Journal of Applied Ecology

British Ecological Society

Journal of Applied Ecology 2010, **47**, 986–993 doi: 10.1111/j.1365-2664.2010.01843.x

FORUM

Lowland farmland bird conservation in the context of wider ecosystem service delivery

Richard B. Bradbury[1]*, Chris Stoate[2] and Jerry R. B. Tallowin[3]

[1]*RSPB, The Lodge, Sandy, Beds SG19 2DL, UK;* [2]*Allerton Project, Game & Wildlife Conservation Trust, Loddington House, Loddington, Leicestershire LE7 9XE, UK; and* [3]*North Wyke Research, Okehampton, Devon EX20 2SB, UK*

Summary

1. Much policy and research in the UK and elsewhere in Europe has been directed towards the conservation of farmland birds. With changes in the drivers of agricultural land management, farmland bird conservation now needs to be considered alongside provision of a range of ecosystem services (ES) indicative of environmentally sustainable land-management.

2. We explore the extent to which land management for farmland bird conservation provides 'cultural' ES, before assessing the potential consistency between management for bird species conservation and for a suite of ES that relate to the regulation of ecosystem processes.

3. We discuss the potential for co-delivery and trade-offs between farmland bird conservation and regulating ES, at a range of locations and spatial scales.

4. Potentially, action to enhance regulating services could provide some co-benefits for farmland bird conservation. However, more targeted management will still be required for certain species.

5. *Synthesis and applications*. Integration of species conservation management practices, in this case in farmland, with provision of other ES will be a significant challenge to land management. This will demand careful planning, at multiple scales, to account for the range of synergies and trade-offs between services, the dependence of service provision on time and location of management, and the dependence of service benefit on the number, locations and preferences of human beneficiaries.

Key-words: agri-environment, climate change, ecosystem approach, land-use, multi-objective, multifunctional, regulating, resource protection

Introduction

There is a great challenge to develop mechanisms for incorporating the conservation of biodiversity into resource and land-use decisions on a large scale (Daily *et al.* 2009). The UK's Ecosystem Approach Action Plan (Defra 2007) exemplifies a national strategy to address this challenge. Central to the issue is the consideration of ecosystem services (ES), the products of an ecosystem that support human well-being (Fisher, Turner & Morling 2009). This focuses attention on the inter-linkage between ecosystems, their functioning and human well being (Millennium Ecosystem Assessment 2005; Haines-Young & Potschin 2009), including the spatial, temporal and social variables that influence values (Nicholson *et al.* 2009).

In the highly exploited environments of western Europe, biodiversity loss and ecosystem degradation has contributed to wide-scale problems that influence human well-being (Stoate *et al.* 2009). Conservation of farmland biodiversity has been attempted in the UK and elsewhere in Europe for over two decades, for example through management measures in organic farming systems, set-aside and, especially, in agri-environment schemes (AES; e.g. Potts 1986; Vickery *et al.* 2004; Wilson, Evans & Grice 2010). Many, but not all, AES management options have been designed to moderate extremes of production in order to benefit nature conservation. Many schemes have been poorly monitored and their overall success in conserving biodiversity is questionable (Kleijn & Sutherland 2003). Birds, though, have been a particular focus and there have been some notable conservation successes, especially concerning rare, range-restricted species (Wilson, Evans & Grice 2009).

With issues such as food security rising in prominence, and increased awareness of the need for ecosystems to provide a range of services (Foley *et al.* 2005), the ES agenda for agro-ecosystems will need to be broad. 'Traditional' species conservation objectives will need to recognize this. The general challenge is not new – the trade-off between species conservation and one particular service, food, has been the subject of

*Corresponding author. E-mail: richard.bradbury@rspb.org.uk

considerable focus for some time. However, the range of services is now expanded, creating a need to identify complementarities and trade-offs between AES objectives to conserve farmland species and those to enhance or maintain other ES (Bradbury & Kirby 2006). These ES include soil conservation, water quality, flood risk mitigation, climate regulation, pollination, recreation and biological pest control (Millennium Ecosystem Assessment 2005).

An ES agenda raises several key questions for species-led conservation approaches, including, but probably not restricted to:

1. Does conservation of species provide services directly?
2. How does farmland management for species conservation affect the provision of other services?
3. Is management for other services an alternative way to provide resources for farmland species?
4. If environmental management follows an ES agenda, what will be the consequences for species conservation?

Here we investigate some potential synergies and trade-offs between management for species conservation, using farmland birds as an exemplar, and for a range of regulating services. Regulating services relate to the regulation of ecosystem processes, including, for example, the regulation of climate, water flows and quality, and some human diseases (Millennium Ecosystem Assessment 2005). Our intention is not so much to explore the importance of biodiversity in underpinning ecosystem function and service provision (except the link between birds and cultural ES), which is much discussed elsewhere (e.g. Loreau 2010). The issues of using an ES approach to underpin species conservation are well rehearsed (e.g. Redford & Adams 2009). Rather, more pragmatically, we explore the potential for land management to co-deliver regulating services and one particular type of biodiversity, birds, to help identify the optimal way to manage land for multiple objectives. We focus on farmland bird conservation in the UK, though contend that the broad issue is applicable to farmland elsewhere and, indeed, to species conservation in other managed habitats.

DOES CONSERVATION OF SPECIES PROVIDE SERVICES DIRECTLY?

Non-economic reasons for conservation underpin a variety of policy drivers for conserving birds, including the Convention on Biological Diversity, and hence Biodiversity Action Plans (BAP: http://www.ukbap.org.uk) and the EU Birds and Habitats Directives. Many UK farmland bird species are BAP species.

Perhaps, the ethical reasons underlying farmland bird conservation are weaker than some other areas of conservation, because the species concerned occupy highly anthropogenically modified habitats and their abundance is already likely to have fluctuated hugely over recent centuries as a result of human activities. However, a pragmatic reason for farmland bird conservation is that farmland covers most of western European landscapes and, proportionally, even more of those landscapes adjacent to human habitation. Hence, farmland biodiversity is that which many people are now likely to experience most, relative to more remote and more 'natural' communities. The concept that flourishing farmland bird populations contribute to well-being is illustrated by the objective of one of the previous UK Government's Public Service Agreements (PSA) 28 (http://www.defra.gov.uk/environment/statistics/wildlife/download/pdf/NSBirds20081031.pdf), which described the Government's aspiration 'to secure a diverse, healthy and resilient natural environment, which provides the basis for everyone's wellbeing, health and prosperity now and in the future, and where the value of the services provided by the natural environment are reflected in decision-making'. The trends in breeding birds, including the farmland bird index (Fig. 1), are one measure against which progress towards the PSA was assessed.

So how do birds influence well-being? The Millennium Ecosystem Assessment classification has limitations for quantifying ES value, particularly in relation to the risk of double accounting some intermediate services (such as pollination) and final services (e.g. pollinated fruit; Fisher, Turner & Morling 2009). However, it still provides a useful starting point for exploring the types of services that an ecosystem may provide. Globally, birds provide a wide range of ES, including meat provision and supporting services such as pollination and invertebrate pest control (Whelan, Wenny & Marquis 2008). In the UK, western Europe and the US, the major service that birds provide is probably cultural. Some, though, such as wildfowl and game-birds, also provide food. The recreational value of birdwatching is potentially huge - birdwatching activities contributed an extraordinary $82 billion to the US economy in 2006 (http://library.fws.gov/Pubs/birding_natsurvey06.pdf), though the majority of such activity probably occurs outside farmed areas.

For farmland birds, the value will depend on the interests of the user. Even corncrakes *Crex crex* on relatively remote Scottish islands, for example, have an 'existence value' to some

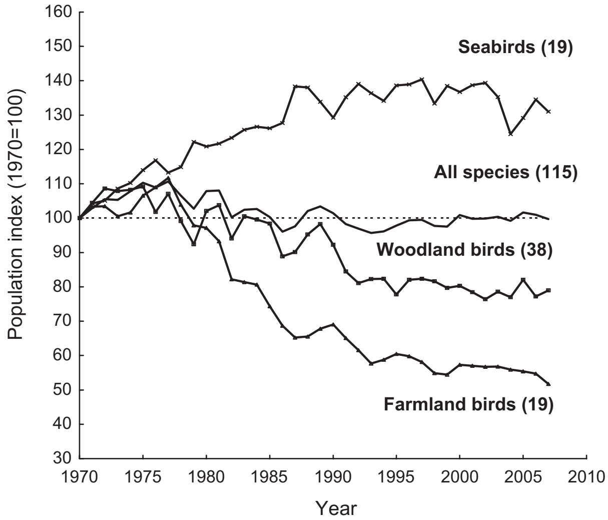

Fig. 1. The UK Wild Bird Indicator, 2008. Source: RSPB/BTO/JNCC/Defra. Numbers in brackets refer to number of species in each category.

people in England, even if they never see them. If we focus more on the benefits obtained from direct interaction with birds in farmland, then particular species such as (currently, in the UK) rare cirl buntings *Emberiza cirlus* are likely to be more narrowly valued than species such as skylarks *Alauda arvensis* which are widespread and familiar elements of our cultural history (Crocker & Mabey 2005). Common generalist species (e.g. chaffinches *Fringilla coelebs*) could also contribute to people's value of farmland. However, we are aware of no evidence that enables us to determine the relative importance of different species, or species diversity, in underpinning value. Indeed, some valuation methods exclude biodiversity associated solely with cultural services because of the potential inverse relationship of worth with diversity/abundance (Christie *et al*. 2008).

Nevertheless, birds in general appear to provide a 'cultural service' to many people that 'use' the countryside, whether through recreational bird watching, hunting, spiritual refreshment and/or aesthetic appeal. This value has been manifest in many ways, from acclimatisation societies who introduced familiar UK farmland birds, including song thrush *Turdus philomelos* and yellowhammer *Emberiza citrinella*, to countries such as New Zealand (Wilson 2004) to campaigns to 'save' birdsong on the radio (http://www.telegraph.co.uk/news/uknews/1584062/Campaign-to-save-birdsong-on-the-radio.html) and public donations to the RSPB to help purchase a lowland farm to research farmland bird conservation solutions (http://www.rspb.org.uk/supporting/campaigns/hopefarm/index.asp).

HOW DOES FARMLAND MANAGEMENT FOR SPECIES AFFECT THE DELIVERY OF OTHER SERVICES?

A range of activities to enhance regulating services on farmland is suggested in Table 1. We examine the options available within the English Entry Level Environmental Stewardship Scheme, many of which are at least partly designed to benefit widespread farmland birds. We build on two previous analyses, to make a preliminary assessment of the potential for consistency between bird conservation and service provision for different Scheme options, focusing specifically on six regulating services.

For birds, we build on Vickery *et al*. (2008) who assessed the importance of each Entry Level Environmental Stewardship Scheme option for each of 13 farmland bird species, for three classes of resource requirement (nesting, breeding season food and non-breeding season food). Methodological details are given in the Appendix S1 (Supporting Information). We ranked the options by the number of key resources they provided for different species (Table 2).

For ES, we used the report by Land Use Consultants & GHK Consulting Ltd (2009), which assessed, for each Entry Level Environmental Stewardship Scheme option, the provi-

Table 1. A selection of management options on lowland farmland that can influence regulating ES

Final service	Benefit	Land management objectives	Management options
Carbon sequestration; Green-house gas emission reduction	Climate change mitigation	Reduce soil carbon oxidation Reduce energy consumption Increase soil carbon sequestration Reduce nitrous oxide emissions Reduce methane emissions	Convert arable land to permanent grassland, in particular on organic soils Reduce cultivation intensity Grow woody vegetation: hedgerows, woodland, biomass crops Improve crop nitrogen (N) use, manure N use, tailor nutrient supplied in feed to livestock nutrient requirement Provide high quality feed, reduce stocking levels, digest manures anaerobically
Water regulation; Erosion regulation	Usable water; Flood risk management; Hazard control;	Improve soil infiltration Reduce surface run-off	Ameliorate soil structural damage and compaction Create/restore semi-natural habitats including scrub, plant trees Maintain/create flow barriers: hedgerows, earth banks, buffer strips, beetle-banks Restore vegetation cover on bare soils, under-sow arable crops such as maize Implement minimal cultivation or no-till techniques on arable land
Water purification	Clean water	Reduce fertiliser leaching and pesticides	Tailor N, P and K inputs to crop requirements Use plants with improved N use efficiency Use manure N efficiently Create low input grassland and conservation headlands Avoid application in inappropriate (e.g. wet / frozen) conditions Prevent pollutant surface run-off, create physical buffer zones Provide reed beds/wetlands to filter water before entry to water courses Reduce/prevent soil erosion

Table 2. Management options in the English Entry Level Environmental Stewardship Scheme, indicating where the provision of farmland bird resources and ES can be complementary. Scoring as described in Appendix S1 (Supporting Information). In brief, the scores reflect the *net* impact of each option on each service, compared to the most typical business as usual practice in the absence of that agri-environment option (2, considerably better provision by the option, per unit area; 1, slightly better provision by the option; 0, no difference; −1, slightly worse provision by the option; −2, considerably worse provision by the option). Details of the scores from which the bird ranks were derived are given in Table S1 (Supporting Information). Note that many ranks are tied

	Regulating ES								
ELS option	Climate	Water regulation	Erosion	Water quality	Pest control	Pollination	Total score	ES rank	Bird rank
EK3 - Permanent grassland with very low inputs	2	1	1	2		1	7	1	1
EG4 - Cereals for whole crop silage followed by over-wintered stubbles		−1	−1	−1			−3	9	2
EF11 - 6 m uncropped cultivated margins (in arable)		−1	−1	1 −1	1	1	0	8	3
EG2 - Wild bird seed mixture in grassland areas	−1	−1	−1	−1	1 −1	1	−3	9	4
EF2 - Wild bird seed mixture					−1	1	0	8	5
EF3 - Wild bird seed mixture on set-aside land	−1	−1	−1	−1	−1	1	−4	10	5
EK2 - Permanent grassland with low inputs	1	1	1	1		1	5	3	6
EL3 - Manage in-bye pasture and meadows with very low inputs	2	1	1	2		1	7	1	7
EF1 - Field corner management	1	1	1	1	1 −1	1	5	3	8
EF6 - Over-wintered stubbles		1	1	1	1 −1		3	5	9
EE3 - 6 m buffer strips on cultivated land	1	1	1	1	1	1	6	2	10
EF7 - Beetle banks	1	1	1	1	2 −1	1	6	2	11
EL2 - Manage permanent in-bye grassland with low inputs	1	1	1	1		1	5	3	11
EE1 - 2 m buffer strips on cultivated land	1	1	1	1	1	1	6	2	12
EE2 - 4 m buffer strips on cultivated land	1	1	1	1	1	1	6	2	12
EG1 - Under sown spring cereals	1	1	2	1	−1		4	4	13
EF10 - Unfertilised conservation headlands in cereal fields	1			2	1 −1	1	4	4	14
EK1 - Take field corners out of management	1	1	1	1	1 −1	1	5	3	15
EF9 - Conservation headlands	1			1	1 −1	1	3	5	16
EE8 - Buffering in-field ponds in arable land	1	1	1	1	1	1	6	2	17
EE4 - 2 m buffer strips on intensive grassland	1	1	1	1		1	5	3	17
EE5 - 4 m buffer strips on intensive grassland	1	1	1	1		1	5	3	17
EE6 - 6 m buffer strips on intensive grassland	1	1	1	1		1	5	3	17
EE7 - Buffering in-field ponds in improved grassland	1	1	1	1		1	5	3	17
EL1 - Field corner management (LFA land)		1	1	1		1	4	4	17
EG3 - Pollen and nectar flower mix on grassland	−1		−1		1	2	1	7	18
EF4 - Pollen & Nectar flower mix	1	1	1	1	1 −1	2	6	2	19
EB3 - Enhanced hedgerow management					1	1	2	6	19
EF5 - Pollen & Nectar flower mix on set-aside land	1 −1				1 −1	1	1	7	19
EC1 - Protection of in-field trees (arable)	1		1	1			3	5	20
EC2 - Protection of in-field trees (grassland)	1						1	7	20
EB8 - Combined hedge and ditch management (incorporating EB1)	−1	1	1	1	1	1	4	4	21
EB9 - Combined hedge and ditch management (incorporating EB2)	−1	1	1	1	1	1	4	4	21
EB1 - Hedgerow management (on both sides of hedge)					1	1	2	6	21
EB2 - Hedgerow management (on one side of hedge)					1	1	2	6	21
EF8 - Skylark plots					−1	1	0	8	22
EK4 - Management of rush pastures (outside of LFA)		1		1		1	3	5	23
EL4 - Management of rush pastures (LFA land)		1		1		1	3	5	24

sion of each service identified in the Millennium Ecosystem Assessment. Again, methodological details are given in the Appendix S1 (Supporting Information). While aware of the risk of double-accounting with the Millennium Ecosystem Assessment classification, we do not think the range of services that we consider is subject to this problem. We recognise that this approach would benefit from systematic scoring by a number of experts in each of the services and we emphasise that the results should be considered indicative, rather than firm guidance on the potential effect of each option. Notwithstanding this, it is clear that there are gaps in our knowledge of the impact of some options on some services. An example is the impact of low input options for permanent grassland on greenhouse gas emission mitigation (Smith *et al*. 2008).

The simple message from the assessment is that action for species does not necessarily enhance other services (Table 2). Win-wins seem to be provided by permanent grassland, very low inputs on either arable or grassland, and field corner management. However, some options that rank highly for birds score negatively for service provision, including cereals for whole crop silage, which could produce more nutrient pollution than the alternative habitat (e.g. a grass ley). Finally, certain solutions may have a more-or-less bespoke importance for some species, e.g. skylark plots, with little consequence for other services.

IS MANAGEMENT FOR OTHER SERVICES AN ALTERNATIVE WAY TO PROVIDE RESOURCES FOR FARMLAND SPECIES?

In seeking to find joint solutions for ES provision and biodiversity conservation, options can be considered which range in scale from the field-edge to the catchment. Examples of some opportunities are given below.

Field-scale: Arable

In arable systems, 'minimum tillage' (cultivation without soil inversion) can reduce transport of sediment and phosphorous from fields (SOWAP 2007; Deasy *et al*. 2008). It is also adopted for economic reasons – less energy is needed to drag lighter equipment, so it reduces crop establishment costs. This may become more important, given increasing fossil fuel costs. Although runoff can be higher under minimum tillage compared to ploughing, loss of sediment and nutrients is normally significantly lower, because of higher soil surface organic matter, higher earthworm densities and greater soil microbial biomass (SOWAP 2007). Minimum-tilled fields may have higher soil organic carbon storage potential than ploughed fields, although this is disputed (Baker *et al*. 2007). There are some potential downsides to minimum tillage, including increased herbicide use associated with increased abundance of annual grass weeds, and enhanced emissions of nitrous oxide.

Reduced tillage has various biodiversity benefits (Holland 2004), though evidence for benefits to birds is limited. In Hungary, winter use of minimum-tilled fields was significantly greater than those prepared by ploughing (Field *et al*. 2007), due perhaps to higher seed food availability. However, this difference was inconsistent across years and was smaller than in other studies comparing plough-prepared winter cereal fields with bespoke seed-providing options such as weedy stubbles and wild bird cover (e.g. Bradbury *et al*. 2008). In the breeding season, skylarks in the UK nested earlier in direct-drilled cereal fields than in ploughed fields. The breeding season for this ground-nesting species, which otherwise would have been truncated by rapid crop growth, was extended (Field, Kirby & Bradbury 2007). While suggestive of benefits of reduced tillage to birds, though, these responses are context-specific and depend on the availability of alternative habitat, and need to be set in context of potential population limiting factors. To fully assess the potential value of such management would require measures at a large enough spatial extent to consider whole home ranges.

Field-scale: Grass

Plant species richness is generally constrained by elevated soil fertility in most agriculturally improved grassland soils, which benefits a few competitive species (Tallowin *et al*. 2005; Pywell *et al*. 2007). This in turn constrains diversity at higher trophic levels, including reducing food resources for a range of farmland birds in modern pastoral landscapes (Vickery *et al*. 2001). Plant functional diversity (i.e. diversity of traits such as stress resilience and nitrogen fixing capability) in agro-ecosystems can positively affect a range of ecosystem processes including primary production, nutrient uptake and resilience to disturbance such as pest damage (Hooper *et al*. 2005; Fig. 2). In particular, swards which incorporate productive and competitive legume species, such as *Trifolium repens, T. pratense, Lotus corniculatus, Medicago sativa* and *Vicia sativa*, have the potential to provide multiple agronomic, environmental and biodiversity benefits (Rochon *et al*. 2004; Mortimer *et al*. 2006). For instance, they (i) are of high nutritional value for livestock and require little or no nitrogen fertiliser, so reducing nutrient pollution impacts; (ii) can reduce greenhouse gas emissions, from the manufacture and application of nitrogen fertiliser; (iii) can ameliorate soil structural damage arising from intensive management (Mytton, Cresswell & Colbourn 1993); (iv) produce biodiversity benefits, by significantly increasing the abundance and diversity of invertebrates, particularly pollen and nectar feeders (Carvell *et al*. 2007); and (v) may enhance soil carbon sequestration (De Deyn, Cornelissen & Bardgett 2008).

Field edge options

If correctly sited, grassy field boundary strips can reduce transport of sediment and nutrients to watercourses via surface runoff (Borin *et al*. 2004). They reduce pesticide spray drift, provide a nesting habitat for farmland birds such as grey partridge *Perdix perdix*, whitethroat *Sylvia communis* and yellowhammer (Potts 1986; Stoate & Szczur 2001) and provide

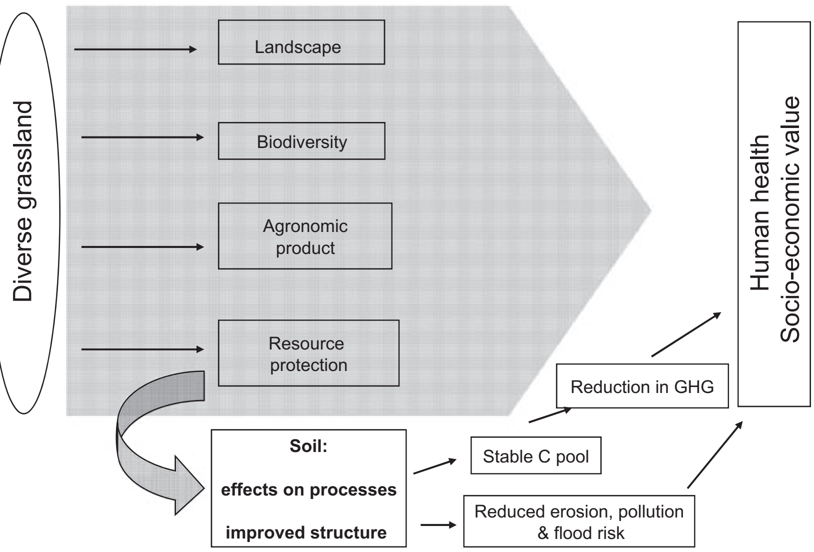

Fig. 2. Potential multifunctional value of diverse grasslands containing a mixture of legume and other broad-leaved species.

wintering habitat for beneficial predatory invertebrates that control aphids and thus reduce crop losses (Collins *et al.* 2002). Grass strips also provide nesting and wintering sites for bumblebees, which pollinate hedgerow shrubs and other plants (Jacobs *et al.* 2009).

Off-field

Under-field drains are an important pathway for sediment and phosphorus (Jarvie *et al.* 2010). Small-scale, field-edge constructed wetlands can intercept such pollutants (Raisin, Mitchell & Croome 1997) and can reduce peak discharge and total runoff volume of water (Evrard *et al.* 2007). In one such system, phosphorus concentration of discharge water was still only 50% of the inflow water a decade after construction (Stoate *et al.* 2006). Despite being eutrophic, the system supported up to 60 invertebrate species per pool, including six nationally scarce coleoptera, and six orthoptera species in the surrounding sward. The pool systems have been colonised by whitethroat, reed bunting *Emberiza schoeniclus*, sedge warbler *Acrocephalus schoenobaenus* and grasshopper warbler *Locustella naevia*, all of which were absent from the site before the wetland was created. In a larger scale study of small wetlands at the same site, invertebrate biomass declined as sedimentation occurred over a four-year period, but was restored following mechanical removal of sediment and associated nutrients to adjacent farmland (P. Williams, personal communication).

Discussion

Recent work provides equivocal evidence of a correlation between patterns of richness of biodiversity, including species of conservation concern, and gross ES provision, at several spatial scales (e.g. Anderson *et al.* 2009; Egoh *et al.* 2009; Nelson *et al.* 2009). Here we attempt to address a different issue, that of trying to identify the optimal way to manage land at a more intimate scale, in order to influence net change in provision of multiple, but potentially competing, objectives.

In our assessment of land management options for biodiversity conservation, we have identified some potential synergies with enhancement of regulating services. Options include those at the sub-field scale (in-field patches, field corners and edges) and changes to the farming system at the field-scale (e.g. minimum tillage, grassland management with reduced agrochemical inputs). Conversely, some actions for farmland bird conservation may involve trade-offs with other ES (e.g. fertilised wild bird seed mixtures, grown in otherwise low-input pasture, might increase the nutrient loss to watercourses).

We have focussed on intensive production landscapes. There are also huge swathes of marginal, low-intensity agricultural landscape in the UK and across Europe – so-called 'High Nature Value' farming landscapes - where production potential will always be limited by environmental conditions. There may be greater opportunities for win-win management of biodiversity and other ES in such systems (Wilson, Evans & Grice 2010).

To consider 'farmland birds' as a single unit glosses over complications caused by differences between species in ecology, habitat preferences and sensitivities to habitat change. Common and rare species, specialists and generalists of farmland, all contribute to bird diversity and the cultural ES provided by the bird community. Their responses to management vary, so the species selected for this type of assessment will affect the conclusions. Conservation organizations would quickly prioritise any species that were affected negatively by particular changes in management, even if most species benefited from 'win-wins' with ES. This is why we have focussed here on the potential for management to co-deliver ES and conservation of a suite of species of current conservation concern.

The results of our assessment are sensitive to the choice of alternative land-use comparison. Changes in the cropping regime, for example, could change the relative value of a field margin to birds, as well as in respect of nutrient loads and run-off. Another issue is that the relative values of different benefits might change in time or space. We have identified relationships between bird conservation and service provision; whether these services are then experienced as benefits by people will be location-specific (depending on the type of service) and subject to considerable spatial variation in value (Fisher, Turner & Morling 2009).

AES will be key instruments for integrating multiple benefits (Defra 2007), but the ES agenda challenges the way in which AES incentive payments are calculated. Traditionally, payments have been based on the market value of agricultural commodity foregone, plus infrastructural cost needed to implement the option. To reflect the true benefits for human well-being arising from the provision of the full range of ES will require a major change (Sukhdev 2008). There is also the considerable challenge of providing evidence for AES option development to optimize complementarities, where possible, and minimise trade-offs between species conservation and ES. The challenge of how to do this, as with other broad habitats, is being considered in the UK National Ecosystem Assessment.

Concluding remarks

Lowland agricultural land in the UK and elsewhere has primarily had a provisioning service focus in the past, but will increasingly be required to deliver other services in addition to food and biomass (Firbank 2005). With food security, climate change mitigation and Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council) implementation as major priorities, species conservation could become marginalised as the 'added value' element of multi-objective landscapes. To return to our fourth question, if environmental management follows an ES agenda, what will be the consequences for species conservation?

There are clearly some complementarities, some resources of value to birds would be provided as a co-benefit of an ES agenda. However, there would appear to be a clear risk that some options for birds (e.g. cereals for whole crop silage in grassland areas) might loose support because of potential negative ES impacts. The same may be true of options that appear benign to other services, unless the target species is of high cultural value (e.g. skylark plots). A fundamental question is 'how much do we need?' For example, if options such as grass field margins are an efficient way to sequester carbon or enhance water quality, at what scale should they be deployed and how does the scale influence the impact on birds? Also, does 'multi-functional' imply single management options which deliver a range of services, including species conservation (land-sharing), or careful deployment of different options across the landscape (land-sparing), so that each can maximise the service it provides while minimising any detrimental impact on other services?

Farmland bird researchers have engaged in an exceptional collaboration with experts in other taxa, and with practitioners and policy makers to identify ecologically sensible, economically affordable, practical solutions to try to reverse the decline of farmland biodiversity. While the dangers of the sole use of an ES rationale to underpin species conservation cannot be ignored (Redford & Adams 2009), the opportunity now exists to broaden this inter-disciplinary effort, to help conserve farmland wildlife as part of the wider ambition of more sustainable farmland management.

Acknowledgements

We thank Lyndis Cole, Marion Potschin and Ken Norris for useful discussion that helped form the ideas in this manuscript. We also thank Jeremy Wilson, Gavin Siriwardena, the Associate Editor and an anonymous referee for their valuable comments.

References

Anderson, B.J., Armsworth, P.R., Eigenbrod, F., Thomas, C.D., Gillings, S., Heinemeyer, H., Roy, D.B. & Gaston, K.J. (2009) Spatial covariance between biodiversity and other ecosystem service priorities. *Journal of Applied Ecology*, **46**, 888–896.

Borin, M., Bigon, E., Zanin, G. & Flava, L. (2004) Performance of a narrow buffer strip in abating agricultural pollutants in the shallow subsurface water flux. *Environmental Pollution*, **131**, 313.

Bradbury, R.B. & Kirby, W.B. (2006) Farmland birds and resource protection in the UK: cross-cutting solutions for multi-functional farming? *Biological Conservation*, **129**, 530–542.

Bradbury, R.B., Bailey, C.M., Wright, D. & Evans, A.D. (2008) Wintering Cirl Buntings *Emberiza cirlus* in southwest England select cereal stubbles that follow a low-input herbicide regime. *Bird Study*, **55**, 23–31.

Carvell, C., Meek, W.R., Pywell, R.F., Goulson, D. & Nowakowski, M. (2007) Comparing the efficacy of agri-environment schemes to enhance bumblebee abundance and diversity on arable field margins. *Journal of Applied Ecology*, **44**, 29–40.

Christie, M., Fazey, I., Hyde, A., Dennis, P. & Warren, J. (2008) *Economic valuation of the benefits of the UK Biodiversity Action Plan*. Defra Project SFFSD 0702, Phase 1 Report.

Collins, K.L., Boatman, N.D., Wilcox, A., Holland, J.M. & Chaney, K. (2002) Influence of beetle banks on cereal aphid predation in winter wheat. *Agriculture, Ecosystems & Environment*, **93**, 337–350.

Crocker, M. & Mabey, R. (2005) *Birds Britannica*. Chatto & Windus, London.

Daily, G.C., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., Pejchar, L., Ricketts, T.H., Salzman, J. & Shallenbergen, R. (2009) Ecosystem services in decision-making: time to deliver. *Frontiers in Ecology and Environment*, **7**, 21–28.

De Deyn, G.B., Cornelissen, H.C. & Bardgett, R.D. (2008) Plant functional traits and soil carbon sequestration in contrasting biomes. *Ecology Letters*, **11**, 516–531.

Deasy, C., Quinton, J., Silgram, M., Jackson, B. & Bailey, A. (2008) *Final Report: Defra PE01206 Field Testing of Mitigation Options*. Lancaster Environment Centre, Lancaster, UK.

Defra (2007) *Securing a Healthy Natural Environment: An Action Plan for Embedding an Ecosystems Approach*. http://www.defra.gov.uk/wildlife-countryside/pdf/natural-environ/eco-actionplan.pdf.

Egoh, B., Reyers, B., Rouget, M., Bode, M. & Richardson, D.M. (2009) Spatial congruence between biodiversity and ecosystem services in South Africa. *Biological Conservation*, **142**, 553–562.

Evrard, O., Persoons, E., Vandaele, K. & van Wesemael, B. (2007) Effectiveness of erosion mitigation measures to prevent muddy floods: a case study in the Belgian loam belt. *Agriculture, Ecosystems & Environment*, **118**, 149–158.

Field, R.H., Kirby, W.B. & Bradbury, R.B. (2007) Conservation Tillage encourages early breeding by Skylarks *Alauda arvensis*. *Bird Study*, **54**, 137–141.

Field, R.H., Benke, S., Badonyi, K. & Bradbury, R.B. (2007) Influence of conservation tillage on bird use of winter arable fields in Hungary. *Agriculture, Ecosystems & Environment*, **120**, 399–404.

Firbank, L.G. (2005) Striking a new balance between agricultural production and biodiversity. *Annals of Applied Biology*, **146**, 163–175.

Fisher, B., Turner, R.K. & Morling, P. (2009) Defining and classifying ecosystem services for decision making. *Ecological Economics*, **68**, 643.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N. & Snyder, P.K. (2005) Global consequences of land use. *Science*, **309**, 570–574.

Haines-Young, R.H. & Potschin, M. (2009) The links between biodiversity, ecosystem services and human well-being. *Ecosystem Ecology: A New Synthesis* (eds D.D. Raffaelli & C. Frid). BES Ecological Reviews Series, CUP, Cambridge.

Holland, J.M. (2004) The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture, Ecosystems & Environment*, **103**, 1–25.

Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setala, H., Symstad, A.J., Vandermeer, J. & Wardle, D.A. (2005) Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs*, **75**, 3–35.

Jacobs, J.H., Clark, S.J., Denholm, I., Goulson, D., Stoate, C. & Osborne, J. (2009) Pollination biology of fruit-bearing plants and the role of flower-visiting insects in fruit set. *Annals of Botany*, **104**, 1397–1404.

Jarvie, H.P., Withers, P.J.A., Bowes, M.J., Palmer-Felgate, E.J., Harper, D., Wasiak, K., Wasiak, P., Hodgkinson, R.A., Bates, A., Stoate, C., Neal, M., Wickham, H.D., Harman, S.A. & Armstrong, L.K. (2010) Streamwater phosphorus and nitrogen across a gradient in rural-agricultural land use intensity. *Agriculture, Ecosystems and Environment*, **135**, 238–252.

Kleijn, D. & Sutherland, W.J. (2003) How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology*, **40**, 947–969.

Land Use Consultants & GHK Consulting Ltd. (2009) *Provision of ecosystem services through the environmental stewardship scheme*. Final report for Defra project NR0121. http://www.defra.gov.uk/wildlife-countryside/natural-environ/research.htm.

Loreau, M. (2010) Linking biodiversity and ecosystems: towards a unifying ecological theory. *Philosophical Transactions of the Royal Society Series V – Biological Sciences*, **365**, 49–60.

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Current State and Trends. Island Press, Washington DC.

Mortimer, S.R., Kessock-Philip, R., Potts, S.G., Ramsay, A.J., Roberts, S.P.M., Woodcock, B.A.., Hopkins, A., Gundrey, A., Dunn, R., Tallowin, J., Vickery, J. & Gough, S. (2006) *Review of the Diet and Micro-habitat Values for Wildlife and the Agronomic Potential of Selected Grassland Plant Species*. English Nature Research Report Number 697. English Nature, Peterborough.

Mytton, L.R., Cresswell, A. & Colbourn, P. (1993) Improvement in soil structure associated with white clover. *Grass & Forage Science*, **48**, 84–90.

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, K.M.A., Daily, G.C., Goldstein, J., Kareiva, P.M., Lonsdorf, E., Naidoo, R., Ricketts, T.H. & Shaw, M.R. (2009) Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. *Frontiers in Ecology and the Environment*, **7**, 4–11.

Nicholson, E., Mace, G.M., Armsworth, P.R., Atkinson, G., Buckle, S., Clements, T., Ewers, R.M., Fa, J.E., Gardner, T.A., Gibbons, J., Grenyer, R., Metcalfe, R., Mourato, S., Muûls, M., Osborn, D., Reuman, D.C., Watson, C. & Milner-Gulland, E.J. (2009) Priority research areas for ecosystem services in a changing world. *Journal of Applied Ecology*, **46**, 1139–1144.

Potts, G.R. (1986) *The Partidge: Pesticides, Predation and Conservation*. Collins, London.

Pywell, R.F., Bullock, J.M., Tallowin, J.R.B., Walker, K.J., Warman, E.A. & Masters, G. (2007) Enhancing diversity of species-poor grasslands: an experimental assessment of multiple constraints. *Journal of Applied Ecology*, **44**, 81–94.

Raisin, G.W., Mitchell, D.S. & Croome, R.L. (1997) The effectiveness of a small constructed wetland in ameliorating diffuse nutrient loadings from an Australian rural catchment. *Ecological Engineering*, **9**, 19–35.

Redford, K.H. & Adams, W.M. (2009) Payments for ecosystem services and the challenge of saving nature. *Conservation Biology*, **23**, 785–787.

Rochon, J.J., Doyle, C.J., Greef, J.M., Hopkins, A., Molle, G., Sitzia, M., Scholefield, D. & Smith, C.J. (2004) Grazing legumes in Europe: a review of their status, management, benefits, research needs and future prospects. *Grass & Forage Science*, **59**, 197–214.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach, M. & Smith, J. (2008) Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal Society B – Biological Sciences*, **363**, 789–813.

SOWAP (2007) *Soil and Surface Water Protection Using Conservation Tillage in Northern and Central Europe*. LIFE ENV/UK/000617 Technical Final Report.

Stoate, C. & Szczur, J. (2001) Whitethroat *Sylvia communis* and Yellowhammer *Emberiza citrinella* nesting success and breeding distribution in relation to field boundary vegetation. *Bird Study*, **48**, 229–235.

Stoate, C., Whitfield, M., Williams, P. & Driver, K. (2006) Wetland creation and mitigation of water pollution from field drains: use of buffer strip pools within an arable landscape. *Water and Landscape: The Landscape Ecology of Freshwater Ecosystems*, (eds. B. Davies & S. Thompson), pp. 331–334. IALE, Oxford.

Stoate, C., Baldi, A., Beja, P., Boatman, N.D., Herzon, I., van Doorn, A., de Snoo, G.R., Rakosy, L. & Ramwell, C. (2009) Ecological impacts of early 21st century agricultural change in Europe – a review. *Journal of Environmental Management*, **91**, 22–46.

Sukhdev, P. (2008) *The Economics of Ecosystems and Biodiversity, "Bridging the Gap"*. An interim report to the Convention on Biological Diversity (CBD, COP-9), Bonn, Germany.

Tallowin, J.R.B., Smith, R.E.N., Goodyear, J. & Vickery, J.A. (2005) Spatial and structural uniformity of lowland agricultural grassland in England: a context for biodiversity loss. *Grass & Forage Science*, **60**, 225–236.

Vickery, J.A., Tallowin, J.R., Feber, R.E., Asteraki, E.J., Atkinson, P.W., Fuller, R.J. & Brown, V.K. (2001) The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. *Journal of Applied Ecology*, **38**, 647–664.

Vickery, J.A., Bradbury, R.B., Henderson, I.G., Eaton, M.A. & Grice, P.V. (2004) The role of agri-environment schemes and farm management practices in reversing the decline of farmland birds in England. *Biological Conservation*, **119**, 19–39.

Vickery, J.A., Chamberlain, D.E., Evans, A.D., Ewing, S., Boatman, N., Pietravalle, S., Norris, K.J. & Butler, S.J. (2008) *Predicting the Impact of Future Agricultural Change and Uptake of Entry Level Stewardship on Farmland Birds*. BTO Research Report No. 485.

Whelan, C.J., Wenny, D.G. & Marquis, R.J. (2008) Ecosystem services provided by birds. *Annals of the New York Academy of Sciences*, **1134**, 25–60.

Wilson, K.-J. (2004) *The Flight of the Huia*. Canterbury University Press, Christchurch.

Wilson, J.D., Evans, A.D. & Grice, P.V. (2009) *Bird Conservation and Agriculture*. Cambridge University Press, Cambridge.

Wilson, J.D., Evans, A.D. & Grice, P.V. (2010) Bird conservation and agriculture: a pivotal moment? *Ibis*, **152**, 176–179.

Received 8 February 2010; accepted 12 June 2010
Handling Editor: Des Thompson

Supporting Information

Additional supporting information may be found in the online version of this article:

Appendix S1. Detailed methods used in the analysis of trade-offs and synergies in managing for species conservation and other services.

Table S1. List of land management practices considered to be the most probable business-as-usual practice, in the absence of ELS, plus detail of scoring of each ELS option against bird resource requirements from Vickery *et al.* (2008).

As a service to our authors and readers, this journal provides supporting information supplied by the authors. Such materials may be re-organized for online delivery, but are not copy-edited or typeset. Technical support issues arising from supporting information (other than missing files) should be addressed to the authors.