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EDITORIAL

The future of agri-environment schemes: biodiversity gains and ecosystem service delivery?

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Summary

1. European agri-environment schemes (AESs) have so far delivered only moderate biodiversity gains. However, recent work has demonstrated that under a range of circumstances AESs can return substantial benefit both to biodiversity and ecosystem service delivery. This Special Profile brings together 13 papers that point the way to greater effectiveness.

2. One study in this Special Profile suggests that AES options modified by experience of working on the ground (i.e. guided by adaptive management) and applied to small fragmented pieces of land can have population level effects on a farmland bird species. Such adaptive management has been shown to correlate with increased levels of biodiversity for a range of taxa in a variety of situations, and thus demonstrates the potential of AESs to achieve significant biodiversity benefits.

3. Examples from this Special Profile provide evidence that AESs can improve ecosystem service provision, such as pollination services, biological control and carbon storage. However, AESs located in heterogeneous landscapes and in areas supporting high levels of biodiversity are likely to yield greater benefits than those in more homogeneous landscapes.

4. Estimating both the economic and non-economic value of ecosystem services is complex. A range of caveats need to be borne in mind if and when management strategies and policies are formulated based upon economics. These are well described in another paper in this Special Profile.

5. *Synthesis and applications*. Agri-environment schemes are more likely to deliver substantial benefit if: (i) they are implemented with clear guidance to land managers, and (ii) they are located in landscapes with high levels of biodiversity. Greater biodiversity on farmland is likely to increase the provision of a range of ecosystem services, which, in turn, should buffer agricultural land against likely future environmental changes.

Key-words: agro-ecology, biodiversity conservation, extinction risk, farmland birds, land sparing versus land sharing, land-use trade-offs, payment for ecosystem services

One of the greatest challenges facing the global (human) community is the provision of sufficient food to feed an expanding population while maintaining farmland biodiversity and the associated ecosystem services that biodiversity provides. While agricultural intensification increases the yield per unit area, it is negatively related to biodiversity (Donald, Green & Heath 2001; Green *et al.* 2005). Agri-environment schemes (AESs) are designed, in part at least, to enhance levels of biodiversity on farmland (Whittingham 2007). However, in 2003, a review suggested that the evidence needed to assess the efficacy of AESs for biodiversity gain was often missing and when present the evidence suggested a limited effect (Kleijn & Sutherland 2003). The general consensus since this paper was published is that AESs can provide only moderate or limited gains for biodiversity (e.g. Kleijn *et al.* 2006; Birrer *et al.* 2007; Davey *et al.* 2010), although larger AESs, especially organic farms, do produce substantial biodiversity benefits (Bengtsson, Ahnstrom & Weibull 2005; Winqvist *et al.* 2011; Jonason *et al.* 2011). The Convention on Biological Diversity 2010 targets for halting biodiversity loss on farmland have not materialized, and so it could be said that AESs have thus far largely failed to deliver for wildlife (e.g. Fig. 1). However, it is important to note that much of the evidence of the efficacy of AESs is judged (by scientific studies) at the plot or farm scale but ultimately their efficacy must be evaluated using measures at the national or international scale (e.g. Fig. 1). It is possible that AESs are achieving effective results at local scales but they are not providing enough resource over larger scales to result in significant population level changes.

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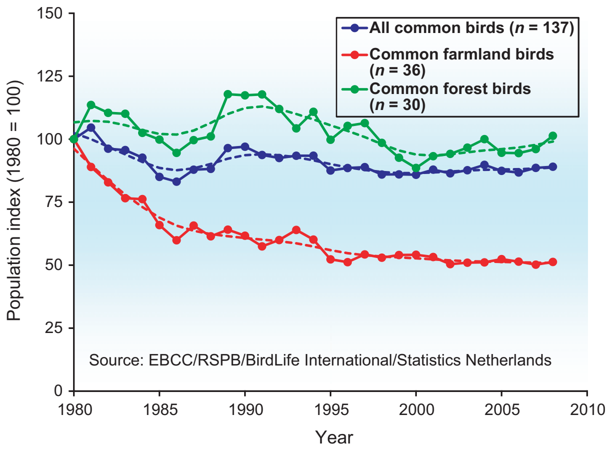

Fig. 1. Despite major investments in agri-environment schemes across Europe over the past two decades, populations of farmland birds have continued to decline, albeit at a slower rate than during the 1980s. The graph shows trends of the European farmland bird indicator from 1980 to 2008. The trends show changes in composite populations of bird species associated with farmland, forest and other common (generalist species). [Source: EBCC/RSPB/BirdLife International/Statistics Netherlands]. The ultimate efficacy of AESs is often judged by trends such as this but tests for the effectiveness of management are often carried out at much smaller scales.

Recent studies on AESs have shown distinct differences in the efficacy of schemes depending on the identity of the species/taxon involved. Plants tend to show the strongest positive responses to AESs, followed by invertebrates, with birds and mammals showing the smallest responses (e.g. Kleijn *et al.* 2006; Gabriel *et al.* 2010). For example, Fuentes-Montemayor, Goulson & Park (2011) provide further support that invertebrates (in this case moth abundance and diversity) can benefit from AESs. Another paper in this Special Profile supports the literature providing evidence that the length of time since conversion to AES is positively related to abundance, in this case of butterflies (Jonason *et al.* 2011).

The *Journal of Applied Ecology* is at the forefront of publishing key papers about agri-environment schemes. Of all 442 papers identified using the search term 'agri-environment scheme' (search conducted on 10 February 2011), the *Journal of Applied Ecology* published more than any other journal (17% of articles which accounted for 30% of citations). So, where does this field go from here? AESs could be considered to be at a cross-road in which their performance is questioned and their future purpose determined. This Special Profile highlights a range of papers that can help guide future AES design. This editorial aims to put these papers in context by drawing them into three themes and suggesting ways in which future research work on AESs could be focused, particularly with regard to ecosystem services.

Adaptive management

Adaptive management, in this context, is an iterative process of decision-making that aims to reduce uncertainty (and thus maximize system success) via monitoring. Adaptive management is a tool that can be used not only to change a system but also to learn about that system (Holling 1978). Recent evidence suggests that adaptive management can make a positive difference to biodiversity across a wide range of case studies throughout Europe and the USA (e.g. Stankey, Clark & Bormann 2005; Nichols *et al.* 2007; Kenward *et al.* in press). Perkins *et al.* (2011) provide a clear example of how adaptive management, in the form of monitoring data that enabled the identification of new management options (notably late silage-cutting), was used to refine AES options to target a key conservation species. They showed that corn bunting *Emberiza calandra* populations significantly increased on land where the farmer was given specialist advice for corn bunting conservation (through targeted AESs modified via adaptive management). This contrasted with farms under general AES agreements in which corn bunting populations remained stable and non-AES farms in which populations fell (see fig. 2a of Perkins *et al.* 2011). Many other studies have considered the impact of AESs on bird populations; however, the results have been mixed – some previous studies found little effect of AESs on populations (e.g. Kleijn *et al.* 2001, 2006), while others showed more positive effects of such options (or potential options) at both the population level (e.g. Peach *et al.* 2001) and at the patch scale (e.g. Douglas, Vickery & Benton 2009). In contrast to these earlier studies, Perkins *et al.* (2011) highlight both local and national population level effects, rather than results based on local populations alone or demonstrable effects on vital rates but not at an actual population level. In summary, the Perkins paper is a step forward, suggesting that with the right implementation, typical AESs (i.e. those applied on small fragmented pieces of land as discussed in Whittingham 2007) can have substantial population level effects when practical guidance is provided for farmers and that advice is modified by adaptive management.

Surrounding landscape influences farmland biodiversity

A number of recent studies have highlighted the importance of the surrounding landscape on the effectiveness of AESs. This has been demonstrated at two differing spatial scales. First, at the smaller, within-farm scale, a positive relationship between noncropped habitat and abundance of farmland birds is known to be important for a range of European birds (e.g. Whittingham *et al.* 2009 and references therein), and this is also true for Australian farmland birds (Hanspach *et al.* 2011). Similar positive relationships also exist between moths (e.g. Fuentes-Montemayor, Goulson & Park 2011) and birds with the amount of AESs within a radius of 500 m of the patch (Dallimer *et al.* 2010). Thus, the extent of noncropped habitat (and AESs) both within and between farms is likely to be an important determinant of the effect of AES management on biodiversity. Secondly, at a larger landscape scale, the effect of AESs on farmland biodiversity has been shown to be positively related to the extent of land under AESs in the surrounding landscape. For example, Gabriel *et al.* (2010) showed greater positive trends for a range of biodiversity measures, including birds, a range of invertebrates (e.g. arthropods, bees and butterflies) and plants, when there was a greater area under AES management at a 10 × 10 km scale. Thus, the extent of AESs within the landscape is likely to alter the potential outcomes of schemes, and logically this also means that placement of AESs in areas of high existing biodiversity is (in general) likely to yield greater gains.

Future developments of agri-environment schemes: the ecosystem service route?

Ecosystem services are categorized by the Millennium Ecosystems Assessment as (i) provisioning (e.g. timber), (ii) regulating (e.g. water quality and quantity; climate, including carbon sequestration), (iii) supporting (e.g. pollination and pest control) and (iv) cultural (e.g. well-being; MEA 2005). Payments for ecosystem services are increasingly common around the world (e.g. Farley & Costanza 2010). AESs are currently designed to deliver improved biodiversity, among other things, but are not explicitly linked with ecosystem services. A number of studies have previously identified a range of AES options that could link directly to ecosystem service provision (e.g. Bradbury, Stoate & Tallowin 2010 and references therein). However, while many of the reported relationships between ecosystem services and biodiversity are based on sensible predictions, what is urgently needed is an evidence-base on which to move forward. Although biodiversity can in itself provide a range of 'cultural' ecosystem services (most of which are likely to be hard to value economically), there are a range of other, mainly economically valuable, services under the other headings defined by the MEA (2005) that wildlife could provide. An evidence base in this area could focus on a number of topics. For example: (i) how much and in what way do AESs designed to deliver biodiversity also deliver economically valued ecosystem services? (ii) do AESs designed to deliver Ecosystem Service benefits, also deliver biodiversity benefits and, if so, which ones? In this Special Profile, we present three examples of ecosystem services delivered by enhanced biodiversity on farmland.

First, enhancing plant biodiversity is a key aim of AESs, e.g. Fritch *et al.* (2011) outline methods both for creating flower-rich swards and for maintaining such swards through appropriate grazing or mowing that could easily be incorporated into AES options. Power & Stout (2011) found higher plant density and diversity under organic management (an AES option in Europe) was a key to enhancing the abundance of pollinating species. They went on to show that these measures enhanced actual pollination levels for hawthorn *Crataegus monogyna*. Further studies carrying this approach over to cropped species would seem a useful way forward.

Secondly, enhanced biodiversity can provide biological control services in place of artificial pesticides. Winqvist *et al.* (2011) report that more aphids (a crop pest) were removed from cereal crops on organic farms attributed to higher abundances of ground beetles and birds. This effect was, however, limited to organic farms in heterogeneous landscapes. Two further studies in this Special Profile illustrate novel ideas that could provide ecosystem services via biological control agents and, as such, could be incorporated into future AESs. First, Simpson *et al.* (2011) describe the approach of 'attract and reward' that uses synthetic herbivore-induced plant volatiles to improve immigration of beneficial taxa into crops and then provides nectar plants to maintain their populations. Secondly, Eitzinger & Traugott (2011) demonstrate the importance of predatory beetle larvae in the food chain. They suggest that by providing suitable conditions for these cold-adapted beetle larvae (e.g. by providing mulch, compost or plant cover in the winter on arable fields), then their ability to reduce agricultural pest populations (i.e. acting as a biological control) could be substantially enhanced. Following on from the previous section, these are the examples of research and practice informing each other. The *Journal of Applied Ecology* is particular keen to publish work that strengthens links between scientists and practitioners (e.g. as outlined in Memmott *et al.* 2010), and in 2011, the journal launched 'Practitioner's Perspective' articles to make a first step to directly bridge the gap between research and implementation.

Thirdly, two papers in this Special Profile consider biodiversity benefits in grassland, suggesting increased biodiversity in this habitat leads to increased carbon storage and improvements in soil structure (De Deyn *et al.* 2011; Lin *et al.* 2011). De Deyn *et al.* (2011) show that enhanced biodiversity under the proper management conditions (in this case when plant species are combined with a single subordinate legume species) can yield increased carbon and nitrogen storage and improved soil structure. Lin *et al.* (2011) describe the lowering of 'functional trait diversity' associated with natural grassland conversion to agricultural land. Functional trait diversity of the plants involved could be linked to carbon storage and soil quality (which is itself linked to a range of ecosystem services, e.g. flood risk and pollution). They suggest that increased heterogeneity of agriculture, which could be achieved via the planting of cover crops, could enable recovery from agricultural conversion and thus improve delivery of a range of ecosystem services.

Tscharntke *et al.* (2011) highlight the related issue of ecological resilience, which is threatened by destruction of shade trees planted in tropical agroforestry landscapes. They advocate that, to maintain long-term viability, 'short-term gains' need to be guarded against and payments for ecosystem services could be a way to achieve this. The relationship between different land-use types has been examined by a range of studies (e.g. Chan *et al.* 2006; Anderson *et al.* 2009), and there are clear 'bundles' of ecosystem services that correlate with one other (Bennett, Peterson & Gordon 2009).

It is important to note that the explicit economic links with ecosystem services are missing from the examples given above (e.g. the financial cost-benefit analyses have not been made for the studies in this Special Profile). This contrasts with other studies that have directly modelled the economic effects of a range of factors on ecosystem services (e.g. Daily *et al.* 2009). There are many other issues for consideration too, some of which are reviewed by Seppelt *et al.* (2011) including (i) what is meant by 'ecosystem services'; (ii) how can we produce general messages given the variety of different studies conducted; and

(iii) the need for clear guidelines for ecosystem services research. Added to these are a range of technical issues such as how to measure and model ecosystem service dynamics, which is no trivial matter (e.g. Nicholson *et al.* 2009). However, in summary, it is clear that there is great potential to link ecosystem services with AESs with benefits to both biodiversity and mankind. In order for this to happen, future land management policies must be informed by more evidence of how the wide range of ecosystem services and other land management practices on farmland relate to each other.

Conclusions

Conversion of natural habitats to agriculture clearly leads to declines in biodiversity (Green *et al.* 2005). Agri-environment schemes have been much criticized but there are signs that targeted AES options, both spatially within the landscape and when implemented with careful management advice, can yield substantial biodiversity benefits. However, it is important to remember that it is farmers who implement AESs, and so it is crucial that such stakeholders are included in the design of the schemes. For example, AES options that include managing land within the crop itself are particularly unpopular with many farmers in England (e.g. see Butler, Vickery & Norris 2007 and references therein) even when some such 'in-field' options are shown to have clear and substantial benefits for biodiversity (e.g. Morris *et al.* 2004). This may be because farmers generally view the field centres as areas for crops and the edges and non-cropped areas as available for other things, such as wildlife.

What is less often considered when biodiversity issues on farmland are discussed is the role of farmland biodiversity in providing a range of ecosystem services. Papers in this issue support the idea that AESs could be linked directly to the provision of ecosystem services. For example, higher levels of flowering plant biodiversity (an achievable target for AESs – Kleijn *et al.* 2006) lead to an increase in both bees and hoverflies and as a consequence a demonstrable increase in pollination of a key shrub within farmland landscapes (Power & Stout 2011). Other studies in this issue suggest a range of management options which could easily be incorporated into AESs to provide ecosystem services such as biological control, carbon storage and soil quality. One way to take these studies forward is to assess the cost–benefit ratio of management actions to, potentially, persuade land managers and policy-makers to adopt such suggestions (e.g. Isaacs & Kirk 2010). The potential to manage farmland to increase biodiversity and thereby improve ecological resilience would not only enhance the delivery of ecosystem services – thereby giving direct value to AESs – but would also provide an important buffer against the effects of further agricultural intensification and the pervasive threat of climate change.

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