) and other less intensive measures (Pywell *et al*. 2007). Farmland bird species that flee from predators prefer to forage in open areas, such as stubble cut short to *c*. 6 cm, whereas species that rely on crypsis prefer longer vegetation, such as stubble of a length of *c*. 13 cm found in typical fields (Butler, Bradbury & Whittingham 2005), and so heterogeneity is a key factor (for a useful discussion see Benton, Vickery & Wilson 2003). However, designing 'good-quality' habitat does not take account of several factors that affect AES. These factors set AES apart from typical protected area schemes and may contribute to suboptimal performance (see below).

APPLICATION TO SMALL PATCHES OF LAND

Prediction of the effect of environmental resource provision (e.g. management of hedges and field margins) to small patches of land by AES is complicated by several factors. First, species require multiple environmental resources when breeding. For example, providing a section of hedge 50 m long may be important for many nesting birds but, if suitable resources for foraging nearby are insufficient, then the hedgerow may be of little value for birds. Secondly, the distance between environmental resource provision and source breeding populations may be important, for example will an isolated hedgerow or weed-rich grass margin created under an AES attract many birds, invertebrates and plants if the nearest breeding individual or population is some distance away? Metapopulation theory predicts that the more distant the source population, the less likely that the patch will be colonized (Hanski & Gilpin 1991; Sutherland 1998): for taxa with poor dispersal abilities (e.g. mainly plants and some invertebrates) even relatively small distances may affect the likelihood that a patch will be colonized. Optimal foraging theory (or more specifically central place foraging theory) predicts that, given two patches of equal 'value', the nearest one (e.g. nearest to the nest for a bird or a bumblebee) will be preferred because it uses up less energy to visit the closer patch (Stephens & Krebs 1986; Krebs & Davies 1991). There are many empirical studies supporting these theories but two good examples from farmland systems are provided in this Special Profile. Öckinger & Smith (2007) found that grass margins further from source patches (in this case semi-natural grassland) were lower in species richness and density for both butterflies and bumblebees (*Bombus* spp.). Clough, Kruess & Tscharntke (2007) report that insect herbivore species diversity was higher on newly created plots of their host-plant (in this case creeping thistle *Cirsium arvense* L.) placed within organic wheat fields compared with those placed within conventionally managed wheat fields, probably because of the naturally higher cover of *C. arvense* in the organic fields (thus plots were on average likely to be closer to source populations in the organic fields). Thus the distance from breeding populations is likely to be critical to the use by insect communities of non-cropped areas (which are often part of AES options). In addition, the application of AES to a variety of small patches of land may mean that collectively these do not provide sufficient additional resources to maintain viable increases in the target populations and/or offset the adverse influences of the surrounding landscape.

PLACEMENT OF ENVIRONMENTAL RESOURCES BY AES WHERE TARGET SPECIES ARE ABSENT

Clearly, AES are likely to be most effective when applied to areas in which target species occur. A good illustration of this is provided within the farmland bird literature. The Countryside Stewardship Scheme (an English AES) has been successful in targeting management for cirl bunting *Emberiza cirlus* L. populations in a small part of south-west England (the only area in which they occur in the UK), resulting in a population

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increase of 83% on Countryside Stewardship land. In contrast, populations lying on land adjacent to agreements areas have increased by only 2% (Peach *et al*. 2001). On the other hand, studies of AES applied over wide areas (which can thus be applied to areas in which a species is absent) have reported either limited or no effect of these schemes on bird abundance (Kleijn *et al*. 2001; Bradbury & Allen 2003; Kleijn *et al*. 2006). This is illustrated in this Special Profile in a study of waders in Holland by Verhulst, Kleijn & Berendse (2007). Dry fields, which are of little value to waders such as redshank *Tringa totanus* L. and lapwings *Vanellus vanellus* L., may still be entered into AES in Holland; unsurprisingly, management changes to such fields as part of the AES agreement made little difference to wader numbers (Verhulst, Kleijn & Berendse 2007).

GENERALITY OF HABITAT MODELS

An underlying assumption of AES is that they will have similar effects on target species across the range at which the scheme is applied. This assumption is relatively underexplored in farmland systems but one recent study suggests it may not be valid. Whittingham *et al*. (in press) found that, for a range of 11 farmland bird species in England and Wales, good predictors derived from sites in one geographical region tended to have little or no predictive value when applied in other areas. For example, the height of boundaries (mainly hedges) had significantly different positive effects on territory occupancy by the 11 species across south-east, northern and south-western England. This suggests that AES options targeted at a regional scale are more likely to yield beneficial results for farmland birds than options applied uniformly in national schemes. In contrast, Kleijn *et al*. (2004) found no differing effects of AES in different landscapes (as determined by soil type, sand, peat or clay). However, neither of the biodiversity measures recorded by Kleijn *et al*. (2004) (plant species richness and meadow bird abundance) differed between control fields and fields under AES, suggesting that this may not have been the best study system to examine the interaction between AES and landscape.

Both Whittingham *et al.* (in press) and Holzschuh *et al*. (2007) showed similar habitat preferences in areas with differing species density for both birds and bees respectively.

Potential changes to AES

There may be benefits to adopting the traditional 'protected area' framework for AES. If whole farms or groups of farms were managed using extensive farming methods and the farmers compensated appropriately, then this may yield greater biodiversity gain (especially if access to this scheme was limited to those farms with existing healthy wildlife populations). This approach is also suggested by Kleijn & Sutherland (2003), who propose that the same level of reduction in agricultural intensification in extensive systems may produce greater biodiversity gains (i.e. the relationship between agricultural intensification and biodiversity is non-linear). The effects both of nearest breeding individuals and multiple resource requirements (discussed above) may be significantly reduced if larger patches of high-quality resource are provided. It could be argued that steps are already in place to this end. For example, the Higher Level Scheme (an English AES) goes some way to addressing this concern but it remains to be seen whether it will provide patches of environmental resource of sufficient quality or size.

Another issue is the current link between conservation research and policy. Currently, conservation policy is often informed by research but, once a policy is formed, the process may take some time to be reviewed and updated. Perhaps AES monitoring could be viewed more as ongoing research that feeds back into policy to inform future changes to AES. A simplistic example to illustrate this point is as follows. The process of policy development usually involves three major steps: first, conservation 'problems' (e.g. why farmland biodiversity is declining) are defined, often by a government or wildlife non-governmental organization (NGO); secondly, research programmes are initiated to investigate the underlying causes and to trial solutions; thirdly, the results from the second step are used to develop policy. However, what if the policy performs poorly or does not work? Changes are clearly needed but the time scale may be speeded up if AES are used as the basis for trialling management options and the results are used to revise current practice.

Could an integrated countryside deliver biodiversity gains?

Farming to maximize economic performance is usually in conflict with wildlife needs. Two papers in this Special Profile address this issue. Olsen & Wäckers (2007) investigated whether field margins, which benefit the conservation of northern bobwhite quail *Colinus virginianus* L., enhance biological pest control in adjacent wheat fields. They found that AES targeted at biodiversity did not affect pest control. Bullock, Pywell & Walker (2007) show that the recreation of diverse grasslands for conservation also increases yields from hay crops. These approaches help to bring farming and wildlife needs together and merit further research.

How can AES be integrated more generally with other countryside needs? Conservation management could be aligned with other anthropogenic issues, such as health, flood protection, water purification, tourism and transport policy (Sutherland 2002, 2004; Stephens, Pretty & Sutherland 2003). Steps in this direction may yield many gains and the organic farming movement (or similar movements such as low-input farming systems) is one area that could deliver, at least in part, this kind of vision, particularly given the increasing consumer demand for organic food (Lohr 2001).

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