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Field-level bird abundances are enhanced by landscape-scale agri-environment scheme uptake

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Despite two decades of agri-environment schemes (AESs) aimed at mitigating farmland biodiversity losses, the evidence that such programmes actually benefit biodiversity remains limited. Using field-level surveys, we assess the effectiveness of AESs in enhancing bird abundances in an upland area of England, where schemes have been operating for over 20 years. In such a region, the effects of AESs should be readily apparent, and we predict that bird abundances will co-vary with both field- and landscape-scale measures of implementation. Using an information theoretic approach, we found that, for abundances of species of conservation concern and upland specialists, measures of AES implementation and habitat type at both scales appear in the most parsimonious models. Field-level bird abundances are higher where more of the surrounding landscape is included in an AES. While habitat remains a more influential predictor, we suggest that landscape-scale implementation results in enhanced bird abundances. Hence, measures of the success of AESs should consider landscape-wide benefits as well as localized impacts.

Keywords: landscape-scale conservation; peak district; environmentally sensitive area

1. INTRODUCTION

Losses of farmland biodiversity have been attributed to the rapid intensification of farming through the late twentieth century (Donald *et al.* 2001). To counteract this trend in Europe, incentive payments (agri-environment schemes; AESs) were introduced to compensate farmers for income losses associated with employing environmentally sensitive land management practices. However, evidence that such schemes benefit biodiversity remains limited (Kleijn *et al.* 2006) and mostly concern individual species (Peach *et al.* 2001; Davies *et al.* 2005), leaving considerable uncertainty about whether AESs applied at the landscape-scale mitigate biodiversity losses (Whittingham 2007, but see Rundlöf *et al.* 2008; Merckx *et al.* 2009).

Here, we assess the effectiveness of AESs in enhancing avian abundance in an upland area of England (Peak District National Park). In this region, AESs have been operating for over 20 years and in 2007 covered 66 000 ha at an annual cost of £3.6 million. In this pastoral system, AESs mainly offer increasing levels of financial compensation to farmers for accepting more stringent limitations on the intensity of land use, by reducing livestock density and fertilizer input on grasslands (table 1), both of which are known to influence bird populations in other regions (Baines 1990; Evans *et al.* 2005). If these prescriptions are effective and farmers are appropriately compensated for their losses, we would predict higher bird abundances on land parcels receiving increasing AES payments. However, birds are highly mobile and we also hypothesize that their abundance in any given field would be enhanced if a greater amount of the surrounding landscape is covered by AESs. Habitat quality and extent are primary drivers of bird distributions in the uplands (Stillman & Brown 1994; Woodhouse *et al.* 2005), and conservation initiatives are less effective when applied to poor quality habitat, such as intensive grassland (Kleijn *et al.* 2009). We therefore anticipate that avian abundances and the impact of AESs will be greater where habitat is more seminatural. To test these hypotheses, we carried out field-level bird abundance and habitat surveys across farmlands in the Peak District, and determined the relative importance of AESs versus habitat type at field and landscape scales.

2. MATERIAL AND METHODS

Field-level bird abundances were assessed across 29 farms selected from within the area covered by the environmentally sensitive area (ESA) AESs in the Peak District (for details of AES implementation in England, see Hodge & Reader 2010). Although closed to new entrants, the long-running ESA remained the dominant AES in the region at the time of our surveys, making it an ideal case study. Fields were surveyed on two separate early-morning visits at least six weeks apart between 28 March and 5 July 2007. A transect was walked through each field and the presence of all birds recorded. Fields were small (median 2.1 ha) with few obstacles obstructing vision, so field-level abundances were taken to be the total number of birds recorded without the necessity of estimating detectability. *Total* avian abundance for each field was defined as the higher of the abundances recorded on the two visits. We further divided this into two assemblages of greater relevance to conservation, *upland specialist* and *conservation concern* abundance (Dallimer *et al.* 2009).

Each field was classified according to whether it was *improved* or *semi-improved* grassland during surveys. We quantified the landscape-scale habitat composition in a 500 m buffer around each field using a GIS based on the Land Cover Map 2000. Two classes of land use were defined: (i) *seminatural* (seminatural grassland, scrub, bracken, moorland, woodland) and (ii) *intensive use* (improved grassland, arable land, urban areas). Data pertaining to all AESs operating in the study system were taken from a GIS layer provided by Natural England, which included reference to the payment made (range £18–260 ha^{-1}), if a given survey field was part of the ESA scheme. The proportion of the buffer around each field that was included in any AES was also determined.

We modelled avian abundance for the three different assemblages, using Poisson errors (corrected for over-dispersion where necessary), against AES and habitat explanatory variables at both field and landscape scales. All possible model combinations were constructed for the predictor variables, using AIC comparisons to identify the most parsimonious model (Burnham & Anderson 2002). We used a generalized linear mixed model to account for the lack of independence between fields within the same property.

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Table 1. Area and total payments distributed among four categories of land use within ESAs across the Peak District National Park (area 143 768 ha), 45% of which was covered by agreements in 2007.

land use	area (ha)	cost (£)
arable	3118	57 635
low-intensity grassland	20 517	1 409 704
moorland	42 172	2 125 171
woodland	178	9652
all land in ESA	65 984	3 602 162

Field area was forced into each model as a covariate of abundance. We anticipated that the relationship between avian abundance, habitat and AES provision may not take a simple linear form. Hence, we included interaction and quadratic terms in the modelling process.

For each assemblage, we determined: (i) model weights for candidate models, (ii) parameter estimates for each explanatory variable calculated by averaging across all models, (iii) the relative importance of each variable in explaining field-level avian abundances, by calculating w_i, the Akaike weight, and (iv) model explanatory power, by assessing the correlation between predicted and observed avian abundances; conventional r^2 measures are not appropriate in our modelling approach. All analyses were carried out using lme4 in R 2.9.2.

3. RESULTS

Across the 29 farms, 346 fields were surveyed, 278 of which were improved and 68 semi-improved grassland. The majority of fields (216) were in the ESA scheme, with a mean payment of £31.69 ha^{-1}. The proportion of the 500 m buffer around each field that was seminatural ranged from 0.03 to 1.00 (median 0.74), and the proportion of land in AESs varied between 0 and 0.99 (median 0.61). Spearman's rank correlation coefficient between AES coverage and seminatural coverage in the buffers was 0.332.

In total, 78 species were encountered (including 16 upland specialists and 36 of conservation concern). Total abundance ranged from 0 to 19 birds per field, and the most parsimonious model retained only property as a random factor. No measures of field or landscape-scale habitat or AES provision were important predictors of total abundance and explanatory power was low (table 2). For upland specialists (range 0–11 birds per field) and species of conservation concern (range 0–18 birds per field), habitat and AES variables from both field and landscape scales appeared in the most parsimonious models and the explanatory power was high. Based on w_i, measures of habitat were relatively better predictors of abundance than AES provision at both scales. Although relationships took a quadratic form making it hard to interpret from parameter estimates alone (table 2), abundances increased with a higher proportion of AES coverage in the landscape buffer (figure 1), and the extent of AES coverage in this buffer was a more important predictor than field-scale payment levels (table 2 and figure 1). Landscape-scale AES and seminatural coverage had a greater influence on conservation concern abundances in semi-improved than in improved fields, but this interaction was not apparent for the upland specialist assemblage (figure 1).

4. DISCUSSION

AES and habitat variables were sufficiently unrelated to allow their direct influences on avian abundances to be examined. At field and landscape scales, the most parsimonious models of upland specialist and conservation concern abundances contained variables relating to AES provision and habitat type or extent. Although habitat variables at both scales had higher model weights, we found a positive relationship between avian abundance and the proportion of land included in AESs, which contrasts with the general pattern for farmland birds in the English lowlands (Davey *et al.* in press). These relationships for assemblages mask a more complicated story of non-uniform responses of individual species (electronic supplementary material). Although overall conservation concern abundance increases with AES provision in the landscape buffer, some species, such as the swallow *Hirundo rustica* or the skylark *Alauda arvensis*, may not benefit from AES options, such as lower livestock densities, commonly employed in this landscape.

The influence of habitat type and extent is unsurprising, as both are key drivers of avian abundance and diversity in the uplands (Woodhouse *et al.* 2005; Dallimer *et al.* 2009). Re-establishing seminatural habitat and returning currently improved grassland to a more seminatural status will therefore provide the greatest benefit for bird abundances. This could be achieved through AESs via land management actions, such as reduced grazing pressure, which can have beneficial effects on habitat characteristics (Berg *et al.* 1997), insect diversity (Littlewood 2008) and the breeding success of upland species (Evans *et al.* 2005). In such circumstances, where fields were less intensive in character, landscape-level AES provision had a greater impact on the abundance of species of conservation concern compared with where fields were intensively managed; a pattern that was also observed for conservation interventions for arable plants (Kleijn *et al.* 2009), although in our case we cannot rule out the possibility of biased enrolment of high conservation value fields.

In conclusion, we have demonstrated that fields surrounded by a greater proportion of land in AESs had higher abundances of upland specialists and species of conservation concern (cf. Rundlöf *et al.* 2008; Merckx *et al.* 2009). This provides evidence in support of the overall effectiveness of AESs, and we suggest that measures of their success must therefore consider the wider landscape scale in addition to localized impacts.

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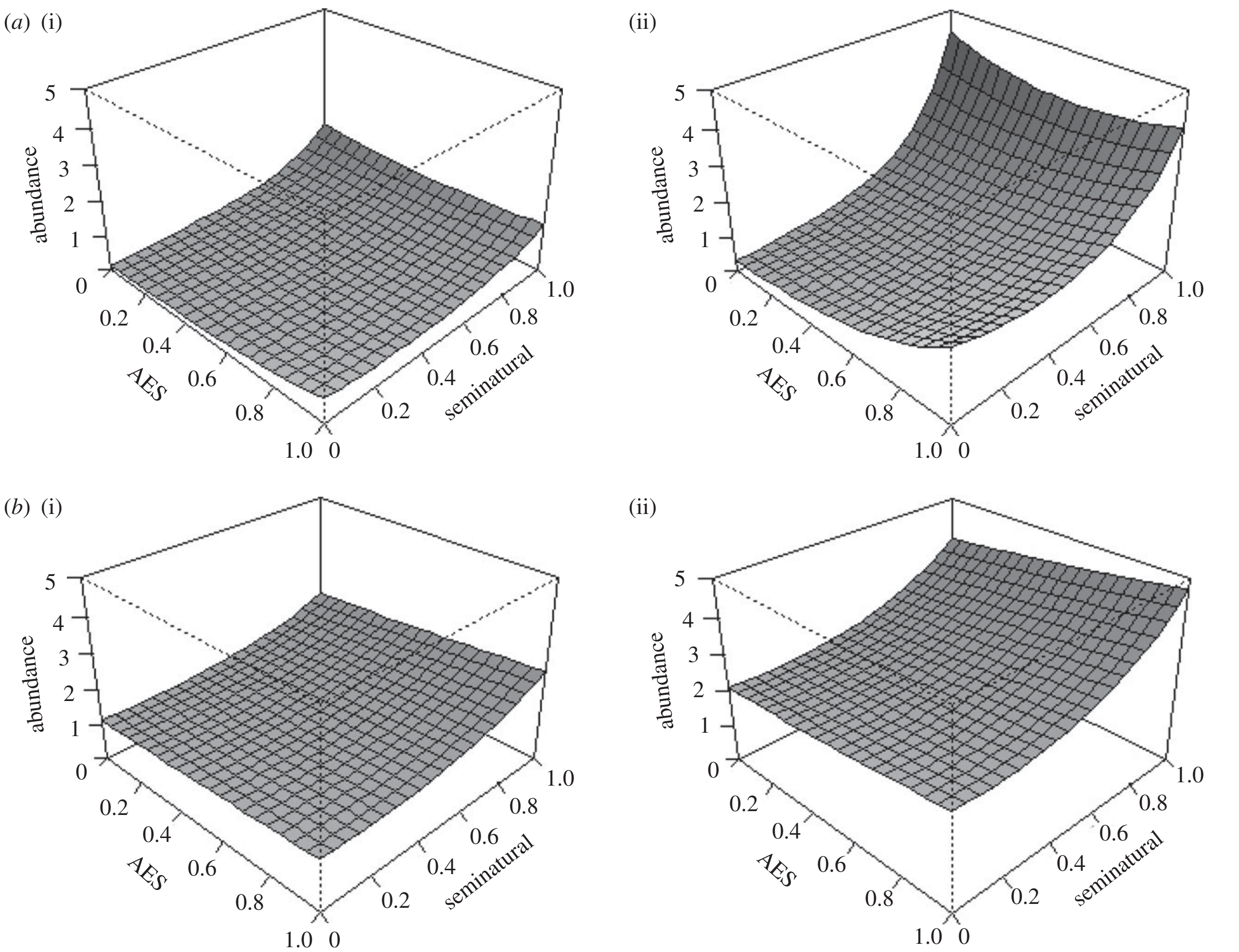

Figure 1. Fitted surfaces based on model parameter estimates for (i) improved and (ii) semi-improved fields illustrating the relationships between: (*a*) upland specialist and (*b*) conservation concern abundance and seminatural and AES coverage in the landscape.

Table 2. Relationship between avian abundance in a surveyed field and payment and habitat type (improved/semi-improved) at the field scale, and seminatural habitat and AES coverage (and their square terms) at the landscape scale. Akaike weights (w_i) and model averaged parameter estimates in bold indicate that the variable appears in the most parsimonious model.

	total		upland		conservation concern	
	parameter	w_i	parameter	w_i	parameter	w_i
field scale						
improved	0.995	—	**−3.547**	—	**0.037**	—
semi-improved	−0.015	0.319	**0.855**	**1**	**0.334**	**0.989**
payment	0	0.343	**0**	**0.621**	−0.003	0.681
habitat: AES interaction	0.001	0.135	−0.001	0.252	0.003	0.469
landscape scale						
AES	−0.057	0.257	**3.539**	**0.990**	**−0.683**	**0.862**
AES^2	0.037	0.063	**−2.034**	**0.685**	**0.361**	**0.615**
seminatural	0.056	0.284	**−0.151**	**0.999**	**−1.725**	**0.940**
$seminatural^2$	0.009	0.063	**1.591**	**0.651**	**1.575**	**0.773**
seminatural: AES interaction	0.001	0.005	0.061	0.305	**1.129**	**0.449**
correlation coefficient between predicted and observed abundance	0.439		0.770		0.662	

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