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A comparison of bird populations on organic and conventional farm systems in southern Britain

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Abstract

Field boundaries and fields on 22 pairs of organic and conventional farms in England and Wales were surveyed over three breeding seasons (April–July) and two autumn (September–November) and winter (December–February) periods in order to ascertain whether organic and conventional farms differed in the size and diversity of their associated bird populations. Species diversity was significantly higher on organic farms in the 1994 breeding season, but in no other year or season. Of 18 species, eight showed a significantly higher density on organic field boundaries in at least one season/year, with a greater number of significant results being detected in the autumn. There were very few significant differences in bird density in fields outside the breeding season. The density of breeding skylarks *Alauda arvensis*, the principal field nesting species, was significantly greater on organic farms in one breeding season. Hedges tended to be higher and wider, field boundaries tended to have more trees and field sizes tended to be smaller on organic farms. Canonical correspondence analysis indicated that components of habitat structure were important in explaining differences in bird density between farm types for certain species. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Canonical correspondence analysis; Habitat structure; Hedgerow; Organic farming; Species density

1. Introduction

Since the advent of long-term population monitoring in the 1960s, many species of farmland bird have shown dramatic declines in both range and population size in northern Europe (O'Connor and Shrubb, 1986; Hustings et al., 1990; Tucker and Heath, 1994; Siriwardena et al., 1998). Fuller et al. (1995) report that of 28 species primarily associated with farmland in the UK, 24 have shown a contraction in range and 15 out of 18 species, which could be accurately censused, showed a decrease in population size between the late 1960s and early 1990s. These declines are far greater than for species associated with other habitats such as woodland or wetlands over the same period.

The period of decline of many of these species occurred at a time when substantial changes in the management of farmland were taking place (O'Connor and Shrubb, 1986; Stoate, 1996). Increased mechanisation, use of chemical fertilizers and pesticides, and specialisation of farming enterprises have resulted in an overall decrease of diversity in farm land use across northern Europe. In the UK, substantial changes in the cropping regime have occurred in recent decades; particularly an increase in cereal farming, a simplification in crop rotations, an intensification of grassland management, a reliance on a wider range of chemical pesticides, and a switch from spring to winter-sown cereals (Fuller et al., 1995). The latter factor may have had particular consequences for seed-eating birds which rely on the weeds and spilt grain provided by stubble fields in the winter (Wilson et al., 1996). The loss of traditional rotations has led to a decrease in the diversity of habitat available to birds on farmland. The skylark *Alauda arvensis* may be particularly affected, as it shows a preference for young grass or clover leys (O'Connor and Shrubb, 1986) which are a common component of traditional crop rotations. Studies in Switzerland have shown that skylarks breed at higher densities when there is a higher diversity of field types in the surrounding farmland (Schläpfer 1988; Jenny, 1990). Removal of non-crop habitats has also contributed to the decline in habitat diversity. Areas of non-crop habitats within farmland, such as hedgerows, are typically the most important features affecting the number of birds present

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on UK farmland (Fuller et al., 1997). It has been estimated that between one quarter and one third of hedgerow in Britain has been removed since 1945 (Watt and Buckley, 1994), and thus a large proportion of the nesting habitat of many farmland species, in addition to an important source of food, has been lost.

The diversity and quantity of pesticides used on farmland increased markedly from the late 1960s (O'Connor and Shrubb, 1986). Although the more toxic organochlorines and organophosphates are now largely obsolete, increased pesticide use may have indirect effects on birds by dramatically reducing food resources available (Campbell et al., 1997) by killing invertebrates and weeds, the latter being both a source of seeds and of invertebrates which use weeds for food plants and cover. The grey partridge *Perdix perdix* is the clearest example of a species particularly affected by pesticide use in this way (Potts, 1986; Rands, 1986).

In recent years, a greater public interest in "green" issues and a growing awareness of possible environmental damage caused by intensive farming has seen a growth in the number of farms managed organically (Lampkin, 1990), although these remain a tiny minority of farms in Britain. Organic management typically employs crop rotations involving nitrogen-building leys to maintain soil fertility in place of chemical fertilizers. Pest and weed control is sought through careful use of rotations coupled with mechanical techniques. Synthetic pesticides and fertilizers are not used. As practised in Britain, organic farming embraces an holistic approach to the management of farmland which includes enhancement of the habitat through perceived sympathetic management of non-crop habitats such as hedgerows and ponds. Implicit in the philosophy of organic farming is the reversal of many of the trends towards intensification outlined above which may have led to the declines in populations of farmland birds. Organic farms may thus be expected to support higher densities of farmland birds with benefits potentially deriving from several mechanisms (Fuller, 1997). Studies on the effects of the overall organic management of farms on wildlife are, however, rare. There is some evidence that organic farms support a greater number of insect species (Dritschillo and Wanner, 1980; Hald and Reddersen, 1990) and a higher number of individuals of certain insect species (Moreby et al., 1994) than conventional farms. (Here, and in the rest of this study, the term "conventional" is used to describe farms where the land use and crop management are within the normal range of variation for the local area.) Also the number of weed species and weed cover have been shown to be higher in organic crops (Moreby et al., 1994).

Amongst birds, there is evidence of higher densities of a number of species on organic farms in Denmark (Braae et al., 1988) and of better reproductive success among yellowhammers *Emberiza citrinella* (Petersen et al., 1995). In these studies the influence of variation in factors not associated with the management system (e.g. farm size, proximity to woodland, amount of non-crop habitat) which may have affected the bird community was not dealt with adequately. However, Wilson et al. (1997) statistically controlled for such effects and demonstrated that organically managed crops support higher densities of skylarks than conventionally managed crops or pasture.

This paper assesses the whole-system benefits of organic farming to birds in Britain by measuring the abundance of all species in a sample of farm sites of each type (organically and conventionally managed) from a wide geographic range in England and Wales. Each organic farm was paired with a nearby conventional farm in order to control for the geographic variation in bird community composition.

2. Methods

2.1. Farm selection

Organic farms were defined according to Soil Association and UK Register of Organic Food standards (Soil Association, 1989; UKROFS, 1992) and were identified from the official Soil Association and Organic Farmers and Growers membership list. Farms only appear on the list when they have been certified as reaching organic standards after a two or three year transitional period of organic management. These standards involve restrictions on the use of artificial fertilizers and pesticides, and outline specific mandatory management practices for crops and livestock. It should also be stressed that organic standards explicitly give recommendations for the management of non-crop habitats, such as hedgerows, farm woods and ponds.

Farms were eligible for inclusion in the survey if they were arable, mixed or pastoral enterprises with at least 30 ha of cropped area. This excluded very small-scale, often horticultural enterprises, which comprised the majority of listed organic producers. In total, 22 fully organic farms across England and Wales which met the above criteria agreed to allow survey work to be carried out on their land and were included in the study, although the number varied between seven and 18 farms per season. There were only four organic farms which were surveyed in each season from the 1992 to the 1994 breeding season. Discounting the first pilot survey when only seven farms were surveyed, 11 farms were covered in the breeding season of both remaining years, and in the autumn and winter there were 15 such farms.

Each organic farm was paired with a nearby conventional farm for a comparison which controlled for geographical variation in bird populations. The conventional farm was selected as the first nearby farm (within 5 km) whose occupier allowed access to the observer. Farms were not paired with respect to crop rotation because one objective of the study was to make overall comparisons between bird populations associated with organic and conventional systems, and differences in crop rotation are intrinsic components of this comparison alongside contrasts in pesticide use and management of non-crop habitats.

2.2. Bird and habitat recording

In some cases, surveyed sites comprised whole farms. Where a farm was too large for adequate coverage by the observer in one morning, however, a smaller study site was selected on the basis of ease of access considerations. Each site received a minimum of four census visits in the breeding season (approximately one census visit per month, April to July) and three visits each in both autumn (September–November) and winter (December–February). During each visit, the perimeter of every field per site was walked and every bird seen in all field boundaries (including hedges, walls, fences, ditches, tracks and woodland edge) and fields was recorded. In the breeding season the number of birds of each species occurring in each field boundary unit (defined as any length of field boundary between intersections) and field was counted. Methods used in the Common Birds Census (Marchant et al., 1990) were employed in order to estimate the number of territorially active pairs. The measure of bird abundance was based on a modified method of identifying clusters of bird registrations. This method does not estimate territories as carried out in standard CBC methodology (Bibby et al., 1992) as it is derived from fewer visits. It is likely to overestimate the actual numbers of birds present as fewer registrations are required to identify a "territory", but we consider this preferable to using a simple average count per visit, as it excludes non-breeding birds or migrants which are not resident on a given site and so are likely to only be recorded on one visit. As long as errors are constant, this method should be adequate for comparative purposes.

In the autumn and winter, the numbers of birds in each individual boundary unit or field were recorded directly on to farm maps, and observers were asked to ensure that counts of birds on fields were accurate by walking across field centres to flush birds where field size or vegetation height made it impossible to obtain accurate counts from the field margin. Sugar beet fields were not surveyed since accurate counts are not possible given the dense vegetation cover. Fieldwork was undertaken by volunteer observers who were issued with detailed instructions for undertaking the field work to ensure that standardisation was achieved. A single observer undertook the fieldwork for each pair of farms within any one season so that differences in observer ability would not bias the data in any systematic way. Visits to the farms within each pair were carried out within a week of one another and were matched as far as possible for time of day and weather. No surveys were carried out in excessively wet or windy weather. The survey covered the autumn and winter of 1992/1993 and 1993/1994 (referred to as 1992 and 1993 autumn or winter, respectively) and the breeding seasons of 1992–1994. In addition to making bird counts, data were collected on numerous habitat characteristics of fields (area and crop type) and field boundaries—length, type (hedge, woodland edge, ditch etc.)—number of trees per boundary, and size and management of hedges.

Differences in the bird populations between farm types were analysed in three ways: (1) by considering the species diversity per site; (2) by considering the total density per site for field boundaries and fields separately; and (3) by considering the variations in the bird community with gradients of environmental variation (including organic management) using Canonical Correspondence Analysis (CCA) (Ter Braak, 1986). This paper only presents separate analyses for the most commonly occurring species, in addition to analysing the combined density of all species recorded. In the breeding season, most arable crops became too tall and dense to obtain accurate estimates of bird numbers without causing unacceptable crop damage. The exception was the skylark which could be censused from the territorial song flights performed by the males. Consequently, only data on abundance of territorial skylarks was analysed on a field-by-field basis during the breeding season.

Outside the breeding season most birds do not maintain territories and are likely to be relatively mobile so that numbers recorded on a farm may fluctuate considerably. To take into account possible seasonal variation, we divided the data set into breeding season (April–July), autumn (September–November) and winter (December to February) since there are likely to be differing constraints on bird distributions in these two periods. A list of the species analysed including scientific names, the habitats and seasons considered and species codes used in the presentation of CCA results (see below) are shown in Table 1.

2.3. Statistical methodology

Species diversity indices were calculated per site using the Shannon–Weiner index (Krebs, 1980),—$\Sigma p_i \ln p_i$, where p_i is the proportion the ith species contributes to the total number of individuals of all species. This index was analysed with respect to farm type using a paired comparison. Density was determined per site for selected species by summing the mean counts of birds per boundary unit or field per visit and dividing by the total length of field boundary (km) or total field area (10 ha)

Table 1
Species considered in the analysis, the habitats and seasons in which they were analysed and two letter species codes used in subsequent CCA bi-plots

Species	Code	Habitat	Season
Red-legged partridge *Alectoris rufa*	RL	Fields	Autumn, winter
Grey partridge *Perdix perdix*	P.	Fields	Autumn, winter
Lapwing *Vanellus vanellus*	L.	Fields	Autumn, winter
Stock dove *Columba oenas*	SD	Fields	Autumn, winter
Woodpigeon *C. palumbus*	WP	Fields	Autumn, winter
Skylark *Alauda arvensis*	S.	Fields	All
Starling *Sturnus vulgaris*	SG	Fields	Autumn, winter
Dunnock *Prunella modularis*	D.	Field boundaries	All
Whitethroat *Sylvia communis*	WH	Field boundaries	Breeding
Robin *Erithacus rubecula*	R.	Field boundaries	All
Blackbird *Turdus merula*	B.	Fields	Autumn, winter
		Field boundaries	All
Redwing *T. iliacus*	RE	Fields	Autumn, winter
		Field boundaries	Autumn, winter
Song thrush *T. philomelos*	ST	Fields	Autumn, winter
		Field boundaries	All
Mistle thrush *T. viscivorus*	M.	Fields	Autumn, winter
Fieldfare *T. pilaris*	FF	Fields	Autumn, winter
		Field boundaries	Autumn, winter
Blue tit *Parus caeruleus*	BT	Field boundaries	All
Great tit *P. major*	GT	Field boundaries	All
Long-tailed tit *Aegithalos caudatus*	LT	Field boundaries	All
Tree sparrow *Passer montanus*	TS	Field boundaries	All
Chaffinch *Fringella coelebs*	CH	Fields	Autumn, winter
		Field boundaries	All
Bullfinch *Pyrrhula pyrrhula*	BF	Field boundaries	All
Greenfinch *Carduelis chloris*	GR	Fields	Autumn, winter
		Field boundaries	All
Goldfinch *C. carduelis*	GO	Fields	Autumn, winter
		Field boundaries	All
Linnet *C. cannabina*	LI	Fields	Autumn, winter
		Fields boundaries	All
Reed bunting *Emberiza schoeniclus*	RB	Field boundaries	All
Yellowhammer *E. citrinella*	Y.	Fields	Autumn, winter
		Field boundaries	All

per site. Differences between farm types were analysed using Wilcoxon matched pairs tests, as data did not conform to the requirements of parametric tests. Similar analyses were also carried out on the difference in density of particular boundary types and difference in the proportion of area covered by various crop types between the two farm types. Analyses of species diversity and density, and habitat characteristics were carried out using SAS programming (SAS Institute, 1996). All means are presented ± one standard deviation (SD).

The effects of organic management and a number of other environmental variables on the bird community were analysed using CCA within the CANOCO package (Ter Braak, 1992). This is an ordination technique which identifies axes of both species and environmental variation across sites. Using CCA enabled the relative effects of various boundary and field characteristics on the bird community as a whole to be determined independently of the effects of organic management. Farm pair was included in the analysis as a dummy covariable (i.e. a variable with n levels, where n = number of farm pairs) to control for geographical variation in bird density. When using CCA, problems of collinearity arise when the number of (environmental variables + covariables)−1 is close to the number of sites (Ter Braak, 1992). To avoid this problem, certain environmental variables with little influence were dropped from the analyses in certain years. This was a particular problem in the 1992 and 1994 breeding seasons which had the smallest number of sites. In the 1994 breeding season, only nine habitat variables were considered, with hedges being divided into only two categories, tall or short. In 1992, too many variables would have been excluded for a meaningful analysis, so this data set was not considered. Bird data were calculated as density/ha at the farm site level, thus the distinction between field boundaries and fields was not maintained. The same suite of species was used as in previous analyses.

3. Results

3.1. Species diversity

The mean Shannon–Weiner diversity indices per farm type for each season are shown in Table 2. Diversity was significantly higher in the 1994 breeding season. However, this did not reflect a general trend, no significant differences in diversity being detected between farm types in any other year.

3.2. Species density

The mean densities per site of 17 species occupying field boundaries in the breeding seasons of 1992, 1993 and 1994 are shown in Table 3. Generally, organic farms held higher densities of birds than conventional farms, the density on organic farms exceeding that on conventional farms in 43 out of 51 cases for individual species. Sign tests (Zar, 1984) revealed that there were a significantly greater number of differences in density in favour of organic farms in two out of three breeding seasons (Table 3). There were few significant differences in individual species' density between farm types detected when analysing density at the farm level. All those detected were in a single year, 1994, when robin, blackbird and greenfinch had significantly higher densities on organic farms, and song thrush showed a weak ($p < 0.06$) difference in density in the same direction. The combined density of all species was higher on organic farms in 1994.

Table 2
Mean ($\pm$SD) Shannon–Weiner species diversity indices on organic and conventional farms

	Organic	Conventional	No. farm pairs	p
1992 breeding season	2.81 ± 0.28	2.93 ± 0.23	7	NS
1992 autumn	2.46 ± 0.42	2.47 ± 0.40	17	NS
1992 winter	2.55 ± 0.28	2.48 ± 0.29	18	NS
1993 breeding season	2.87 ± 0.19	2.90 ± 0.20	18	NS
1993 autumn	2.47 ± 0.48	2.43 ± 0.28	17	NS
1993 winter	2.12 ± 0.43	2.04 ± 0.44	17	NS
1994 breeding season	2.89 ± 0.14	2.73 ± 0.20	13	*

NS, not significant; *$p < 0.05$ (paired t-test).

Table 3
Mean ($\pm$SD) densities (pairs per km) in field boundaries in the breeding season

	1992			1993			1994		
	No. farm pairs 7			No. farm pairs 17			No. farm pairs 13		
Farm type	Organic	Conventional		Organic	Conventional		Organic	Conventional	
Dunnock	0.57 ± 0.46	0.37 ± 0.27	NS	0.50 ± 0.48	0.44 ± 0.33	NS	0.53 ± 0.37	0.46 ± 0.36	NS
Wren	0.93 ± 0.81	0.77 ± 0.81	NS	0.96 ± 0.67	1.00 ± 0.66	NS	0.90 ± 0.63	0.77 ± 0.62	NS
Robin	0.65 ± 0.61	0.52 ± 0.44	NS	0.96 ± 0.82	0.77 ± 0.61	NS	1.10 ± 1.02	0.74 ± 0.81	*
Blackbird	0.86 ± 0.63	0.74 ± 0.54	NS	0.97 ± 0.53	0.94 ± 0.59	NS	1.17 ± 0.61	0.82 ± 0.47	**
Song thrush	0.08 ± 0.05	0.09 ± 0.08	NS	0.14 ± 0.16	0.11 ± 0.14	NS	0.22 ± 0.23	0.09 ± 0.07	(*)
Whitethroat	0.35 ± 0.30	0.29 ± 0.22	NS	0.17 ± 0.16	0.18 ± 0.21	NS	0.16 ± 0.13	0.11 ± 0.18	NS
Long-tailed tit	0.08 ± 0.09	0.07 ± 0.09	NS	0.05 ± 0.07	0.09 ± 0.12	NS	0.09 ± 0.07	0.07 ± 0.10	NS
Blue tit	0.93 ± 1.09	0.77 ± 1.02	NS	0.72 ± 0.69	0.69 ± 0.61	NS	0.84 ± 0.74	0.75 ± 0.62	NS
Great tit	0.44 ± 0.71	0.24 ± 0.27	NS	0.50 ± 0.54	0.45 ± 0.48	NS	0.52 ± 0.63	0.44 ± 0.58	NS
Tree sparrow	0.02 ± 0.03	0.03 ± 0.05	NS	0.06 ± 0.14	0.03 ± 0.06	NS	0.03 ± 0.08	0.02 ± 0.04	NS
Chaffinch	1.24 ± 0.42	1.11 ± 0.55	NS	1.42 ± 0.87	1.38 ± 0.70	NS	1.34 ± 0.52	1.32 ± 0.67	NS
Greenfinch	0.12 ± 0.12	0.06 ± 0.04	NS	0.19 ± 0.16	0.14 ± 0.16	NS	0.23 ± 0.26	0.13 ± 0.23	*
Goldfinch	0.10 ± 0.11	0.07 ± 0.08	NS	0.09 ± 0.17	0.07 ± 0.08	NS	0.10 ± 0.13	0.10 ± 0.18	NS
Linnet	0.10 ± 0.10	0.05 ± 0.06	NS	0.18 ± 0.26	0.21 ± 0.42	NS	0.14 ± 0.17	0.12 ± 0.20	NS
Bullfinch	0.07 ± 0.01	0.03 ± 0.03	NS	0.04 ± 0.05	0.03 ± 0.05	NS	0.07 ± 0.11	0.03 ± 0.04	NS
Yellowhammer	0.64 ± 0.53	0.35 ± 0.25	NS	0.58 ± 0.34	0.55 ± 0.41	NS	0.49 ± 0.36	0.47 ± 0.37	NS
Reed bunting	0.18 ± 0.31	0.06 ± 0.15	NS	0.03 ± 0.05	0.03 ± 0.09	NS	0.01 ± 0.03	0	NS
Total density	9.67 ± 4.40	7.77 ± 3.25	NS	9.47 ± 4.85	9.62 ± 4.60	NS	9.76 ± 0.44	7.86 ± 4.10	**
Species where O > C	15			12			16		
Species where C > O	2			5			1		
Sign test									

NS, not significant; (*)$p < 0.06$; *$p < 0.05$; **$p < 0.01$ (Wilcoxon matched pairs test).

More significant differences were detected in field boundaries outside the breeding season (Table 4), with a total of nine individual cases showing a significant result, and a further three showing weaker evidence ($p < 0.06$) of a difference between farm types. All of these showed a higher density on organic farms. Overall, the density on organic farms exceeded that on conventional farms in 56 out of 64 individual cases, sign tests showing that the number of differences in favour of organic farms was significantly greater than chance expectation (50%) in three out of four seasons/years. Within each year the autumn period showed more significant differences than the winter period. The combined density of all species was significantly higher on organic farms in the autumn of 1992.

The density of breeding skylarks was significantly higher on organic farms in 1993 only (densities/10 ha: 1992 organic $= 1.88 \pm 2.28$, conventional $= 0.49 \pm 0.47$ ($n = 7$ farm pairs), $p < 0.07$; 1993 organic $= 0.54 \pm 0.58$, conventional $= 0.31 \pm 0.37$ (18), $p < 0.05$; 1994 organic $= 0.33 \pm 0.36$, conventional $= 0.33 \pm 0.39$ (13), $p < 0.50$). Outside the breeding season, with a wider range of species analysed, densities in fields on organic farms exceeded those on conventional farms in 50 out of 68 individual cases (Table 5), although the number of differences where density was higher on organic farms was significantly different from chance expectation only in winter 1992. Only two individual species, yellowhammer and woodpigeon, showed significantly higher densities on organic farms, in the autumn and winter of 1992, respectively.

3.3. Habitat characteristics

There was no significant difference in boundary length between farm types in any year (Table 6). Fields on conventional farms were significantly larger in the samples for autumn 1993 and the 1994 breeding season (Table 6). The mean difference in the proportion of total boundary length per site composed of each boundary type, and the difference in the density of trees in field boundaries per site between farm types, are shown in Table 7. Organic farms had a greater number of trees per boundary. Hedge dimensions also differed between farm types, organic farms having a significantly greater proportion of high hedge in both autumn periods, and a significantly greater proportion of wide hedges in three years/seasons. Organic and conventional farms did not differ in the proportion of hedgerow or woodland edge boundaries.

Fields were classified into 16 types. Considering data from the second (middle) visit within each season, there was a significant difference in the number of field types between farm types in autumn 1992, organic farms having on average 1.13 ± 1.50 ($n = 18$ farm pairs) more field types per farm than conventional farms ($p < 0.05$, Wilcoxon matched pairs test), but there was no significant difference in any other year/season. The proportions of total site area made up by the commonest field types in the breeding season (grass, winter cereals and spring cereals) and in autumn and winter (grass, winter cereal, stubble and bare till) were analysed in relation to farm type. Other field types tended to occur on only a small number of farms, or occupy a small area. In the breeding season, there was only a single crop type which differed between farm types, with organic farms having a greater proportion of spring cereals in 1993 (mean difference $= 0.19 \pm 0.25(18)$, $p < 0.05$, Wilcoxon matched pairs test) in the first three visits. Only the proportion of bare till fields differed significantly between farm types outside the breeding season, with on average $0.20 \pm 0.18(18)$ greater proportion of organic farm area occupied by bare till than conventional farm area in autumn 1992 ($p < 0.01$, Wilcoxon matched pairs test).

3.4. Controlling for the effects of habitat structure

In order to evaluate the effects of organic management, crop type, boundary characteristics and other habitat variables on bird density, the data were analysed using CCA. Up to 16 habitat variables were analysed, mostly expressed as a proportion of the total site area or density per site (Table 8). Farm pair accounted for between ca. 60 and 80% of variation in the species data, demonstrating the importance of controlling for variation between farm pair due to geographical location and observer differences. Eigenvalues of the axes (which measure the proportion of environmental variation which each axis accounts for) varied between 3 and 21%, and were noticeably lower in the 1993 breeding season. The effects of habitat variables on species can be demonstrated using a bi-plot of species and habitat scores on the first two axes of the ordination.

Fig. 1 shows bi-plots for the 1993 and 1994 breeding seasons, presenting habitat variables with the axis scores of greatest magnitude (i.e. those with the greatest influence on species distributions). The axes and arrows representing environmental variables in the diagram explain 58.9 and 56.7% of the remaining variation in the species data for 1993 and 1994, respectively, after taking into account the effect of farm pair. Note that organic management is represented as a point in the diagrams as it was a binomial variable, but it is interpreted in the same way as the other environmental variables. Tall hedgerows (AHED, BHED), short hedgerows (CHED, DHED), field boundary density (LENG), woodland edge (WEDG) and organic management (ORGA) had the greatest effects on the axes in 1993, the latter showing an association with grass leys (LEY). Farm plots with a large proportion of permanent grass (GRAS) and winter cereals (WCER) tended not to be associated with organic management.

Table 4
Mean (±SD) density (individuals/km) of birds using field boundaries outside the breeding season

	1992						1993					
	Autumn			Winter			Autumn			Winter		
	No. farm pairs 16			No. farm pairs 18			No. farm pairs 16			No. farm pairs 14		
	Organic	Conventional		Organic	Conventional		Organic	Conventional		Organic	Conventional	
Wren	0.77 ± 0.61	0.79 ± 0.65	NS	0.61 ± 0.44	0.61 ± 0.53	NS	0.78 ± 0.47	0.72 ± 0.47	NS	0.48 ± 0.32	0.52 ± 0.62	NS
Dunnock	0.86 ± 0.68	0.57 ± 0.50	(*)	0.84 ± 0.75	0.72 ± 0.41	NS	0.73 ± 0.60	0.79 ± 0.71	NS	0.80 ± 0.53	0.75 ± 0.99	NS
Robin	1.52 ± 1.22	1.53 ± 1.88	NS	1.19 ± 1.00	1.14 ± 0.89	NS	1.68 ± 1.44	1.70 ± 1.61	NS	1.13 ± 0.93	1.07 ± 1.20	NS
Blackbird	2.21 ± 1.97	1.14 ± 1.00	**	1.91 ± 1.16	1.74 ± 1.05	NS	2.48 ± 2.04	1.72 ± 0.91	*	1.92 ± 1.37	1.83 ± 1.32	NS
Fieldfare	0.60 ± 0.91	0.89 ± 1.90	NS	1.23 ± 3.13	1.27 ± 2.65	NS	4.08 ± 11.88	2.71 ± 3.50	NS	0.88 ± 1.96	0.67 ± 1.47	NS
Song thrush	0.39 ± 0.42	0.37 ± 0.47	NS	0.51 ± 0.66	0.45 ± 0.47	NS	0.47 ± 0.80	0.20 ± 0.29	NS	0.27 ± 0.37	0.19 ± 0.17	NS
Redwing	1.78 ± 2.71	1.25 ± 1.83	NS	2.06 ± 2.60	0.92 ± 1.48	*	8.56 ± 30.30	1.33 ± 1.63	NS	2.51 ± 6.52	0.60 ± 1.10	NS
Long-tailed tit	0.52 ± 0.85	0.33 ± 0.76	NS	0.50 ± 0.53	0.39 ± 0.62	NS	0.67 ± 0.69	0.57 ± 0.80	NS	0.13 ± 0.23	0.24 ± 0.53	NS
Blue tit	1.65 ± 1.30	1.21 ± 1.07	*	1.58 ± 1.37	1.24 ± 1.60	(*)	1.76 ± 1.77	1.56 ± 1.34	NS	1.48 ± 1.66	1.13 ± 1.72	NS
Great tit	0.69 ± 0.76	0.44 ± 0.45	*	0.79 ± 0.93	0.61 ± 0.96	NS	0.89 ± 1.24	0.67 ± 0.90	NS	0.85 ± 1.31	0.66 ± 1.32	NS
Tree sparrow	0.17 ± 0.51	0.03 ± 0.07	NS	0.26 ± 0.69	0.08 ± 0.27	NS	0.10 ± 0.28	0.19 ± 0.06	NS	0.01 ± 0.02	0.01 ± 0.04	NS
Chaffinch	2.75 ± 2.73	1.38 ± 1.34	*	2.91 ± 2.16	2.31 ± 3.97	*	2.70 ± 3.54	2.26 ± 2.28	NS	2.25 ± 2.21	1.32 ± 1.85	NS
Greenfinch	1.30 ± 2.34	0.52 ± 1.11	*	0.53 ± 0.75	0.63 ± 1.22	NS	0.29 ± 0.58	0.40 ± 0.77	NS	0.30 ± 0.35	0.41 ± 0.61	NS
Goldfinch	0.29 ± 0.48	0.21 ± 0.38	NS	0.15 ± 0.39	0.61 ± 1.77	NS	0.81 ± 2.02	0.15 ± 0.28	(*)	0.11 ± 0.20	0.05 ± 0.12	NS
Linnet	0.35 ± 0.91	0.16 ± 0.48	NS	0.56 ± 1.62	0.01 ± 0.03	NS	0.29 ± 0.81	0.21 ± 0.40	NS	0.17 ± 0.59	0.18 ± 0.47	NS
Bullfinch	0.22 ± 0.24	0.11 ± 0.13	NS	0.18 ± 0.19	0.09 ± 0.15	NS	0.17 ± 0.26	0.11 ± 0.28	NS	0.21 ± 0.25	0.09 ± 0.15	*
Yellowhammer	0.88 ± 1.22	0.87 ± 1.20	NS	0.68 ± 1.21	0.49 ± 0.74	NS	0.43 ± 0.46	0.42 ± 0.72	NS	0.38 ± 0.63	0.44 ± 0.83	NS
Reed bunting	0.14 ± 0.44	0.02 ± 0.05	NS	0.20 ± 0.48	0.16 ± 0.64	NS	0.03 ± 0.08	0.02 ± 0.03	NS	0.04 ± 0.12	0	NS
Total density	25.53 ± 12.79	18.14 ± 11.49	***	23.82 ± 12.50	21.06 ± 13.34	NS	34.91 ± 49.92	24.84 ± 16.68	NS	19.67 ± 16.62	15.62 ± 12.96	NS
Species where O > C	15			14			14			13		
Species where C > O	3			4			4			5		
Sign test	$p < 0.02$			$p = 0.05$			$p = 0.05$			NS		

NS, not significant; (*)$p < 0.06$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$ (Wilcoxon matched pairs test).

Table 5
Mean (±SD) density (individuals/10 ha) of birds using fields outside the breeding season

	1992						1993					
	Autumn			Winter			Autumn			Winter		
	No. farm pairs 16			No. farm pairs 18			No. farm pairs 16			No. farm pairs 14		
	Organic	Conventional		Organic	Conventional		Organic	Conventional		Organic	Conventional	
Red-legged partridge	0.26 ± 0.66	0.24 ± 0.38	NS	0.35 ± 0.69	0.18 ± 0.36	NS	0.16 ± 0.42	0.26 ± 0.69	NS	0.09 ± 0.32	0.10 ± 0.21	NS
Grey partridge	0.09 ± 0.31	0.15 ± 0.31	NS	0.11 ± 0.26	0.10 ± 0.21	NS	0.05 ± 0.19	0	NS	0.02 ± 0.01	0	NS
Lapwing	0.05 ± 0.06	0.06 ± 0.23	NS	0.34 ± 1.29	0.28 ± 0.76	NS	0.41 ± 1.17	0.63 ± 1.90	NS	0	0.55 ± 1.95	NS
Stock dove	0.03 ± 0.08	0.04 ± 0.11	NS	0.17 ± 0.41	0.08 ± 0.18	NS	0.02 ± 0.05	0.03 ± 0.10	NS	0.42 ± 1.44	0.01 ± 0.04	NS
Woodpigeon	4.45 ± 6.35	2.29 ± 6.15	(*)	7.48 ± 9.53	4.78 ± 10.97	*	4.88 ± 5.97	3.67 ± 6.66	NS	10.39 ± 10.32	5.52 ± 11.65	NS
Skylark	1.20 ± 1.90	1.02 ± 1.98	NS	2.50 ± 4.17	1.72 ± 2.99	NS	1.93 ± 4.53	0.77 ± 1.52	NS	1.34 ± 2.58	1.05 ± 2.76	NS
Blackbird	0.10 ± 0.15	0.09 ± 0.17	NS	0.43 ± 0.58	0.35 ± 0.57	NS	0.50 ± 0.81	0.29 ± 0.67	NS	1.22 ± 1.76	0.71 ± 1.16	NS
Fieldfare	0	0.05 ± 0.13	NS	2.63 ± 5.96	2.06 ± 3.11	NS	3.57 ± 8.69	5.48 ± 17.76	NS	9.39 ± 18.38	3.97 ± 6.29	NS
Song thrush	0.02 ± 0.11	0.02 ± 0.05	NS	0.09 ± 0.20	0.16 ± 0.41	NS	0.05 ± 0.11	0.04 ± 0.07	NS	0.23 ± 0.69	0.12 ± 0.20	NS
Redwing	0.36 ± 1.02	0	NS	2.24 ± 4.51	1.49 ± 3.17	NS	2.41 ± 8.71	1.75 ± 5.20	NS	6.53 ± 20.33	6.58 ± 21.29	NS
Mistle thrush	0.02 ± 0.07	0.19 ± 0.60	NS	0.12 ± 0.29	0.10 ± 0.24	NS	2.08 ± 7.94	0.09 ± 1.54	NS	0.06 ± 0.13	0.17 ± 0.32	NS
Starling	5.88 ± 9.72	4.40 ± 6.49	NS	8.93 ± 15.49	3.93 ± 6.04	NS	4.26 ± 5.76	9.90 ± 12.94	NS	15.66 ± 29.76	4.72 ± 5.04	NS
Chaffinch	1.67 ± 3.93	0.41 ± 0.66	NS	1.26 ± 2.52	0.91 ± 1.97	NS	2.76 ± 6.09	1.48 ± 3.51	NS	4.44 ± 8.77	2.09 ± 5.99	NS
Greenfinch	1.84 ± 6.66	0.01 ± 0.05	NS	0.93 ± 3.95	0.04 ± 0.18	NS	1.48 ± 4.65	1.71 ± 5.36	NS	0.29 ± 1.03	0.02 ± 0.08	NS
Goldfinch	0.47 ± 1.16	0.17 ± 0.58	NS	0.20 ± 0.50	0.19 ± 0.65	NS	1.68 ± 3.82	1.20 ± 2.31	NS	0.05 ± 0.18	0.04 ± 0.09	NS
Linnet	2.39 ± 9.60	0.31 ± 0.92	NS	0.34 ± 1.32	0	NS	4.43 ± 12.57	0.34 ± 1.21	NS	0.54 ± 1.63	0.25 ± 0.94	NS
Yellowhammer	3.17 ± 11.02	0.11 ± 0.26	*	0.37 ± 1.19	0.38 ± 0.10	NS	0.12 ± 0.21	0.28 ± 0.57	NS	0.10 ± 0.39	0.09 ± 0.28	NS
Total density	37.52 ± 36.72	22.42 ± 20.40	NS	39.02 ± 30.07	30.65 ± 29.68	NS	43.17 ± 29.21	34.99 ± 38.34	NS	61.42 ± 48.54	38.45 ± 42.20	NS
Species where O < C	11			16			10			13		
Species where C > O	6			1			7			4		
Sign test	NS			$p < 0.005$			NS			$p = 0.05$		

NS, not significant; (*)$p < 0.06$; *$p < 0.05$ (Wilcoxon matched pairs test).

Table 6
Mean (±SD) boundary length (100 m) and field size (ha) per farm. n = number of farm pairs

	Field boundaries			Fields			
	Organic	Conventional		Organic	Conventional		n
1992 breeding season	1.88 ± 0.40	1.92 ± 0.35	NS	4.81 ± 1.29	5.81 ± 1.87	NS	7
1992 autumn	1.98 ± 0.55	1.96 ± 0.46	NS	4.44 ± 1.89	4.87 ± 1.95	NS	18
1992 winter	2.01 ± 0.54	2.11 ± 0.62	NS	4.34 ± 1.77	5.01 ± 1.89	NS	18
1993 breeding season	2.12 ± 0.55	2.18 ± 0.50	NS	4.21 ± 1.72	5.11 ± 2.03	NS	18
1993 autumn	1.98 ± 0.56	2.11 ± 0.57	NS	4.09 ± 1.58	5.53 ± 2.60	*	16
1993 winter	2.04 ± 0.56	2.17 ± 0.54	NS	4.05 ± 1.57	5.27 ± 2.62	(*)	16
1994 breeding season	2.12 ± 0.57	2.25 ± 0.55	NS	4.16 ± 1.47	5.55 ± 2.46	*	13

NS, not significant; (*)$p < 0.06$; *$p < 0.05$ (paired t-test).

Table 7
Mean differences (±SD) in the proportion of total boundary length per farm of various boundary types and the density of trees per farm between organic and conventional farms. Negative values indicate conventional > organic. Sample sizes (farm pairs) are given in parentheses, means having been calculated per farm for all variables

Habitat variable	1992			1993			1994
	Breeding season	Autumn	Winter	Breeding season	Autumn	Winter	Breeding season
%boundary = hedge	0.09 ± 0.18 (7)	0.03 ± 0.23 (17)	−0.02 ± 0.19 (18)	−0.01 ± 0.19 (18)	−0.01 ± 0.21 (17)	0.00 ± 0.28 (14)	−0.03 ± 0.22 (13)
%boundary = woodland	0.01 ± 0.09 (5)	0.02 ± 0.08 (12)	0.02 ± 0.08 (12)	0.02 ± 0.09 (14)	0.01 ± 0.08 (12)	0.02 ± 0.07 (9)	0.03 ± 0.08 (8)
%hedges width > 2m	0.11 ± 0.20 (7)	0.09 ± 0.16** (17)	0.07 ± 0.17(*) (18)	0.09 ± 0.18* (18)	0.08 ± 0.16* (17)	0.07 ± 0.17 (13)	0.08 ± 0.17 (12)
%hedges height > 2m	0.21 ± 0.26 (7)	0.15 ± 0.22* (17)	0.13 ± 0.22(*) (18)	0.13 ± 0.23 (18)	0.14 ± 0.27 (17)	0.16 ± 0.25* (14)	0.14 ± 0.21 (13)
Total trees /100m	−5.11 ± 52.18 (7)	35.48 ± 190.56 (17)	27.28 ± 225.24 (18)	6.89 ± 19.29(*) (12)	7.75 ± 73.09 (17)	17.23 ± 56.19 (14)	8.67 ± 17.66* (13)

(*)$p < 0.07$; *$p < 0.05$; **$p < 0.01$ (Wilcoxon matched pairs test).

Table 8
Habitat variables used in Canonical Correspondence Analysis. No data were analysed from 1992 breeding season

Code	Definition	Years analysed
AREA	Total plot area (ha)	All
AHED	Density of hedgerow > 2m high and > 2m wide (km/ha)	All, but combined with BHED for 1994 breeding
BHED	Density of hedgerow > 2m high and > 2m wide (km/ha)	1992 autumn, 1992–1993 winter, 1993 breeding
CHED	Density of hedgerow < = 2m high and > 2m wide (km/ha)	All, but combined with DHED for 1994 breeding
DHED	Density of hedgerow < = 2m high and < = 2m wide (km/ha)	1993 autumn, 1992 winter
BARE	Proportion of area of bare till fields	1992–1993 autumn, 1992 winter
GRAS	Proportion of area of permanent grass fields (includes pasture and permanent grass for silage)	All
LENG	Density of all field boundaries per plot (km/ha)	All
LEY	Proportion of area of temporary grass leys	All
ORGA	Organic management (1 = organic, 0 = conventional)	All
ROOT	Proportion of area of root vegetables	1993 autumn
SCER	Proportion of area of spring sown cereals	1993–1994 breeding
STUB	Proportion of area of stubble	1992–1993 autumn, 1992–1993 winter, 1993 breeding
TREE	Density of trees, excluding woodland edge (no./ha)	1992–1993 autumn, 1992–1993 winter, 1993 breeding
WCER	Proportion of area of winter sown cereals	All
WEDG	Density of woodland edge boundary (km/ha)	1992–1993 autumn, 1992–1993 winter, 1993 breeding

Granivorous species tended to show the strongest associations with environmental variables in both years, other species tending to be clustered around the origin indicating that they had no particular associations with the habitats considered. Tree sparrow was the species most strongly associated with organic farming, but greenfinch and bullfinch showed weaker evidence of an association, although the latter was more strongly associated with tall narrow hedgerow (BHED) and field boundary density. In 1994, organic management had much the greatest effect on species distribution, and was associated with field boundary density and ley grass. Linnet, song thrush and yellowhammer all showed an association with organic management.

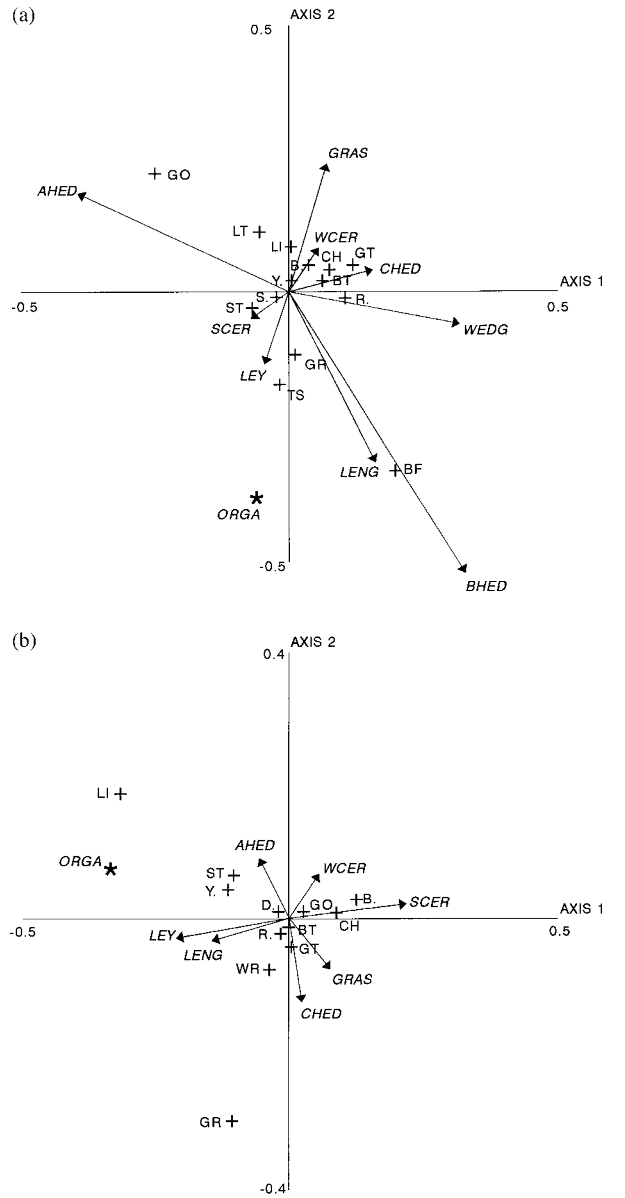

Fig. 1. Ordination of species and environmental variables in the breeding season calculated from CCA; species are indicated by +, environmental gradients are represented by arrows and organic farming is represented by an asterisk, the length of the arrows and distance of the asterisk from the origin representing the strength of influence of the variable on species distributions. Species abbreviations (Roman type) are given in Table 1 and habitat variables (italics) are given in Table 8. Clusters of species identify species of similar ecological requirements, and their proximity to the arrows, and in particular their perpendicular distance along an arrow, indicates the effect of that habitat variable on the species. Only species and environmental variables with the largest axis scores are shown. (a) 1993; (b) 1994. Species from Table 1 not represented occupied positions as follows: (a) WH in the same position as CH; D. and WR in the same position as R.; (b) BF, TS and RB in the same position as the origin.

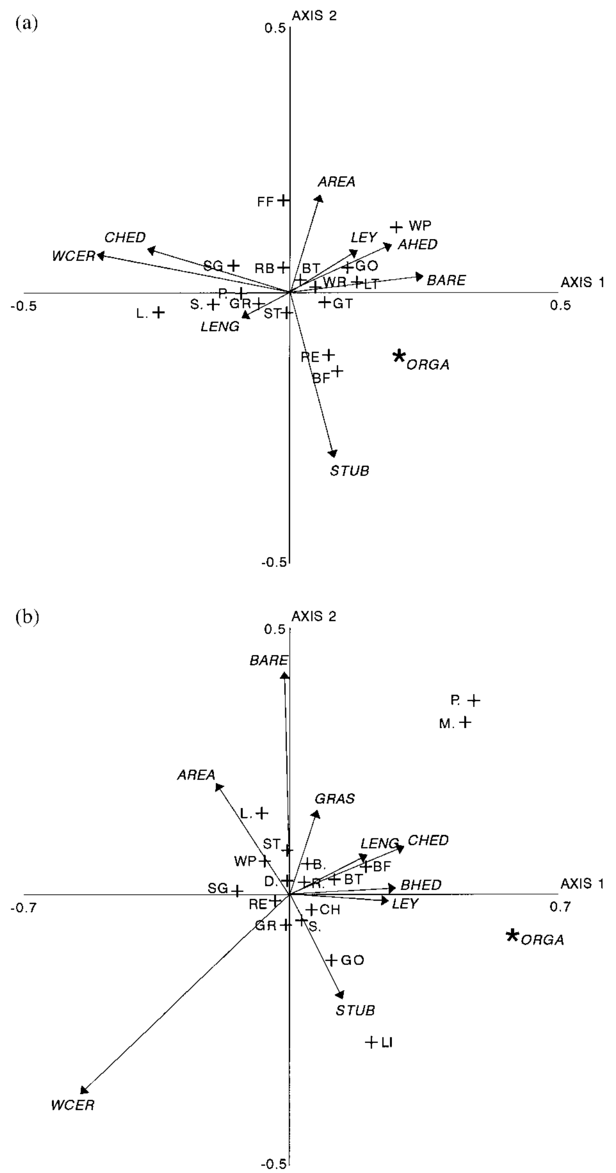

Fig. 2. Ordination of species and environmental variables in the autumn calculated from CCA. Only species and environmental variables with the largest axis scores are shown. (a) 1992; (b) 1993. Species from Table 1 not represented occupied positions as follows: (a) Y. in the same position as GR, B. and R. in the same position as GT (b) FF in the same position as RE, GT in the same position as BT, TS in the same position as the origin, WR in the same position as B. and Y. in the same position as D.

Figure 2 shows the same bi-plots for the 1992 and 1993 autumn periods, which explained 46.1 and 52.9% of variation in the species data, respectively, after taking into account the effect of farm pair. The environmental variables having the greatest effects on the species distributions were similar in both years, including farm area, hedgerow types, winter cereals, bare till (BARE), stubbles (STUB) and organic management. Stubble fields in 1992 and grass leys in 1993 showed some association with organic management. Individual species tended to be more strongly associated with other habitat variables than with organic management and there were also more species which were clustered around the origin. Redwing in 1992 and goldfinch and linnet in 1993 were the species most closely associated with organic farming, but these showed much stronger associations with stubble fields.

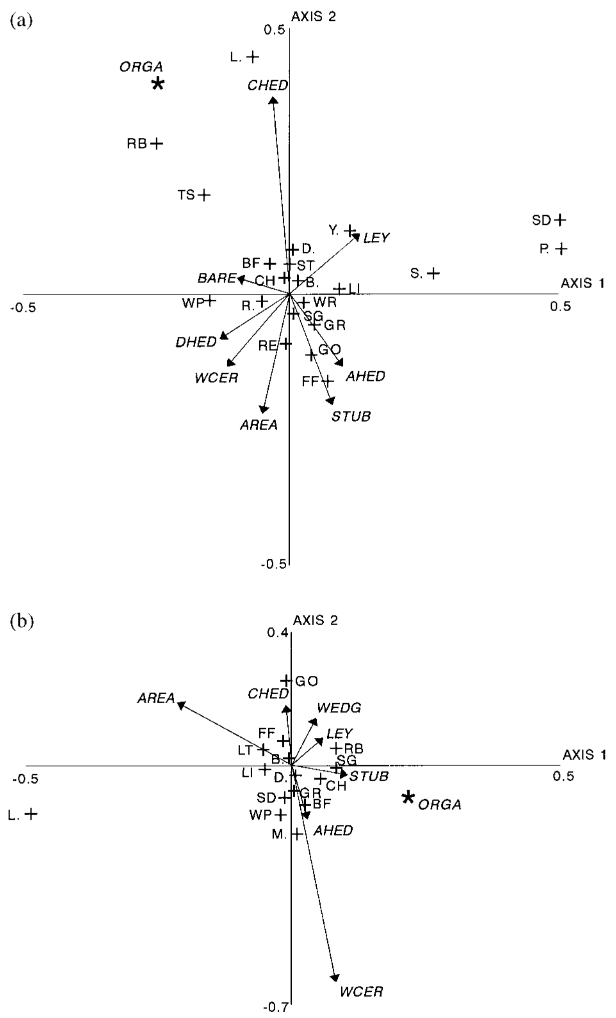

Fig. 3. Ordination of species and environmental variables in the winter calculated from CCA. Only species and environmental variables with the largest axis scores are shown. (a) 1992; (b) 1993. Species from Table 1 not represented occupied positions as follows: (a) GT in the same position as SG, LT in the same position as CH; (b) BT, GT and RE in the same position as B.; S. in the same position as SG; WR in the same position as CH; Y. and R. in the same position as the origin.

In the winter, the bi-plots explained 46.3% of variance in the species data in 1992 and 54.6% in 1993 after taking into account the effect of farm pair, similar figures to those from the autumn of each year. Hedgerow characteristics, farm area, winter cereals and organic management again had the greatest effects on species distribution across sites (Fig. 3). In 1992 there was evidence of a negative association between organic management and stubble fields, but in 1993 organic management was positively associated with stubble fields and negatively associated with farm area. Once again, granivorous species showed the strongest habitat associations. In 1992, reed bunting, tree sparrow and to a lesser extent bullfinch were strongly associated with organic farms, although no species stood out as being strongly associated with organic management in 1993. However, in this year and in all other years/seasons, there was no species which was strongly associated with conventional management (i.e. diametrically opposite the point representing organic management).

4. Discussion

Species diversity was significantly higher on organic farms in only one of three breeding seasons, but organic farms had consistently higher densities of both individual species and of all species combined than conventional farms. A number of individual species showed significantly higher densities on organic farms which were mainly detected in field boundaries and outside the breeding season. In no species was a significantly higher density detected on conventional farms.

The stronger trends towards higher densities on organic farms outside the breeding season may be associated with seasonal variation in territorial behaviour. In the breeding season, birds may be more constrained in their habitat use due to territorial exclusion, thus large numbers of birds may be forced into sub-optimal habitats (Fretwell and Lucas, 1970). In the autumn and winter, even in territorial species, there tends to be less territorial exclusion and thus a distribution according to resources (such as food) may be more apparent.

Although a number of species exhibited significant differences in density between farm types, few species showed consistently significant results between years. This, in part, was due to having partially overlapping samples, with some farms only being surveyed in single years. The differences in habitat composition between farm types across years (see below) may therefore explain the lack of consistency, although for both the autumn and winter surveys, consistency between years was high, with 15 farms surveyed in both years. Some variation may also have been caused by particular conditions in any one year, such as differences in weather or food abundance. This could lead to very different conclusions about the relative importance of different habitats depending on when censuses were undertaken (O'Connor, 1986).

4.1. The influence of hedgerow structure and cropping regime

Organic farming as practised in our sample of farms differed from conventional farming not only in crop management (e.g. pesticide and chemical inputs and cropping regime), but also in the physical management of the farm (e.g. hedge structure). Most differences in field boundary structure and crop type occurred in autumn 1992, also the period showing the greatest number of significant differences in bird density. Boundary type and structure differed between farm types in a way likely to increase bird density on organic farms in the majority of species studied (Green et al., 1994; Macdonald and Johnson, 1995). Organic farms tended to have higher, wider hedges and, in one year, more trees than conventional farms, all of which have been shown to increase density for a wide range of species (Lack, 1992).

The proportion of total farm area occupied by bare till and spring cereal fields per farm differed between farm types. Differences in the former may affect birds as these fields may provide a good source of invertebrates, although they may only be of value if ploughed in the late winter which brings invertebrates to the soil surface at a time of food shortage (Lack, 1992). Spring cereals may be more attractive to ground nesting and foraging species such as skylarks than winter-sown cereals later in the breeding season, as they have a less dense sward (Schläpfer, 1988; Wilson et al., 1997). They may also be indicative of a greater amount of winter stubble preceding their sowing. The reduction in food-rich stubbles over the winter, brought about by the increased winter sowing of cereals at the expense of spring-sown crops, has been held as a major reason for the decline of some species of farmland birds (Wilson et al., 1995, 1996). The lack of significant differences in the proportion of stubble fields between farm types may be due to a recent increase in stubble area on conventional farms which has occurred after the introduction of the EC Arable Area payments scheme and associated widespread set-aside in 1992 (Wilson et al., 1995).

When variations in habitat and organic management were considered in tandem using CCA, organic management showed associations with the proportion of stubble fields and ley grass, whereas conventional farming was more associated with a large site area and a high proportion of winter cereals. However, differences in hedgerow type tended to have the greatest influence on variation in bird abundance between farm plots. A number of bird species showed some associations with organic management, particularly seed eaters such as tree sparrow, bullfinch, greenfinch and reed bunting. To an extent this may have been due to similar close associations with other habitat variables, particularly stubble fields which provide a rich source of winter food. In certain cases there were clearly very close associations with organic management indicating that the density of these species is affected by some unmeasured variable associated with organic farming (such as pesticide use). However, other species showing overall differences in density between farm types (Tables 3–5) were often more strongly associated with other habitat variables, indicating that some differences may have been caused by variations in field boundary structure or cropping regime between plots, rather than other aspects of organic management such as crop rotations or absence of agrochemical input.

4.2. The effectiveness of the pairing procedure

There were sometimes substantial differences in specific crop types and the distribution of non-crop habitats between farm pairs which was revealed in the significant differences in the number of crop types and crop extent between farm types. However, differences in the cropping regime are part of the overall difference between organic and conventional farming systems, organic farms typically having a greater diversity of land-use than conventional farms (Lampkin, 1990). Additionally, although all organic farms surveyed had met official Soil Association guidelines, the small number of suitable organic farms available for study made it impossible to take account of the length of time a farm had been under organic management. The extent to which this affects the bird community is not known, but it seems likely that if there is an effect, there will be an increase the farm's suitability to birds with increasing time under organic management (Fuller, 1997).

A further problem in the pairing procedure was that selection of the conventional farm pair was carried out largely on the recommendation of the organic farm's owner. The organic farmers may have chosen (albeit unintentionally) conventional farms which were operated in a more environmentally friendly way than a typical conventional farm. Indeed, the very fact that conventional farmers allowed such a survey to take place on their land may indicate that they are more interested in wildlife than other conventional farmers, and so the farm may have been managed in a way beneficial to birds. Both the failure to take into account the time a farm had been under organic management, and the possibility that conventional farms surveyed were better than average for birds, would tend to decrease the recorded differences between organic and conventional farms rather than cause inflated densities on organic farms. Therefore, the farm selection procedure is likely to have been conservative, with potential differences between farm types being minimised. (For further discussion of methodological issues concerning pairing of organic and conventional farms see Fuller, 1997).

4.3. Density as an indicator of habitat quality

Throughout this study, there has been an implicit assumption that higher bird density reflects better habitat quality in both fields and field boundaries. This is not necessarily the case as social dominance factors may affect the distribution of animals, and a large proportion of a given population may be non-breeders or unsuccessful breeders occupying less favoured habitats (van Horne, 1983; Vickery et al., 1992). However, most of these strictures apply to situations where territorial behaviour is affecting breeding density. Many of the significant results in this study were observed outside the breeding season when territories are no longer defended in the majority of species. In the absence of territorial exclusion, birds are more likely to distribute themselves according to resource availability (Fretwell and Lucas, 1970), thus higher densities will be observed in areas of greater resource abundance. Therefore density is likely to be a good indicator of habitat quality for the majority of species in the autumn and winter. In the breeding season, density may be less indicative of habitat quality if there is unequal exploitation of resources within species (Fretwell, 1972). However, even within species which show marked differences in dominance between individuals, higher nesting density is typically observed in the better quality habitat, e.g. great tit (Krebs, 1971) and blackbird (Hatchwell et al., 1996). In order for firmer conclusions to be drawn on the quality of habitat of each farming system, more detailed information on the survival and productivity of individual species is needed.

4.4. Is organic farming beneficial to bird populations?

Evidence from birds using both field boundaries and fields indicated that organic farms tended to hold higher densities of birds than conventional farms. This effect was more pronounced in field boundaries than in fields, especially in the autumn, although breeding densities of skylarks were significantly higher on organic fields in one breeding season. The differences in bird density were probably mainly attributable to structural differences (differences in hedgerow management and crop types) between the two farm types, which indicates that these factors alone are important to the farmland bird community, and their sympathetic management is likely to be beneficial to a number of farmland species. It is impossible to draw any inferences on the likely impacts of the absence of pesticides and artificial fertilizers on the bird populations of organic farms given the sometimes large differences in hedgerow structure and cropping regimes between farm types. However, it should be remembered that these latter differences arise as a consequence of organic management. For example, changes in crop rotations are inevitable consequences of withdrawal of pesticide and inorganic fertilizer inputs from arable land. Furthermore, guidelines for the management of non-crop habitats are included in the Standards for Organic Food Production (UKROFS, 1992). For these reasons, Fuller (1997) has argued that it is entirely valid to ask what are the effects of organic farming at the "whole farm" or "whole cropped area" scale. This study has indicated that at a whole farm level, farming practices which are characteristic of organic agriculture would greatly benefit several species of farmland bird. It is highly desirable, of course, to understand how the usage of pesticides, fertilizers and crop rotations contributes to observed differences in bird abundance between organic and conventional systems. This can only be achieved adequately through long-term experimental manipulation of crop management (Fuller, 1997).

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