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# biology letters

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Supplementary data	"Data Supplement" http://rsbl.royalsocietypublishing.org/content/suppl/2009/09/09/rsbl.2009.0643.DC1.ht ml
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## Does organic farming benefit farmland birds in winter?

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The generally higher biodiversity on organic farms may be influenced by management features such as no synthetic pesticide and fertilizer inputs and/or by differences in uncropped habitat at the site and landscape scale. We analysed bird and habitat data collected on 48 paired organic and conventional farms over two winters to determine the extent to which broad-scale habitat differences between systems could explain overall differences in farmland bird abundance. Density was significantly higher on organic farms for six out of 16 species, and none on conventional. Total abundance of all species combined was higher on organic farms in both years. Analyses using an informationtheoretic approach suggested that both habitat extent and farm type were important predictors only for starling and greenfinch. Organic farming as currently practised may not provide significant benefits to those bird species that are limited by winter food resources, in particular, several declining granivores.

**Keywords:** agri-environment schemes; farming systems; Farmland Bird Indicator

#### 1. INTRODUCTION

Abundant evidence exists to show that recent largescale declines in farmland biodiversity in Europe are linked to profound changes in agricultural management (e.g. Donald et al. 2001). Organic farming provides a less-intensive approach to food production. Biodiversity on organic farms tends to be greater (Bengtsson et al. 2005; Fuller et al. 2005; Hole et al. 2005), hence organic farming has been proposed as a potential tool by which biodiversity declines may be reversed. It is evident from a number of studies that organic farms tend to have greater farm-level habitat heterogeneity owing to broad differences in cropping patterns and better/more extensive non-crop habitats at the site and landscape levels (e.g. Rundlof & Schmidt 2006; Norton et al. 2009). It therefore remains unclear whether organic farms support greater biodiversity owing to management of inputs to the system (e.g. no synthetic pesticides or fertilizers), to

Electronic supplementary material is available at http://dx.doi.org/ 10.1098/rsbl.2009.0643 or via http://rsbl.royalsocietypublishing.org. heterogeneity in wider habitat composition (Chamberlain *et al.* 1999; Gibson *et al.* 2007) or both.

We compare winter bird abundance and species richness between farm types (FTYP) (organic or conventional) for a group of Farmland Bird Indicator (FBI) species. Trend in a combined FBI index has been adopted by the UK government as an indicator of the health of the wider farmland environment and is a key driver of agri-environmental policy (Gregory *et al.* 2004). We use an information-theoretic approach (Burnham & Anderson 2002) to consider the relative importance of FTYP, compared with variables describing habitat extent, in predicting bird numbers and species richness for FBI species.

#### 2. MATERIAL AND METHODS

Organic sites were selected from a certified list and paired with a conventional farm on the basis of proximity and crop type, and identical bird surveys were carried out on both (details in electronic supplementary material). During each survey visit, the observer walked the perimeter and once across the centre of each field. The locations of all birds seen or heard were recorded when first detected. Surveys were undertaken once per month to each site between October and February inclusive and were carried out over two winters (2000/2001 and 2002/2003, referred to as 2001 and 2003, respectively). Forty-three farm pairs were surveyed in 2001 and 34 pairs in 2003. Habitat attributes of the fields (e.g. crop or other field type) and non-crop habitats (hedgerows, presence and extent of field margins, small woods) were recorded.

The analysis focused on 16 FBI species (table 1). Total abundance  $(A_{\rm FBI})$  and species richness  $(S_{\rm FBI})$  of FBI species were also determined per site. The latter was estimated from rarefaction curves (Magurran 2004) standardized to 20 individuals. Bird count per visit (for individual species and  $A_{\rm FBI}$ ) was analysed using a generalized linear model with log(survey area) included as an offset, in relation to FTYP (i.e. organic or conventional) and farm pair (thus maintaining the paired structure). Negative binomial errors were specified, which provided better fitting models than Poisson errors (most species considered show high variability in counts owing to the occurrence of sometimes large flocks). If a given species was not recorded on either site in a pair, then that pair was omitted from the analysis (hence sample sizes differ between species). In order to account for multiple visits to each site, a repeated-measures model structure was specified. Species richness was analysed using a normal errors model, including farm pair and FTYP as above. Initial analyses considered the effect of FTYP only in order to determine overall differences in density/richness between farm systems.

A second set of analyses using the same model structures was undertaken, which included additional habitat variables identified from previous studies as being possible determinants of winter bird density. For each species, a literature search was undertaken to identify potential predictors of winter bird abundance and therefore to construct candidate models (table S1 in electronic supplementary material). Seven variables were at the site level: habitat diversity (calculated with the Shannon formula), hedgerow density (km ha<sup>-1</sup>), arable area (except stubbles), grass area, stubble area, field margin area and woodland area. A further three variables were extracted from Land Cover Map 2000 data (Fuller *et al.* 2002) at a  $3 \times 3$  km scale, where the survey site occupied the central square: woodland area, arable–grass ratio and this ratio squared.

For species showing FTYP effects, an information-theoretic approach was used (Burnham & Anderson 2002). We determined the average parameter estimate for FTYP over all candidate models, weighted by Akaike information criteria (AIC<sub>c</sub>), and calculated the Akaike weight,  $\omega_i$ , for FTYP across all candidate models (model-averaged parameter estimates, and  $\omega_i$  for other predictor variables are given in tables S2 and S3 in electronic supplementary material).

#### 3. RESULTS

Density was significantly higher on organic farms for stock dove *Columba oenas*, starling *Sturnus vulgaris*, jackdaw *Corvus monedula* and linnet *Carduelis cannabina* in 2001, and for woodpigeon *Columba palumbus* and greenfinch *Carduelis chloris* in 2003. *A*<sub>FBI</sub> was significantly higher on organic farms in both years Table 1. Mean  $\pm$  s.e. difference (organic-conventional) in species abundance (individuals per hectare for separate species), combined species abundance ( $A_{\rm FBI}$ , individuals per hectare for combined FBI species) and species richness standardized to 20 individuals ( $S_{\rm FBI}$ ) on organic and conventional farms, derived from least-squares means. (n =number of sites. n.a. = model did not converge on a solution. Scientific names of species are given in the electronic supplementary material.)

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goldfinch $0.372 \pm 0.270$ 74 $0.40$ linnet $2.033 \pm 0.376$ 40 $0.02$ yellowhammer $0.067 \pm 0.238$ 80 $0.85$ reed bunting $1.276 \pm 0.562$ 22 $0.18$ corn bunting $-3.463 \pm 0.818$ 8 $0.21$ $A_{FBI}$ $0.489 \pm 0.143$ 86 $0.01$ $S_{FBI}$ $0.457 \pm 0.254$ 80 $0.08$ 2003kestrel $0.029 \pm 0.264$ 62 $0.91$ grey partridge $-0.270 \pm 0.367$ 40 $0.68$ lapwing $-1.031 \pm 0.451$ 36 $0.67$ woodpigeon $0.568 \pm 0.194$ 68 $0.04$ stock dove $0.789 \pm 0.352$ 48 $0.28$ skylark $-0.061 \pm 0.217$ 66 $0.84$ tarling $0.476 \pm 0.264$ 62 $0.40$ rook $0.798 \pm 0.285$ 58 $0.17$	greenfinch	$0.936 \pm 0.306$	74	0.064
linnet $2.033 \pm 0.376$ $40$ $0.02$ yellowhammer $0.067 \pm 0.238$ $80$ $0.85$ reed bunting $1.276 \pm 0.562$ $22$ $0.18$ corn bunting $-3.463 \pm 0.818$ $8$ $0.21$ $A_{FBI}$ $0.489 \pm 0.143$ $86$ $0.01$ $S_{FBI}$ $0.457 \pm 0.254$ $80$ $0.08$ 2003 $2003$ $8estrel$ $0.029 \pm 0.264$ $62$ grey partridge $-0.270 \pm 0.367$ $40$ $0.68$ lapwing $-1.031 \pm 0.451$ $36$ $0.67$ woodpigeon $0.568 \pm 0.194$ $68$ $0.04$ stock dove $0.789 \pm 0.352$ $48$ $0.28$ skylark $-0.061 \pm 0.217$ $66$ $0.84$ tarling $0.476 \pm 0.264$ $62$ $0.47$ rook $0.798 \pm 0.285$ $58$ $0.17$ iackdaw $1.467 \pm 0.318$ $58$ $0.08$	goldfinch	$0.372 \pm 0.270$	74	0.401
yellowhammer $0.067 \pm 0.238$ 80 $0.85$ reed bunting $1.276 \pm 0.562$ $22$ $0.18$ corn bunting $-3.463 \pm 0.818$ $8$ $0.21$ $A_{FBI}$ $0.489 \pm 0.143$ $86$ $0.01$ $S_{FBI}$ $0.457 \pm 0.254$ $80$ $0.08$ 2003 $2003$ $8$ $80$ $0.682$ grey partridge $-0.270 \pm 0.367$ $40$ $0.682$ lapwing $-1.031 \pm 0.451$ $36$ $0.048$ stock dove $0.789 \pm 0.352$ $48$ $0.288$ skylark $-0.061 \pm 0.217$ $66$ $0.844$ starling $0.476 \pm 0.264$ $62$ $0.476$ rook $0.798 \pm 0.285$ $58$ $0.177$ iackdaw $1.467 + 0.318$ $58$ $0.084$	linnet	$2.033 \pm 0.376$	40	0.027
reed bunting $1.276 \pm 0.562$ $22$ $0.18$ corn bunting $-3.463 \pm 0.818$ $8$ $0.21$ $A_{FBI}$ $0.489 \pm 0.143$ $86$ $0.01$ $S_{FBI}$ $0.457 \pm 0.254$ $80$ $0.08$ 2003 $2003$ $88876$ $62$ $0.91$ grey partridge $-0.270 \pm 0.367$ $40$ $0.688$ lapwing $-1.031 \pm 0.451$ $36$ $0.048$ stock dove $0.789 \pm 0.352$ $48$ $0.288$ skylark $-0.061 \pm 0.217$ $66$ $0.844$ starling $0.476 \pm 0.264$ $62$ $0.447$ rook $0.798 \pm 0.285$ $58$ $0.177$ iackdaw $1.467 + 0.318$ $58$ $0.086$	yellowhammer	$0.067 \pm 0.238$	80	0.854
$\begin{array}{cccc} {\rm corn \ bunting} & -3.463 \pm 0.818 & 8 & 0.21 \\ A_{\rm FBI} & 0.489 \pm 0.143 & 86 & 0.01 \\ S_{\rm FBI} & 0.457 \pm 0.254 & 80 & 0.08 \\ \hline \\ 2003 & & & & & & & & & & & & & & & & & & $	reed bunting	$1.276\pm0.562$	22	0.188
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	corn bunting	$-3.463 \pm 0.818$	8	0.211
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$A_{\rm FBI}$	$0.489 \pm 0.143$	86	0.012
2003kestrel $0.029 \pm 0.264$ $62$ $0.91$ grey partridge $-0.270 \pm 0.367$ $40$ $0.68$ lapwing $-1.031 \pm 0.451$ $36$ $0.67$ woodpigeon $0.568 \pm 0.194$ $68$ $0.04$ stock dove $0.789 \pm 0.352$ $48$ $0.28$ skylark $-0.061 \pm 0.217$ $66$ $0.84$ starling $0.476 \pm 0.264$ $62$ $0.47$ rook $0.798 \pm 0.285$ $58$ $0.17$	$S_{\rm FBI}$	$0.457\pm0.254$	80	0.080
kestrel $0.029 \pm 0.264$ $62$ $0.91$ grey partridge $-0.270 \pm 0.367$ $40$ $0.68$ lapwing $-1.031 \pm 0.451$ $36$ $0.67$ woodpigeon $0.568 \pm 0.194$ $68$ $0.04$ stock dove $0.789 \pm 0.352$ $48$ $0.28$ skylark $-0.061 \pm 0.217$ $66$ $0.84$ starling $0.476 \pm 0.264$ $62$ $0.40$ rook $0.798 \pm 0.285$ $58$ $0.17$	2003			
grey partridge $-0.270 \pm 0.367$ 400.68lapwing $-1.031 \pm 0.451$ 360.67woodpigeon $0.568 \pm 0.194$ 680.04stock dove $0.789 \pm 0.352$ 480.28skylark $-0.061 \pm 0.217$ 660.84starling $0.476 \pm 0.264$ 620.40rook $0.798 \pm 0.285$ 580.17iackdaw $1.467 \pm 0.318$ 580.08	kestrel	$0.029 \pm 0.264$	62	0.915
lapwing $-1.031 \pm 0.451$ 360.67woodpigeon $0.568 \pm 0.194$ 68 $0.04$ stock dove $0.789 \pm 0.352$ 48 $0.28$ skylark $-0.061 \pm 0.217$ 66 $0.84$ starling $0.476 \pm 0.264$ 62 $0.40$ rook $0.798 \pm 0.285$ 58 $0.17$ iackdaw $1.467 \pm 0.318$ 58 $0.08$	grey partridge	$-0.270 \pm 0.367$	40	0.683
woodpigeon $0.568 \pm 0.194$ $68$ $0.04$ stock dove $0.789 \pm 0.352$ $48$ $0.28$ skylark $-0.061 \pm 0.217$ $66$ $0.84$ starling $0.476 \pm 0.264$ $62$ $0.40$ rook $0.798 \pm 0.285$ $58$ $0.17$ iackdaw $1.467 \pm 0.318$ $58$ $0.08$	lapwing	$-1.031 \pm 0.451$	36	0.679
stock dove $0.789 \pm 0.352$ 48 $0.28$ skylark $-0.061 \pm 0.217$ 66 $0.84$ starling $0.476 \pm 0.264$ 62 $0.40$ rook $0.798 \pm 0.285$ 58 $0.17$ jackdaw $1.467 \pm 0.318$ 58 $0.08$	woodpigeon	$0.568 \pm 0.194$	68	0.046
skylark $-0.061 \pm 0.217$ 66 $0.84$ starling $0.476 \pm 0.264$ 62 $0.40$ rook $0.798 \pm 0.285$ 58 $0.17$ jackdaw $1.467 \pm 0.318$ 58 $0.08$	stock dove	$0.789 \pm 0.352$	48	0.281
starling $0.476 \pm 0.264$ $62$ $0.400$ rook $0.798 \pm 0.285$ $58$ $0.17$ jackdaw $1.467 \pm 0.318$ $58$ $0.085$	skylark	$-0.061 \pm 0.217$	66	0.845
rook $0.798 \pm 0.285$ 58 0.17 iackdaw 1.467 + 0.318 58 0.08	starling	$0.476 \pm 0.264$	62	0.400
$1467 \pm 0.318$ 58 0.08	rook	$0.798 \pm 0.285$	58	0.171
$1.407 \pm 0.510$ 50 0.00	jackdaw	$1.467\pm0.318$	58	0.084
tree sparrow $1.551 \pm 0.701$ 16 0.20	tree sparrow	$1.551\pm0.701$	16	0.203
greenfinch $0.859 \pm 0.276$ 64 0.04	greenfinch	$0.859 \pm 0.276$	64	0.044
goldfinch $0.815 \pm 0.326$ 56 $0.18$	goldfinch	$0.815\pm0.326$	56	0.182
linnet $0.902 \pm 0.367$ 54 0.69	linnet	$0.902 \pm 0.367$	54	0.694
yellowhammer $-0.419 \pm 0.241$ 62 0.27	yellowhammer	$-0.419 \pm 0.241$	62	0.272
reed bunting $0.574 \pm 0.462$ 38 0.47	reed bunting	$0.574 \pm 0.462$	38	0.472
corn bunting $-1.233 \pm 0.795$ 8 0.57	corn bunting	$-1.233 \pm 0.795$	8	0.575
$A_{\rm FBI}$ 0.428 $\pm$ 0.152 68 0.03	$A_{\rm FBI}$	$0.428 \pm 0.152$	68	0.035
$S_{\rm FBI}$ 0.161 $\pm$ 0.246 66 0.51	$S_{ m FBI}$	$0.161\pm0.246$	66	0.517

(table 1). For those species that showed an effect of FTYP that was significant, or that approached significance (p < 0.10), model-averaged parameter estimates and model weights are given in table 2. This revealed strong support of an effect of FTYP, in terms of a high  $\omega_i$  and confidence intervals not overlapping zero, only for starling and greenfinch (table 2).

#### 4. DISCUSSION

A minority of FBI species had (mostly weakly) significantly higher densities on organic farms, although the majority of species' densities were greater on organic farms and there was significantly greater total density on organic farms. Only lapwing *Vanellus vanellus*  Table 2. Model-averaged parameter estimates and 95% confidence limits for the effects of FTYP for species/groups showing a tendency for farm-type differences. (Positive parameter estimates indicate greater density/species richness on organic farms than on conventional farms.  $\omega_i$  is the summed model weight for FTYP.)

species	FTYP	$\omega_i$
2001		
lapwing	-0.373 ( $-0.584$ , $5.101$ )	0.126
stock dove	0.302(-3.082, 3.686)	0.162
starling	2.878 (1.565, 4.189)	0.966
jackdaw	0.659(-1.267, 2.585)	0.420
greenfinch	0.111(-1.411, 1.633)	0.145
linnet	1.207(-0.657, 3.070)	0.595
$A_{\rm FBI}$	0.169(-0.542, 0.881)	0.353
$S_{\rm FBI}$	0.001 (-1.028, 1.028)	0.001
2003		
woodpigeon	0.015(-0.553, 0.583)	0.065
jackdaw	0.181 (-1.590, 1.953)	0.182
greenfinch	1.693 (1.037, 2.350)	0.999
$A_{\rm FBI}$	0.052 (-0.610, 0.713)	0.160

(in 2001) showed a (non-significant) trend towards higher density on conventional farms. The informationtheoretic approach suggested that both habitat extent and FTYP were important predictors for starling and greenfinch, but otherwise there was no evidence that FTYP was an important predictor when accounting for other habitat variables.

Habitat structure is a principal correlate of spatial variation in bird abundance on farmland (Fuller et al. 1997). Norton et al. (2009) found a greater extent of non-crop habitats and more heterogeneous land use in a sample of organic farms in the UK (of which this study is a subset). Variation in structural habitat is likely to be a key factor in explaining the organicconventional contrast in birds. For example, variables that are known to systematically vary between farming systems (Norton et al. 2009) and which were strongly linked to winter bird density included hedgerow density  $(A_{\text{FBI}})$ , proportion of arable area at the farm scale (stock dove, jackdaw) and grass : arable ratio at the landscape scale (woodpigeon, jackdaw), although there were some models where no consistent effects of any variable were found (table S2 in electronic supplementary material). Similar effects of cropping patterns and landscape complexity, coupled with relatively weak effects of organic management, have been found for breeding birds (Piha et al. 2007; Kragten & de Snoo 2008). Furthermore, landscape structural heterogeneity is a key component of overall system differences for invertebrates (Schmidt et al. 2005; Rundlof & Schmidt 2006). Similarly, the results presented here suggest that the 'physical' habitat of farmland is likely to explain much variation in winter bird abundance between systems.

Availability of food resources in winter is likely to be a key limiting factor for many FBI species, especially granivorous passerines, and their decline is strongly linked to loss of key foraging habitats such as stubbles (e.g. Gillings *et al.* 2005). Our observations suggest that this group of species may not benefit (in winter) from wider adoption of organic farming practices. The general lack of farm-type differences could be strongly influenced by stubble availability. Although higher arable weed abundance on organic farms (Fuller et al. 2005) may be expected to increase winter food resources, at the time of the study stubbles were more prevalent on conventional farms (Norton et al. 2009), as organic farmers cannot afford the resulting weed burden. The majority of species identified in this paper likely to most benefit from organic farming practices in winter were increasing species and as such are not of conservation priority. Starling was the only decreasing species (Gregory et al. 2004) to show strong effects of FTYP when accounting for broadscale habitat variation, possibly owing to better foraging provided by organic grass management (temporary grass leys and application of farmyard manure).

We conclude that variation in broad-habitat extent is a better predictor of bird abundance and richness than FTYP per se. As well as lack of pesticide and synthetic fertilizer use, organic farms differ from conventional farms in terms of a range of habitat variables and management practices (Norton et al. 2009), which vary in the extent to which they could be considered intrinsic to the system. Organic farming has clear benefits for a range of taxa (e.g. Hole et al. 2005), but some aspects of organic farming may not currently provide significant benefits to bird species that are limited by winter seed resources. However, a reduction in stubbles on non-organic farmland, as has recently occurred with the phasing-out of setaside, could result in organic farms becoming more heavily used by some granivorous species.

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