DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS

CSG 15

Research and Development

Final Project Report

(Not to be used for LINK projects)

Two hard copies of this form should be returned to:
Research Policy and International Division, Final Reports Unit
DEFRA, Area 301
Cromwell House, Dean Stanley Street, London, SW1P 3JH.
An electronic version should be e-mailed to resreports@defra.gsi.gov.uk

Project title	FACTORS INFLUENCING BIODIVERSITY WITHIN ORGANIC AND CONVENTIONAL SYSTEMS OF ARABLE FARMING
DEFRA project code	**OF0165**
Contractor organisation and location	British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU (Joint contractors: Wildife Conservation Research Unit at Oxford University and Centre for Ecology & Hydrology (Lancaster))
Total DEFRA project costs	£ 415,141
Project start date	01/01/99
Project end date	30/09/04

Executive summary (maximum 2 sides A4)

(1) Previous studies suggest widespread positive responses of biodiversity to organic farming. Many of these studies, however, have been small-scale. The purpose of this project was to test the generality of responses to arable organic farming (i.e. cereal-growing farms) in England through a multi-taxa study of a large number of farms. Abundance and diversity of higher plants, spiders, carabid beetles, wintering birds and bats were measured on matched pairs of organic and conventionally managed farms. Extent and potential quality of non-crop habitat were also measured. Two key issues addressed by the project were (a) whether biodiversity differences between organic and conventional systems arise from amount and management of non-crop habitat or from differences in crop management systems and (b) the importance of duration under organic management.

(2) Plants and invertebrates were examined in 89 pairs of cereal fields (target fields). Birds and bats were studied at a larger spatial scale, extending over several fields on each study farm. Virtually all suitable organic farms in England were studied. The farm pairing procedure was purely geographical and not based on any attributes of either system. Target fields were stratified by cereal type (spring or winter sown) and by age since conversion.

(3) Habitat and management comparisons were carried out at landscape, farm and field scales using data collected in the field and existing landscape datasets (Land Cover Map 2000 and CS2000 field survey data). Within England, organic farms tended to be located to the south of the wheat-growing region, in areas with more grassland than conventional farms. It is difficult to disassociate many landscape level variables from farming system. Organic arable farms were more often mixed farms than their conventional counterparts, leading to smaller field sizes, livestock-proof hedges, diverse rotations and greater extents of grassland. Hedges on organic farms occurred at higher density (length per unit area) and were taller, wider and less gappy than those on conventional farms. All these factors are likely to enhance many components of biodiversity. By contrast, conventional farms were more likely to contain stubble and naturally regenerated set-aside which can be beneficial to wildlife.

(4) Plants were recorded on the target fields using three different plot types to provide information from field boundaries, crop edges and within the crop. Organic farming systems were clearly 'good' for arable plants, both

of fields and field edges. Plant species richness was higher on organic than conventional farms. Organic fields contained on average over 80% more weed species and greater quantities of them. Organic fields were more likely to contain some of the less common arable species, although only a very small number of BAP listed species were found during this extensive survey. Weed communities at the boundaries of fields tended to be similar for both organic and conventional farms, whereas weed species found within crops showed greater differences between the systems and are likely to be related to field management practices. The duration of organic practice on fields did not affect the numbers of species found, with newly converted fields just as likely to have high species richness as long-term organic fields.

(5) Spiders and carabid beetles both showed responses to farming system, although spiders showed more consistent effects than did carabids. Overall, spiders showed a positive response to organic systems, although significant effects were only detected in winter, rather than spring, cereals. In winter cereals, there were significantly more spiders, and more species of spider, within the crop before harvest on organic compared to conventional farms, and more spiders in organic than conventional boundaries after harvest. Carabid beetles were more abundant in organic compared to conventional winter cereal fields before harvest, but after harvest there were more species in conventional boundaries. They were significantly more abundant in spring cereal crops before harvest on organic farms. The largest observed effect was an average of 25% more spiders in organic cropped areas before harvest for the winter crop. There was weak evidence that time since conversion affected spider species richness and carabid community structure showed some evidence for change in the first 20 years after conversion. Individual species showed contrasting responses to organic and conventional systems, while community analyses suggested that spider and carabid communities differed with system. Both groups were affected by weediness, but not in a straightforward way. While weediness in the cropped area tended to be associated with greater numbers and species of our measured invertebrates, the weediness effect was not significant *in addition* to the effect of system. Within system, there was little evidence for the same effect.

(6) The invertebrate and plant data were spatially and temporally synchronised. We investigated if system effects were correlated, and therefore if benefits to predators resulted at least partly via effects on lower trophic levels. The evidence that invertebrate and plant species richness were correlated within system was generally weak. No effects were observed in the cropped area and, where effects were observed in boundary samples, there was a tendency in organic systems for more invertebrate species to be observed where there were more plant species, but not in conventional.

(7) Bird surveys were carried out in target and adjacent fields and field boundaries in two winters. Density was significantly higher on organic farms, either across the whole site or in fields and field boundaries separately, in at least one winter for 15 species. Total density and species richness were also higher on organic farms. Red-legged Partridge density was significantly higher in conventional field boundaries. Skylark and House Sparrow density showed a significant interaction with farm type and season, each showing a higher density on conventional farms in early winter but no significant difference in late winter. A more complex analysis was carried out to identify variation caused by farm type in addition to habitat extent. There were six species where density estimates were significantly higher on organic farms in at least one year after controlling for habitat differences: Lapwing, Blue Tit, Carrion Crow, Rook, Greenfinch and Reed Bunting. Species richness was also significantly higher on organic farms. In these cases, gross habitat differences alone did not account for overall differences in density. There were only two species that showed a significant effect of duration under organic management: Grey Partridge density significantly decreased and Song Thrush density significantly increased with organic duration.

(8) Bat species diversity was higher on organic than conventional farms. Organic farms also had a higher intensity of activity for noctules, and for all bat species recorded in the field survey combined (noctules, serotines, Leisler's and pipistrelles). Recordings of bat calls were made on a subset of farms to permit investigation of species difficult to identify in the field. Analysis of these sonograms showed that activity of Daubenton's bats and of all *Myotis spp*. combined was also higher on organic farms. There was no difference between systems in the intensity of feeding for any species. The presence of cattle was associated with a higher rate of bat activity on both farm types. On organic farms only, there was also a positive association between hedgerow density and bat activity. Some of the differences in bat activity between organic and conventional systems were explained by the greater amount of water present in the local landscape around organic farms.

(9) This study has confirmed that organic systems do generally support higher levels of biodiversity but that the differences are often quite small. Some, but not all, differences in biodiversity between systems appear to be a consequence of differences in habitat quantity. Plants and invertebrates appear to be responding mainly to crop management practices that are intrinsic to the system. Birds and bats benefit from increased quantities of various non-crop habitats and higher diversity of habitats on organic but this does not account for all differences between

systems in these groups. Few relationships with duration of organic management were detected. This may be partly because it was not possible to account for pre-conversion management.

(10) We highlight the potential value to biodiversity on conventional farms of non-crop habitat management (especially hedges), mixed farming and the incorporation of 'organic' field margins. High priority areas for future related research include the potential biodiversity benefits of organic livestock farming, long-term controlled studies on responses to conversion, and the effect of extent of organic management at larger scales.

Scientific report (maximum 20 sides A4)

1. Introduction

The impact of agricultural intensification on biodiversity is a global issue that will become increasingly severe with continued growth of human populations (Tilman *et al.* 2001). There is worldwide interest in developing less intensive, but economically viable and productive, farming systems with reduced environmental impacts. Organic farming is widely perceived as one such potential system. Accordingly, many studies have sought to quantify biodiversity responses to organic farming and considerable evidence now exists that a range of taxa do benefit from organic farming (Hole *et al.* 2005). However, a high proportion of these studies have been local in focus and based on small numbers of sites. The project reported here was designed to test the generality of responses to organic farming in England through a multi-taxa study of a large number of farms.

Organic farms display many of the features that have become scarce on much farmland. These include crop rotations incorporating grass leys, exclusion of synthetic pesticides and fertilisers, and dependence on animal and green manures. They therefore offer an opportunity for understanding the mechanisms by which intensification has affected biodiversity; this may give insights as to how wider biodiversity may be restored. If specific elements of organic farming can be associated with biodiversity benefits, it may be possible to integrate these elements into wider non-organic systems (the latter are hereafter referred to as ‘conventional systems’).

There were two principal reasons for focusing the project on arable systems. First, it was desirable to reduce some of the variation in the farming systems examined and therefore increase sensitivity for detecting system differences. Second, organic farming may offer solutions to problems that are especially associated with arable systems, for example the decline in seed-eating birds (Fuller 1997). One might expect a larger range of biodiversity benefits to derive from organic arable than organic grass. This is because organic arable systems typically contain a higher diversity of field types due to the incorporation of nutrient-building leys or legumes. Furthermore, most organic arable systems have livestock, whereas stockless conventional systems are common.

The project had five scientific objectives:

(1) To assess the generality of differences in biodiversity between organic and conventional farming systems.
(2) To assess the extent to which amounts and potential quality of non-crop habitat differ between organic and conventional farms.
(3) To determine whether biodiversity differences between organic and conventional systems arise from amount and management of non-crop habitat or from differences in crop management systems.
(4) To assess the importance of duration under organic management. Biodiversity benefits may be expected to accrue with time since conversion (e.g. Dessaint *et al.* 1997).
(5) To identify features of organic systems that are associated with biodiversity benefits and predict the ecological and agro-economic implications of incorporating them within conventional systems.

2. General approach and study design

It is often argued that organic farming is a holistic system in which an integrated approach is taken to all aspects of the farming process. Nonetheless, it is theoretically possible to examine environmental effects of organic farming on a continuum of levels ranging from the whole enterprise down to individual components such as specific inputs. In this study we undertook a comparative examination of biodiversity on organic and conventional farms at the individual field scale and the farm scale. Work at the ‘field scale’ focused on a large sample of paired cereal fields (hereafter termed ‘target fields’). The ‘farm scale’ involved collections of several adjacent fields within the same pairs of farms, typically including the target field, though these fields did not usually equate to the whole enterprise. The project did not attempt to isolate the specific effects of differences in fertiliser inputs, pesticide inputs, or rotational differences. To do so would require experimental manipulations of crop management.

Habitat data were collected at landscape, farm and field scales. This was necessary to address objectives 2 and 3. The landscape context of each farm was examined using land cover data, extent of habitats was mapped at the whole farm scale, and the structure and plant composition of individual field boundaries were quantified. Farm management information was gathered for all the study farms through a farmer questionnaire. Details of methods and results are given in section 3.

The following taxonomic groups were quantified (objective 1): higher plants, spiders, carabid beetles, birds and bats. In choosing these groups we attempted to represent a range of trophic levels, niches and ecological requirements.

Further information on the rationale of studying each group, the methods used and results are given in sections 4 to 8. Plants and invertebrates were sampled in three summers (2000, 2002, 2003), bats were mainly sampled in the summers of 2002 and 2003, and birds were sampled in two winters (2000/01 and 2002/03). Fieldwork for the project was disrupted by the outbreak of Foot and Mouth Disease which prevented data collection in summer 2001 and winter 2001/02.

A problem for multi-taxa projects of this kind is that the different groups vary strikingly in their space requirements and therefore sampling scales cannot be the same for all the taxa. Plants and invertebrates were sampled at the field scale, with data gathered from exactly the same samples of cereal fields (these are termed ‘target fields’). Birds and bats were sampled at the farm scale.

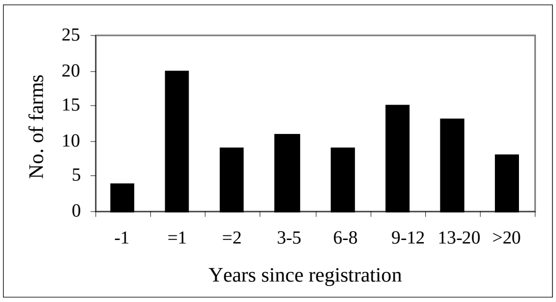


Fig. 2.1. Frequency distribution of the duration of organic practice (based on registration dates for the conversion of target fields) for farms in the study. Negative dates indicate target fields in conversion.

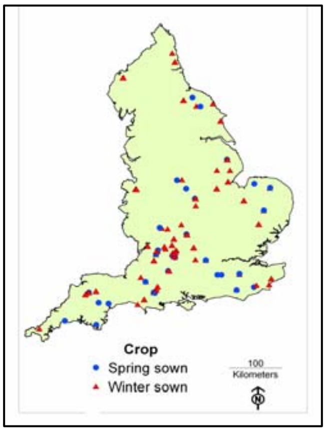


Fig. 2.2 Location of organic study farms with crop identity of target field.

Selection of study farms

The selection procedure for study sites initially focused on the organic farms. Criteria for selecting organic farms were: (1) they should be at least 30 ha, (2) highly fragmented holdings (i.e. where organic fields were interspersed with non-organic fields) were avoided, (3) agro-forestry and predominantly horticultural and grass enterprises were excluded, (4) they had to be growing the right crops in the right years. The Soil Association’s database was the initial source of potential farms. This was supplemented by farms certified by Organic Farmers and Growers. The outcome was that we collected data from virtually all suitable organic farms in England.

The organic farms were paired with conventional farms using a procedure that, critically, was purely geographical and not based on any attributes of either system. Initially we attempted to match organic farms with conventional farms by ITE Land Classes. This involved determining the Land Class of the 1-km square containing the organic farm and then identifying all potentially matching 1-km squares within 10 km. Maps and Yellow Pages were then searched for potential farms within these squares. Unfortunately this approach did not work, so assistance was sought from MAFF, and later from HGCA, who contacted farmers in the proximity of the organic farms on the basis of postcodes. Additional advice was provided by seed suppliers and the NFU. This approach successfully resulted in the samples being matched mainly by location (80% of pairs were within 10 km) but less so by ITE Land Class (63% of pair members were the same). Approximately 25% of conventional farmers approached agreed to take part in the study. Within the organic sample, there was a good spread of conversion dates, essential for addressing objective 4 (Fig. 2.1). None of the matched conventional farms was adjacent to the organic farm, and none was included on the basis of recommendation by the organic farmer. The selected study farms were widely distributed but there was a notable cluster to the east and south of Bristol (Fig. 2.2).

Selection and attributes of target fields

Target fields within each farm were examined for plants and invertebrates. The original intention was to survey spring barley and winter wheat on 30 and 60 pairs of target fields respectively. However, fundamental differences between the farming systems meant that this was impossible to achieve and, inevitably, the target fields reflected the typical cropping regimes of the different systems (Fig. 2.3). This gave 30 pairs of spring cereal and 59 pairs of winter cereal fields; the former were assessed in 2001 and 30 different pairs of the winter cereal fields were visited in each of 2002 and 2003. Both the spring cereal and the winter cereal fields were approximately equally divided between recently converted (<5 years) and old organic (>5 years).

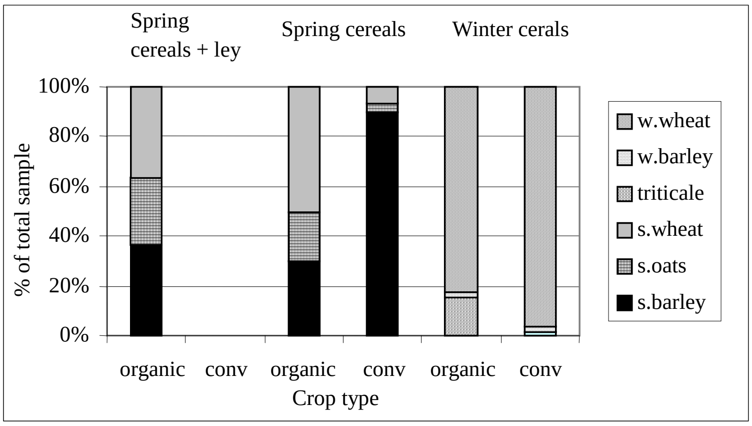


Fig.2.3. The crops grown within the samples of spring and winter cereals of target fields.

Information from the questionnaires indicated that >90% of target fields were typical of arable fields on the sample of farms. Ninety eight percent of target fields were surrounded by at least some (all or majority = 81%) fields owned by the same farmer. In 84% of cases, surrounding fields were in the same or a similar rotation to the target field. Conventional farmers tended to manage surrounding fields in broadly similar ways to their target fields (in terms of inputs). Organic fields were mostly surrounded by other organic fields (82%); only 8% were entirely surrounded by conventionally managed fields (these farms and their pairs were not used for bird/bat surveys). There were particularly large differences between systems in spring crops, with conventional growers not including undersown leys and organic farmers growing a wider variety of spring crops (Fig. 2.3).

Project workshop

On 1 July 2004 a workshop was held. Preliminary results were presented to a wide audience including policy advisors, professional conservationists, scientists, farm advisors and representatives of the organic sector. The purpose was to obtain feedback on the approach and findings and to discuss several issues arising from the project. Four questions were tackled in breakout sessions: (1) What *could* be the contribution of organic farming to biodiversity? (2) Are there lessons for enhancing biodiversity in arable systems? (3) What are the constraints to achieving this? (4) What key knowledge gaps remain? A summary of key points arising from these discussions is included in Appendix 6 and feedback from the workshop has been incorporated into the General Discussion and Conclusions (Section 10).

3. Habitat and management comparisons

Comparisons of habitat availability on organic and conventional farms were carried out at a range of scales using new field data and existing landscape scale datasets. Quantification of any habitat and management differences between organic and conventional farms was a key element in determining whether biodiversity differences could arise from habitat variation rather than from intrinsic system effects. Previous work has suggested that organic and conventional farms may tend to differ in boundary structure and field size (Chamberlain *et al.* 1999).

Methods (habitat and management comparisons)

Data from Countryside Survey 2000 (Haines-Young *et al*. 2000, Firbank *et al.* 2003) were used to assess the landscape context of organic farms. Land Cover Map (LCM) data were integrated with CS2000 field survey data to produce a land cover data set based on Broad Habitats for use in two analyses:

- Comparisons were made between the mean extents of all Broad Habitats (as defined in Jackson 2000) in 1,000 random samples of 89 1-km squares in wheat-growing areas of England and in the 89 1-km squares in which the surveyed organic fields were located (organic target squares).
- Comparisons were made between organic and conventional farm pairs in terms of the extents of Broad Habitats in the 1-km square in which the target fields were located (target squares), a 3-km square (i.e. 9 km^2) surrounding and including the target square, and a 5-km square (i.e. 25 km^2) surrounding and including the target square. Wilcoxon matched pair tests were used to test for significant differences.

At the field and farm scale the following analyses were undertaken:

- Detailed information was collected for the boundaries of target fields on tree / shrub composition, numbers of trees, hedge height and width, gaps, and longer breaks. These data were collected at 10 evenly spaced locations around each field. Wilcoxon matched pair tests were used to test for significant differences.
- BTO bird surveyors collected and mapped habitat information for the bird survey areas during the winter. Locations of crops and 'habitat patches' were mapped on 1:2500 maps (habitat patches included hedges of various structures, copses, ponds, game cover strips).
- Farmers were interviewed at the time of the plant survey to complete questionnaires comprising 40 questions concerning both the target field and the whole farm to provide both general and management information.

Results (habitat and management comparisons)

Landscape scale

Comparisons between 1,000 random samples of wheat-growing squares in England and the organic target squares revealed a number of significant differences (Table 3.1). Target squares had significantly more Improved Grass than a random sample and significantly less ‘other grass’ and non-cropped habitats (including Woodland, Standing Water, Bracken, Built Up and Gardens, Fen, Marsh, and Swamp and Bog). In addition, target squares were located further to the south of the wheat-growing area of England than the mean of random samples of wheat-growing squares within England.

Variable	P greater	P less
% Arable	0.731	0.269
% Improved Grass	**0.001**	0.999
% Other Grass	0.999	**0.001**
% Non-crop Habitats	0.999	**0.001**
Easting	0.648	0.352
Northing	0.999	**0.001**

Table 3.1. Results of analysis comparing distributions of individual and grouped Broad Habitats in the organic target squares and 1000 random samples of 89 1-km squares in the wheat-growing areas of England. Significant results are indicated in bold type. P values are the proportions of cases in which the mean value of each habitat or attribute was greater or less than the mean value for the sample of organic squares.

Comparisons in terms of the ‘local’ landscape in which organic and conventional farms were located, revealed significant differences at the target square and 3-km square scales (Table 3.2). There were no differences at the 5-km square scale. In summary, at both the smaller scales, squares in which organic target fields were located contained greater amounts of grassland than their conventional counterparts. In addition, 3-km squares containing organic target fields had greater amounts of non-crop habitat than their conventional counterparts.

Table 3.2. Descriptive statistics and results of Wilcoxon matched pair tests for comparison between landscape composition of the 1-km and 3-km squares in which the organic and conventional target fields were centred. Significant results are indicated in bold type.

		1-km square				3-km square				
Broad Habitat type or grouping	**Farm type**	**Mean % cover**	**St Deviation**	**Wilcoxon statistic**	**P value**	**Mean % cover**	**St Deviation**	**Wilcoxon statistic**	**P value**	**No. of farms**
Arable and	O	40.5	17.5	3.2	**<0.01**	42.0	15.7	2.7	**<0.01**	89
Horticultural (a)	C	47.1	20.6			44.8	16.7			
All non-crop	O	19.9	8.2	3.0	**<0.05**	20.5	6.7	2.8	**<0.01**	89
Broad Habitats	C	17.1	9.3			19.2	8.0			
All grassland	O	39.4	15.6	2.6	**<0.01**	36.7	12.7	1.3	NS	89
Broad Habitats (g)	C	35.6	17.4			34.8	13.5			
Ratio a:g	O	1.0		3.6	**<0.001**	1.1		2.8	**<0.01**	89
	C	1.3				1.3				

Field and farm scale

Detailed information about field boundaries on the target cereal fields revealed significant differences between key hedgerow characteristics. Hedgerow height, width and base width were higher on organic farms and there tended to be higher numbers of species of trees and woody shrubs but this was not significant. There were higher numbers of breaks and gaps in hedgerows surrounding conventional fields. Significant results are given in Table 3.3; there were no significant differences between base height, number of trees (alive or dead) and the number of tree / shrub species recorded.

Table 3.3. Descriptive statistics and Wilcoxon matched pair tests for comparison between organic and conventional farm types for the target field. The sign next to the Wilcoxon score indicates which farm type has the highest score; '+' =organic, '-' = conventional.

Hedge features	Organic farms		Conventional farms		Wilcoxon statistic	P value	No. of farm pairs
	Mean	S.D.	Mean	S.D.			
Base width	1.77	0.22	1.36	1.14	+511	0.013	80
Height	1.95	1.07	1.59	1.16	+482	0.018	80
Width	2.15	1.25	1.66	1.41	+619	0.002	80
No. breaks	2.96	3.56	4.28	4.71	-270	0.046	80
No. gaps	1.35	1.86	2.83	4.84	-257	0.044	80

Habitat information for bird survey areas across five winter visits for organic/conventional farm pairs revealed differences between organic and conventional farms both in terms of boundaries and agricultural land use. Total overall boundary (hedge, ditch, fence and wall) length within the bird survey area was significantly higher on conventional farms (n=48, P< 0.05) but the density (km per ha) of all boundaries and hedges alone was significantly higher on organic farms (n =48, P<0.05, n=48, P<0.01 respectively). The proportion of the bird survey area that was cropped land was higher on conventional farms (Table 3.4) as was total area of stubble (n=56, P<0.01) In contrast, organic farms contained proportionally more grass, in accordance with the results found for the 1-km squares in the above landscape scale analyses (Table 3.4).

Table 3.4. Descriptive statistics and Wilcoxon matched pair tests for comparison between organic and conventional farm types for the bird survey area. The sign next to the Wilcoxon score indicates which farm type has the highest score; '+'=organic, '-' = conventional.

	Organic farms		Conventional farms		Wilcoxon statistic	P value	No. of pairs
Linear features (km)	Mean	S.D.	Mean	S.D.			
Hedge	2.4.	1.21	2.17	1.32	+78	n.s.	48
Boundary	0.64	0.80	1.17	1.48	-156	<0.05	48
Linear features (km/ha)							
Hedge	0.12	0.15	0.07	0.05	+268	<0.01	48
Boundary	0.15	0.17	0.10	0.05	+196	<0.05	48
Field habitats (ha)							
Grass	12.91	10.14	7.77	8.71	+368	<0.001	56
Crop	9.11	9.21	21.06	16.96	-518	<0.001	56
Stubble	6.66	10.05	11.30	10.81	-266	<0.01	56
Field habitats (% of total ha)							
Grass	37.67	26.33	17.18	18.91	+531	<0.001	56
Crop	22.46	19.80	37.13	22.57	-438	<0.001	56
Stubble	16.83	17.67	23.12	19.52	-190	0.06	56

Interviews with farmers provided a wealth of information which is difficult to summarise concisely. Some of the information from the questionnaire was collected as validation of the study sample (see General Approach). Results given here emphasise those management variables likely to influence farm biodiversity and differences between systems. A summary of all the results relating to potential differences between the farming systems is provided in Appendix 1.

The following were significantly different between farming systems at the field level:

- Organic fields were smaller than their conventional pairs.
- Organic farmers sowed crops later in all three years.
- Rotations in organic systems always included a ley as part of a cereal/vegetable rotation. Conventional rotations consisted of cereals with vegetables, oilseed rape or set-aside as a break crop.
- Approximately a fifth of conventional farms cropped continuously but no organic farmers did.
- More conventional than organic farmers managed hedges around target fields in the survey year.
- All conventional farmers applied fertiliser and the majority applied broadleaf herbicides and graminicides (the latter on winter crops), 15% applied molluscicides, 34% insecticides and 67% fungicides. Organic farmers used techniques such as rotations and mechanical control to improve soil fertility and control pests.

The following were significantly different between farming systems at the farm level;

- Conventional farms contained more arable land (70%) than organic (58%).
- Organic farms were more likely to include livestock (and a wider variety of types) and use them on arable land.
- Organic farmers cut their hedges less often and were more likely to lay them than conventional.
- More organic farms (64% of those who gave information) had agri-environment agreements (in addition to the Organic Farming Scheme) than conventional (43% of those who gave information).
- More conventional farmers used natural regeneration as a set-aside option than organic.

There were no significant differences between farm types in terms of farm size, the amount of permanent pasture and the way in which it was managed, area of woodland, number of ponds or whether set-aside was rotated or permanent.

Discussion and conclusions (habitat and management comparisons)

It is clear that habitats on organic and conventional farms differ in a number of ways, especially in terms of crop types, presence of livestock and boundary characteristics. These differences may be expected to influence biodiversity between systems in a variety of ways (see also section 9). Very broadly, the habitat and management differences recorded are likely to promote higher habitat diversity and higher quality and quantity of boundary habitats for several groups of animals and plants on organic farms relative to conventional farms. Biodiversity on organic farms may be further affected by their broad landscape context, notably their relatively southerly position and relatively large extent of grassland in the surrounding countryside.

System differences in habitat may arise for several reasons. Firstly, organic guidelines specify that certain standards of non-crop habitat management should be adhered to. Secondly, many organic farmers may be pre-disposed towards more sympathetic management of their land for wildlife. Third, maintenance of thick hedges without gaps may be a higher priority on arable organic compared to conventional farms because of the higher likelihood of having livestock. To some extent habitat quality may be intrinsic to the system. For example, in the case of hedgerows, there may be interactions between adjacent crop and field management and habitat quality through factors such as spray drift and maintaining effective stock barriers. Therefore, benefits of non-crop habitats cannot necessarily transfer directly from one system to another.

Many of the habitat attributes shown by organic farms are essentially inter-related. Organic arable farms are, by necessity, more often mixed farms than their conventional counterparts leading to smaller field sizes, livestock-proof hedges, diverse rotations and greater extent of grassland, all of which are recognised as likely to encourage biodiversity. Interestingly, organic farmers are less likely to over-manage hedges and more likely to be in agri-environment schemes than conventional farmers but, rather than indicating that organic farmers are more ‘wildlife friendly’, this may reflect the fact that organic systems result in farms with more of the features likely to gain admission to, and relative ease of compliance with, agri-environment schemes. Indeed it is clear that organic systems encourage many of the features recognised as important for biodiversity on farmland including not just non-crop habitats but also overall diversity of structure. In contrast, conventional farms are more likely to contain certain habitats beneficial to wildlife (notably stubble and naturally regenerated set-aside). Nonetheless, it may be argued that organic systems tend to provide a more continuous and diverse set of resources for biodiversity.

4. Plants

The exclusion of synthetic herbicides and fertilisers from organic systems and the use of leys in rotations would be expected to benefit a wide range of plants and lead to higher species richness and abundance of non-crop plants. Several previous studies have indicated that this is likely to be the case. Of ten studies reviewed by Hole *et al.* (2005), 9 broadly showed the expected pattern and a recent additional study by Aude *et al.* (2004) concluded that slightly more herbaceous species are found in the bases of organic than conventional hedges. Many of the previous studies, however, have been restricted to particular sites or small samples; the present study allows an opportunity to test the generality of previous findings.

Methods (Plants)

Plants were recorded on both the target field and its boundaries, using three different plot types. This approach was used to ensure adequate coverage of different parts of the field and to account for the fact that botanical richness is typically higher in the field margins (Marshall 1989). The first two plot types follow the methods used in CS2000 (Haines-Young *et al.* 2000, Smart *et al.* 2003) with one plot per field.

A plots – were used to record species richness in the arable margin of the crop. The plots extended 1 m into the crop from the ploughed edge of the field and extended 100m along the field edge, incorporating corners where necessary. Plant species were recorded by presence only.
B-plots – were used to record both the presence and abundance of species in field boundaries. The plots extended 1 m from the centre of the field boundary (fence line, hedge or other) and ran for 10 m parallel to the boundary. All species found in the plot were recorded together with an estimate of % cover.
Quadrats – were placed along 12 transects running from the ploughed margin of the crop into the crop. Transects were placed evenly around the field edge at a minimum distance of 30 m from a field corner or gateway. Quadrats of 0.5 x 0.5 m were placed to the right of the transects at distances of 2, 4, 8, 16 and 32 m into the crop and all species present were recorded together with their % cover.

For each of the above three data sets, analysis was by GLM models (SAS GLM procedure), in all cases using the pairing and year, as well as pairing nested within year, as blocking variables to examine effects of system (organic and conventional) on species richness.

Results (plants)

In total, 222 species were recorded on **A plots** on conventional farms and 253 on organic. There were consistent and highly significant differences in species richness between systems ($F_{1,177}$ = 73.68, P<0.0001) as well as significant differences between pairs and years. For the majority of farm pairs, species richness was higher on the organic farm (mean = 27 species) than on the conventional (mean = 18 species) hence the majority of points fall above the line of equality in Fig. 4.1a.

Species most commonly recorded in **A plots** overlapped between organic and conventional farms to a certain extent with five of the top ten from each farming system being the same (*Cirsium arvensis*, *Poa annua*, *Galium aparine*, *Veronica persica* and *Polygonum aviculare*). Where species differed they tended to represent weeds typically associated with the particular farming system i.e. ley species (*Lolium perenne* and *Trifolium repens*) and *Rumex obtusifolia* in organic systems and *Anisantha sterilis*, *Alopecurus myosuroides* and *Chenopodium album* in conventional systems.

Data derived from the **A plots** in this study were compared with the same type of data collected nationally as part of CS2000. Because the numbers of plots surveyed in England as part of CS2000 was considerably higher than in this study, the results are presented as proportions of plots with different species richness (Fig. 4.2a). There were highly significant differences (t-tests) between A plots surveyed for CS2000 (mean = 12 species) and both organic and conventional A plots.

In total, 214 species were recorded on **B plots** on conventional farms and 208 on organic. There were consistent and significant differences in species richness between systems ($F_{1,177}$ = 14.39, P<0.001) as well as significant differences between pairs and years. A plot of species richness for each farm pair (Fig. 4.1b) shows that for the majority of farm pairs species richness was higher on the organic farm (mean = 16 species) than on the conventional (mean = 13 species) hence the majority of points fall above the line of equality.

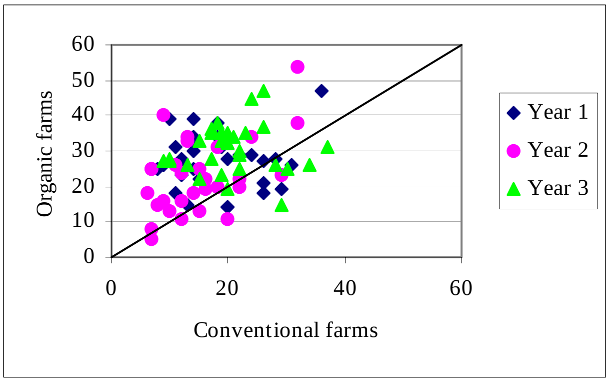
B plots from this study were also compared with B plots surveyed as part of CS2000 in the same way as for the A plots (Fig. 4.2b). There were significant differences (t-tests) between B plots surveyed for CS2000 (mean = 12 species) and organic B plots, but no significant differences between species richness on conventional farms and in CS2000.

Species recorded in **B plots** showed much greater overlap than those recorded in A plots with eight of the top ten species in terms of occurrence being the same for both farm types. These species included both ‘hedge’ species (*Crataegus monogyna* and *Rubus fruticosus*) and ‘bottom of the hedge’ species (e.g. *Galium aparine* and *Urtica dioica*). The non-overlapping species were all grasses with *Poa* species featuring on organic farms whilst *Anisantha sterilis* and *Elytrigia repens* were more prominent in conventional systems. The cover of the most common species recorded on B plots differed relatively little between the systems, although there was a trend towards higher cover of ‘hedge’ species (above) on organic farms and lower cover of ‘bottom of the hedge’ species (above). The only species commonly recorded that showed a large difference in percent cover was *Anisantha sterilis* where mean cover on conventional farms was 16% compared to 6% on organic farms.

In total, 189 non-crop (volunteers are also excluded) species were recorded on conventional farms in quadrats and 259 species on organic farms. There were consistent and significant differences in species richness between systems ($F_{1,177}$ = 150, P<0.0001) with marginally significant differences between years. A plot of species richness for each farm pair (Fig. 4.3) shows that for the majority of farm pairs, species richness was higher on the organic farm (mean = 35 species) than on the conventional (mean = 19 species) hence the majority of points fall above the line of equality. Analysis of species richness differences was carried out both on species richness across the whole field (above) and at each of the distances at which quadrats were placed. Differences were significant at all distances into the crop field with organic fields always containing more species than their conventional counterparts (Fig. 4.4).

Mean cover for both crop and non-crop (weed) species recorded in the transects was calculated for each of the farm types at each of the five quadrat distances (Fig. 4.5). As well as a larger numbers of species contributing to higher weed cover on the organic farms, a number of those species occurred at greater percentage cover than weed species on conventional farms. The most commonly occurring weed on conventional farms (*Poa annua*) occurred at an average of around 6% cover at all distances into the crop. Other common weeds (*Poa trivialis*, *Alopecurus myosuroides*, *Anisantha sterilis*, *Stellaria media*, *Polygonum aviculare*, *Veronica persica*) occurred at 1% or less. On organic farms no one species dominated so entirely as within the conventional system. However, there were 7 species which covered between 2-5% at all distances (*Poa annua*, *Poa trivialis*, *Alopecurus myosuroides*, *Lolium perenne*, *Tripleurospermum inodorum*, *Trifolium repens and Stellaria media)* and a number of other species at around 1%.

a)



b)

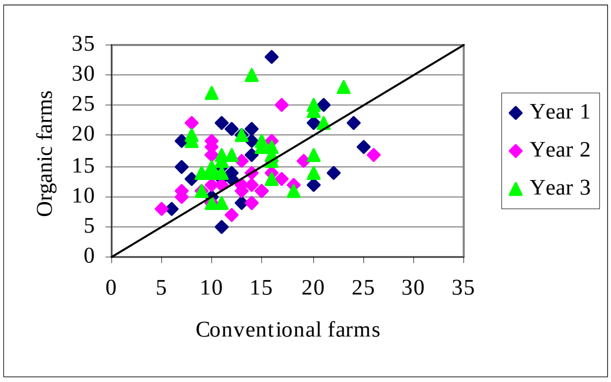
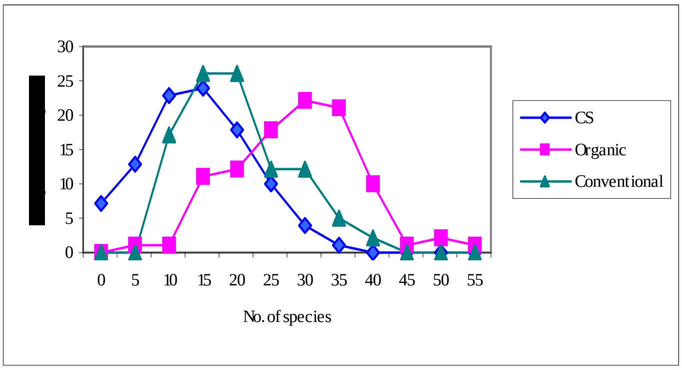


Fig. 4.1. Species richness in a) A plots and b) B plots on organic and conventional farm pairs

a)



b)

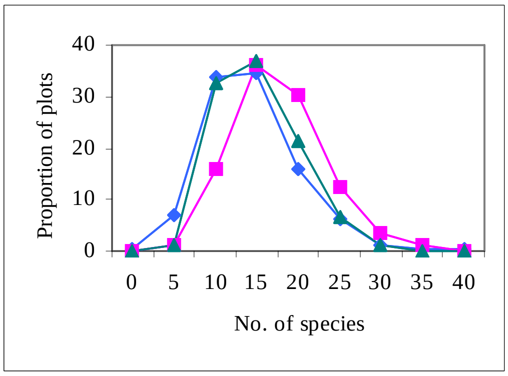


Fig. 4.2. Species richness in a) A plots in this study compared to CS2000, b) B plots in this study compared to CS2000.

Fig 4.3. Species richness on fields (measured in quadrats along 12 transects at 5 distances into the crop).

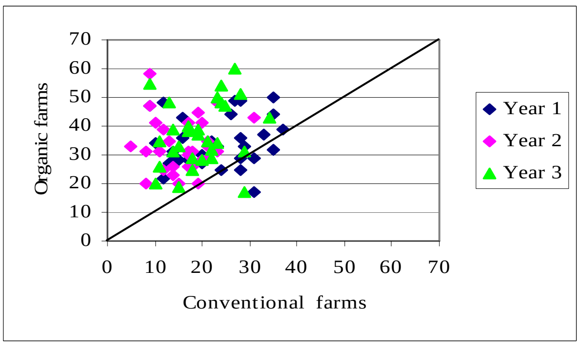
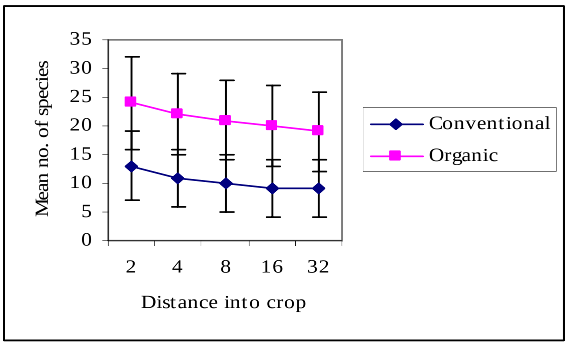


Fig 4.4 Mean number of species recorded at various distances into the crop on different farm types.



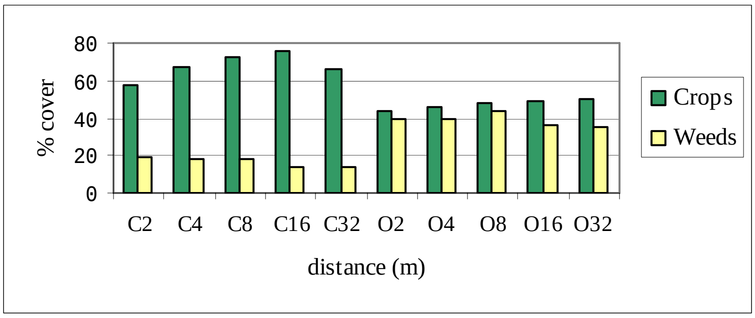


Fig 4.5. Crop and weed cover along transects into the crop on conventional farms (C) and organic farms (O) at different distances from the crop edge.

Analysis was also undertaken using the same basic GLM model but including field size, rotation type, proportion of non-crop habitat and grass in the target 1-km square. The purpose was to identify whether such factors could explain the observed differences in species richness between organic and conventional systems. There were no significant effects of any of these variables in addition to the overall system effects.

Regressions were carried out to examine effect of organic duration (as measured by date since certification) on species richness differences between organic and conventional farm pairs (organic species richness – conventional species richness). These analyses revealed no significant relationships (see Appendix 2).

Only one (*Centaurea cyanus*) of the 15 arable plants on the UK BAP list was recorded during the survey at 3 separate farms (2 organic, 1 conventional). Eight other species listed by the UK arable plant project (Plantlife) were recorded during the survey. Overall there were more than three times as many records of uncommon species on organic farms as conventional, although two species were only found on conventional farms (see Appendix 2).

Discussion and conclusions (plants)

It is very clear that organic farming systems are ‘good’ for arable plants, both of fields and field edges. The findings were consistent with predictions and with most previous work (reviewed by Hole *et al.* 2005). Organic fields contained on average over 80% more weed species and greater quantities of them (Fig. 4.5). Even so, records of scarce arable weeds were few. Weed communities round the edges of fields tend to be similar for both organic and conventional farms, whereas weed species found in fields show greater differences between the systems and are likely to be related to cropping practices on the fields. The duration of organic practice on fields did not affect the numbers of species found on any of the plot types used in this study, with newly converted fields just as likely to have high species richness as long-term organic fields.

5. Invertebrates

Surface-active predatory invertebrates, such as carabid beetles and spiders, are abundant in arable fields, and their numbers and diversity are likely to indicate those of their prey, especially small invertebrates including mites, Collembola and aphids. Small carabids and spiders also form important foods for several declining farmland birds (Wilson *et al.* 1999). Hole *et al.* (2005) reviewed the effects of organic management on both spiders and carabids and found widespread evidence for differences between farming systems in communities of both groups. Whilst the general pattern appears to be one of higher abundance and diversity in organic fields, this is not universal. This study is the first large-scale assessment of these invertebrates on organic and conventional farms in Britain.

Methods (invertebrates)

Spiders and carabid beetles were sampled using pitfall trapping. Eighteen traps were set in a grid formation in each target field, arranged so that 9 were placed within the crop and 9 within the uncropped boundary. Traps were set for one week before emptying, and the target invertebrates sorted, then preserved for later identification. Organic and conventional target fields within a farm pair were always sampled at the same time. Two sampling rounds were conducted, one before and one after harvest. Spiders and carabids were identified to species level.

Data from field margins and field centres were analysed separately, using GLM models (SAS GLM procedure) that included farm pair identity as a categoric factor and year as a blocking factor for the winter crop data. Three response variables were considered: abundance (log x+1 transformed), species richness (square–root transformed) and factor scores derived from multivariate analysis describing gradients in community structure. Response variables were derived from the aggregate of traps on each farm and system giving a single value for each pair/system combination.

Results (invertebrates)

In winter cereals, spiders tended to be more abundant and species-rich on organic farms. Although this was not consistent with respect to location (i.e. crop or boundary), or sample time (i.e. before or after harvest), the direction of the effects was consistent: values were always higher on organic farms (Table 5.1). The maximum observed effect was an average of 25% more spiders in the cropped area before harvest. For carabid beetles, the results were more variable. Before harvest, carabid abundance was significantly higher in organic compared to conventional crops, while after harvest, species richness was lower on organic boundaries.

Table 5.1. The effect of system and habitat on (a) spider and (b) carabid beetle abundance and species richness (for winter cereals 2002/2003). Statistically significant results are emboldened, and effect sizes presented following the format of Perry *et al.* (2003): D values are the mean difference between log-scale abundances. R values represent the sample mean ratio of the organic/conventional attribute. CI = confidence interval. So, for example, for spider post-harvest boundary abundance, our estimate for the population system effect is between 5% and 42% more spiders on organic farms. Evidence for the effect of potential boundary/field habitat and field management predictors of invertebrate attributes is tabulated for margin width (MW), hedge bulk (HB), proportion of points where hedge or other woody structure recorded (PSW), time since conversion (TIME_SC), use of insecticide on the conventional field (INS), whether grass was reported to be used in the organic rotation (GRASS_R) and the estimated area (%) covered by weeds in the field (Pweed). Significance is as in GLM models *not* adjusting for system, except where noted, and for TIME_SC and INS where the (O-C) difference was used as the response. '+' or '-' preceding P values shows the direction of the effect.

a) System and habitat effects on spiders.

				Boundary/field Quality					
	SYSTEM (P)	**D**	**R (CI)**	**MW**	**HB**	**PSW**	**TIME_SC**	**INS**	**GRASS_R**
Boundary									
Before harvest:									
Abundance	0.322	0.10	1.10 (0.92-1.32)	NS	NS	NS	NS	NS	NS
Species richness	0.544	0.03	1.03 (0.92-1.17)	NS	NS	NS	NS	NS	NS
After harvest:									
Abundance	**0.0112**	**0.20**	**1.22 (1.05-1.42)**	NS	NS	NS	NS	NS	NS
Species richness	0.171	0.10	1.11 (0.92-1.34)	NS	NS	NS	NS	NS	NS
Crop									
				Pweed					
Before harvest:									
Abundance	**0.0127**	**0.22**	**1.25 (1.05-1.48)**	+P=0.07			+ P = 0.06	NS	NS
Species richness	**0.0025**	**0.16**	**1.17 (1.06-1.30)**	**+P=0.02**			**+ P = 0.01**	NS	NS
After harvest:									
Abundance	0.690	0.05	1.06 (0.83-1.36)	NS			NS	+P=0.06	NS
Species richness	0.175	0.12	1.17 (0.92-1.46)	NS			NS	NS	NS

b) System and habitat effects on carabid beetles.

				Boundary/field Quality					
	SYSTEM (P)	**D**	**R (CI)**	**MW**	**HB**	**PSW**	**TIME_SC**	**INS**	**GRASS_R**
Boundary									
Before harvest:									
Abundance	0.876	0.04	1.04 (0.78-1.37)	NS	**-** P=0.06	NS	NS	NS	NS
Species richness	0.212	0.26	0.91 (0.79-1.06)	NS	NS	NS	NS	NS	NS
After harvest:									
Abundance	0.119	-0.12	0.83 (0.69-1.06)	NS	NS	NS	NS	NS	NS
Species richness	**0.046**	**-0.11**	**0.83 (0.66-1.03)**	NS	NS	NS	NS	NS	NS
Crop									
				Pweed					
Before harvest:									
Abundance	**0.044**	**0.26**	**1.30 (1.02-1.66)**	NS			NS	NS	NS
Species richness	0.158	0.09	1.09 (0.99-1.20)	NS			NS	NS	NS
After harvest:									
Abundance	0.590	0.16	0.87 (0.64-1.21)	NS			NS	NS	NS
Species richness	0.345	0.09	0.92 (0.77-1.09)	NS			+P=0.09	NS	NS

In spring cereals (pre-harvest 2000 samples, results not tabulated), there were significantly more carabid species in the cropped area on organic farms compared to conventional farms. No other statistically significant results for either spiders or carabids were observed.

There was some evidence that abundance and species richness of spiders in the cropped area was affected by weediness, where weediness was a visual assessment of the proportion of the cropped area that was weed-covered (Table 5.1). Both tended to be higher where a higher proportion of the sampled area was weed-covered. Weediness was, however, confounded with system, and within system there was no evidence for an effect. Spiders also showed some evidence that the system difference was higher for the pairs where the organic field was longest-converted (Fig. 5.1). The relatively few farms converted for longer than 20 years were highly influential in producing this observation and there was no trend if only pairs below this were considered. Little other evidence was observed for habitat or management effects; neither the presence of grass in the organic rotation, nor whether the conventional farmer reported having used insecticide sometime before we sampled, appeared to be influential. There was weak evidence for a positive effect of hedge bulk on boundary carabid beetle abundance (before harvest).

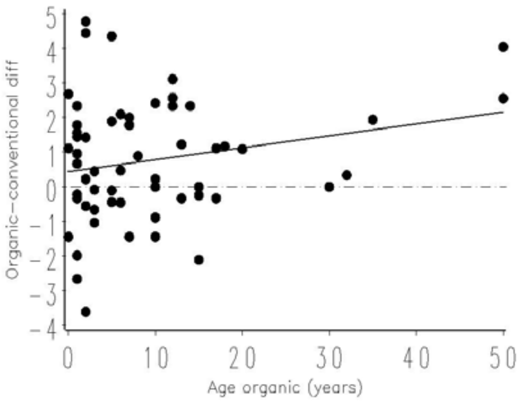


Fig 5.1. The effect of years since conversion on the (organic-conventional) difference for spider species richness in the cropped area (winter crop 2002/2003). Solid line indicates least-squares regression trend. ($F_{1,53}$ = 6.9, P = 0.01).

Many individual species revealed statistically significant effects for system (many more than could be accounted for by multiple testing). For spiders, 8 species were more abundant on organic farms in the cropped area before harvest, including 5 ground-dwelling Lycosidae (hunting spiders) and one Linyphiid (money spiders which make small sheet webs low in vegetation). Four species, three Linyphiids and a Clubionid (foliage spider), were more abundant in conventional. For carabids, before harvest in the cropped area, seven species showed strong evidence for a system effect on abundance (O>C). Five showed an effect in the opposite direction, including *Loricera pilicornis*, which specialises in feeding on Collembola. A full list of system effects for individual species is presented in Appendix 3.

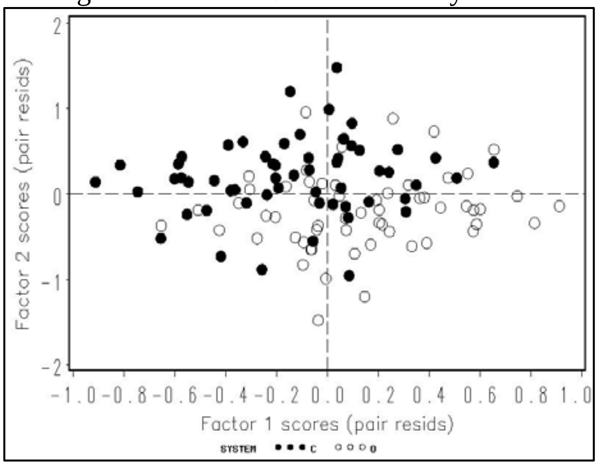


Figure 5.2. Ordination (Principal Components Analysis) plot summarising system differences for carabid communities in the cropped area (before harvest, winter cereals). Factor scores (adjusted for farm pair ID) differ significantly on both axes ($F_{1,57}$= 9.0, P = 0.0039 and $F_{1,57}$= 11.4, P = 0.0013).

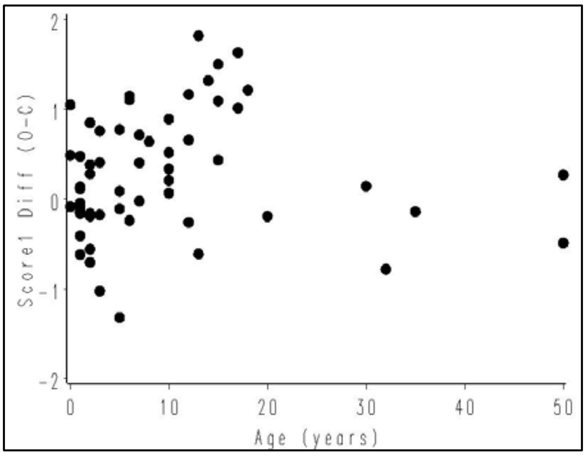


Figure 5.3. Axis 1 PCA score differences (O-C. cropped area carabids, winter cereal) and time since conversion. Overall, there is no trend (r=0.04, P=0.71), but within the 'recent' pairs (<20 years), a strong upward trend is evident (r=0.54, P < 0.0001).

Multivariate analyses were used to summarise and visualise system effects. For the spider data, this approach did not yield any patterns. For carabid beetles, though, some patterns emerged. In Fig. 5.2, generated using carabid data for the cropped area, the lower right quadrant of the ordination space is dominated by organic farms, while conventional farms predominate in the opposite quadrant, reflecting a subtle difference between systems. The axis scores were subjected to further analysis; the factor1 scores in this plot, adjusting for year and farm pair were found to be positively related to cropped area weediness (as was overall carabid abundance); scores were higher where weediness was higher ($F_{1,36}$ = 6.04, P = 0.02). While there was no evidence that weediness had an effect adjusting for system ($F_{1,36}$ = 1.2, P = 0.28), the evidence for an effect on organic farms was stronger than on conventional farms ($F_{1,35}$ = 4.4, P = 0.04 and $F_{1,36}$ = 0.13, P= 0.73 respectively). There was also evidence for a trend in factor 1 scores in the earlier years following conversion (Fig.5.3).

Discussion and conclusions (invertebrates)
Overall, the results suggest that organic systems were generally beneficial to our measured invertebrate groups. The results were particularly consistent for spiders and, for both groups, most consistent with regard to cropped areas before harvest. These areas are likely to have represented a less variable habitat, within system, than uncropped boundaries or post-harvest fields. The results suggested that the between system difference was related to weediness within the crop (see also section 6). After harvest, the higher abundance of spiders in organic margins may have been a consequence of system differences in hedgerow and associated vegetation structure (important for many spiders), whereas higher numbers of carabids in the corresponding conventional samples could have been due to use of herbicides, resulting in more bare ground (important for most of the carabids found). A few specialist feeders like *Loricera pilicornis* may be commoner in conventional fields as a response to prey abundance. Herbicide use in conventional fields may result in greater amounts of detritus, upon which the Collembola feed, possibly leading to an increase in *Loricera* numbers (Brooks *et al.* 2003).

6. Integrated analyses of plants and invertebrates

The comparisons of invertebrate data with some crude indices of weediness suggested that, while some attribute of weediness might contribute to the differences between systems in their invertebrate fauna, the evidence that invertebrates are influenced by weediness within systems was much weaker (see section 5). Here, we compare invertebrate attributes with the plant species diversity observations to further explore questions concerning the extent to which different trophic levels react to between and within system differences among target fields. These analyses are possible because a very high level of spatial integration was achieved between the plant and invertebrate sampling. Because invertebrate abundance and species richness are highly correlated, we focus on invertebrate species richness as a response. As we expect that in nature the order of cause and effect might be expected to run from plants, via herbivorous invertebrates, to predatory invertebrates, we ask questions of the form, how well can invertebrate diversity be predicted with knowledge of plant diversity? Table 6.1 summarises the statistical evidence for this question. In the cropped area, there is little evidence for any effect in addition to that accounted for by system. Confounding between system and plant SR in the cropped area is extreme as exemplified by Fig. 6.1.

Table 6.1. Strength of evidence for a predictive effect of plant species richness (SR) on invertebrate species richness based on GLM models. The effects in models including 'all' farms is adjusted for system: i.e. does plant SR have an effect other than is explained by the difference in plant SR *between* system. AH = after harvest; BH = before harvest.

Response:	Cropped Area			Boundary		
	All farms	O farms	C farms	All farms	O farms	C farms
Carabid SR (BH)	NS +	NS +	NS +	NS -	NS -	NS -
Carabid SR (AH)	NS +	NS +	NS +	NS +	0.04 +	NS -
Spider SR (BH)	NS +	0.08 +	NS +	NS -	NS -	NS -
Spider SR (AH)	NS -	NS +	NS +	NS +	NS +	NS +

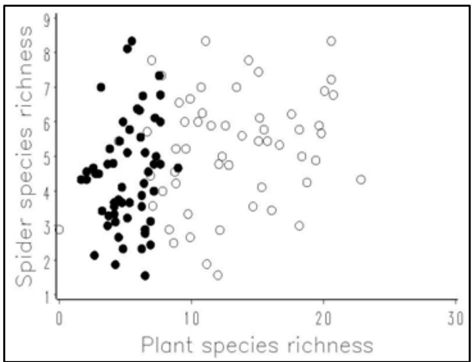


Figure 6.1. Spider and plant species richness (cropped area before harvest). Open circles = organic, closed = conventional.

While the effect of system on plant species richness is marked within the crop (Fig.6.1), it is also clear that plant species richness does not 'explain' the system effect on spider richness (Table 6.1). If it did, and there were a causal relationship between the two (however indirect), we would expect a correlation between spider and plant species richness among both organic and conventional farms. This is true for neither organic or conventional farms.

In the boundary, where the confounding of system and plant SR was not as extreme, there was some evidence that in post-harvest samples, the relationship between invertebrate and plant SR differed between systems. Figure 6.2 illustrates this for carabids (a similar pattern was observed for spiders). As no effect was observed in pre-harvest samples, and carabids were less abundant and species-rich on organic boundaries after harvest (Table 5b), this is not a simple relationship. Further multivariate analyses of both plants and invertebrates will be necessary to elucidate it.

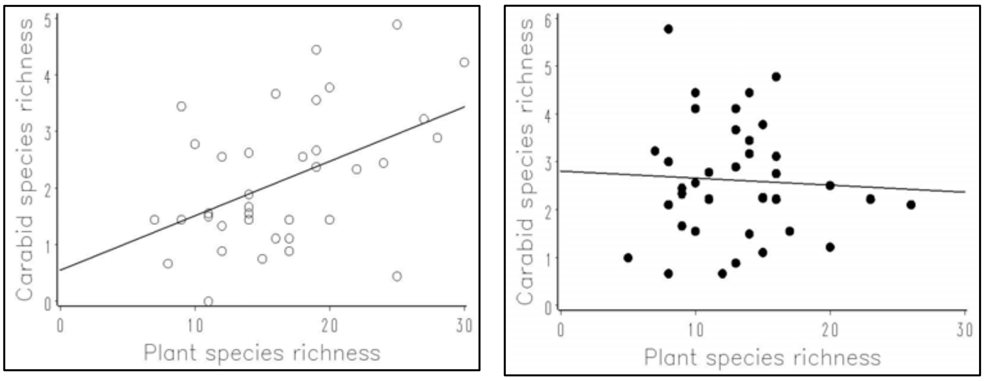


Figure 6.2. Carabid and plant species richness in boundary samples (post-harvest). Adjusting for year, upward trend is significant for organic fields (left plot GLM adjusting for year $F_{1,33} = 4.34$, $P = 0.04$) but not for conventional fields (right plot $F_{1,33} = 0.0$, $P = 0.95$).

7. Wintering birds

Most studies that have examined responses of birds to organic farming have concluded that the effects are broadly positive (see review by Hole *et al.* 2005). However, most have focused on breeding rather than wintering birds. A previous comparison of birds on organic and conventional farms in Britain suggested that differences between organic and conventional farms were slightly more evident outside the breeding season (Chamberlain *et al.* 1999). Furthermore, the relative mobility of birds in winter, frequently coupled with gregarious behaviour especially in seed-eating species, potentially enables them to exploit localised food resources. It has been hypothesised that organic farms may provide local concentrations of food and therefore potentially benefit populations over wider areas (Fuller 1997).

Methods (birds)

Bird surveys took place on the target field and up to a maximum of five adjacent fields. During each survey visit, the observer walked the perimeter of each field and once across the centre of each field. The locations of all birds seen or heard were recorded when first detected, taking care not to record the same individual bird twice. Observers were also asked to record habitat attributes of the fields (e.g. crop or other field type, presence of grazers, crop or grass height), field boundaries (boundary type, height, width, presence of ditch, presence of field margin) and other non-crop habitats (woods, ponds, farmyards). Bird surveys were undertaken once per month to each site between October and February inclusive and were carried out over two winters (2000/01 and 2002/03). Birds were mapped on large scale maps and individual records were subsequently allocated to habitat categories. Abundance values for individual farms were based on mean counts across visits.

There were two levels of analysis. First, a simple paired comparison of densities between organic and conventional sites was carried out using a Wilcoxon signed rank test (thus repeating the analysis carried out in Chamberlain *et al.* 1999). Second, a more complex modelling procedure was carried out which first sought to identify those habitat variables that were significantly associated with bird density regardless of farm type, then to see if there was additional significant variation caused by farm type in addition to that caused by habitat extent. A subset of habitat variables that were considered to have likely impacts on bird density based on previous work were entered into the model. These were area of grass, area of cereal stubble, area of woodland in the surrounding 3 km radius, grass:arable ratio in the surrounding 3 km radius, total hedgerow length, total field margin length and site area (and the quadratic equivalent of each of these). In addition, farm pair was entered into the model as a dummy variable in order to account for potential effects of location. Non-significant terms were sequentially deleted until only significant habitat variables remained with the exception of site area and farm pair which were forced into every model. Once a minimum adequate model (MAM) had been identified, farm type was entered into the model. Significant effects imply that differences in density between farm types cannot be explained by differences in the habitat variables entered into the model. In order to assess potential seasonal effects of farm type, season was defined as autumn (Oct- Nov) and winter (Dec-Feb) and a season*farm type interaction was added to each MAM. Where significant interactions were found, the modelling procedure was repeated for autumn and winter separately. Farm pairs where a given species was never recorded were not included in the models. Analysis was carried out on the 30 most abundant species.

A similar approach was taken when considering relationships between species density and time under organic management, although only organic farms were considered in this analysis. First, relationships between species density and organic duration were analysed with Spearman rank correlations. Second, habitat MAMs were identified as previously. Time under organic management (as a continuous variable) was then added to the model to see if additional variation could be explained to that caused by habitat extent.

One further piece of analysis was undertaken within this project. This involved a reanalysis of the data collected in the earlier extensive project on birds and organic farming (Chamberlain *et al.* 1999). This analysis aimed to assess whether higher abundance of birds in organic than conventional hedgerows was a consequence of differences in hedgerow structure rather than organic management. The methods and results are given in Chamberlain and Wilson (2000) which is included as Appendix 4.

Hedgerow berries are an important autumn and winter food resource for several birds, especially thrushes. A short study was conducted in the winter of 2002/03 on a sub-set of 10 farm pairs to assess whether organic and conventional farms differed in the diversity of their shrub vegetation and the stocks of berries they carried. Winter counts of berry-feeding birds were examined in relation to berry abundance.

Results (birds)

Mean densities per site on organic and conventional farms are given in Table 7.1. According to the paired comparisons using Wilcoxon tests, there were seven species in 2000/01 and 12 species in 2002/03 where rank density was significantly higher on organic than conventional farms. Furthermore, total density of all species combined and species richness was significantly higher on organic farms in both years. No species had a significantly higher density on conventional farms. In 2000/01 there were approximately equal numbers of species where density was higher on organic and higher on conventional (21 versus 19). However, in 2002/03 all 30 species showed a higher density (regardless of significance) on organic farms. This was highly significantly different to the proportion expected by chance (sign test, $P<0.001$). The Wilcoxon analysis was repeated for hedges and fields separately. Results were similar in that several species showed higher rank densities on organic farms. A notable exception was Red-legged Partridge which showed a significantly higher rank density in conventional hedgerows (this species was obviously using the hedge base not the hedge itself).

Habitat-only models (i.e. without farm type) showed that the density of several species was closely associated with habitat (full details in Appendix 5). In particular, total hedgerow density was significantly positively associated with the density of Wren, Dunnock, Robin, Blackbird, Redwing, Great Tit, Blue Tit, Long-tailed Tit, Magpie, Bullfinch, Reed Bunting and Yellowhammer and species richness in at least one year. Starling showed negative associations and Carrion Crow and Song Thrush showed both significant positive and negative effects depending on year. Total site area was also significantly negatively associated with density of 16 species. These variables are of particular importance as they varied significantly between farm types and so they were potential sources of variation that needed to be accounted for before the farm type comparison was made. When farm type was added to the MAM, there were four species that showed significant effects in 2000/01, in each case organic density exceeding that on conventional: Blue Tit, Carrion Crow, Greenfinch and Reed Bunting (Table 7.1). Blackbird ($P<0.07$) and to a lesser extent Bullfinch ($P<0.085$) showed nearly significant effects. In 2002/03 there were only two species where a significant difference was detected, Lapwing and Rook (Table 7.1). Blackbird was again almost significant ($P<0.08$). In each case, significant or nearly significant effects involved higher densities on organic farms. Species richness was also significantly higher on organic farms in 2002/03.

In 2000/01 there were two species that showed a significant interaction between season and farm type: Blue Tit and Redwing. In both cases there was no significant effect of farm type in autumn, but organic density estimates were significantly higher than conventional in winter. In 2002/03 there were four species that showed significant interactions between farm type and 'season': Skylark, Blue Tit, House Sparrow and Bullfinch. When analysed separately by season, there were significant effects of farm type for all except Bullfinch. Blue Tit estimates were significantly higher on organic than conventional farms ($P<0.012$), but for both Skylark ($P<0.009$) and House Sparrow ($P<0.04$) estimates were significantly higher on conventional farms. There were no significant differences between farm type in the winter for any of these species.

There were no significant relationships between density or species richness and time under organic management according to Spearman rank correlations. For the GLM analysis where habitat extent was also taken into account, there was a significant effect of time under organic management for Grey Partridge only ($P<0.029$, $n = 44$ organic farms) where density decreased with increasing organic duration in the 2000/01 sample. In the 2002/03 sample, only Song Thrush showed a significant effect ($P<0.048$, $n = 35$ organic farms) but in this case density increased with increasing organic duration. There was no significant effect of duration on species richness after controlling for effects of habitat extent.

The results of the hedgerow and berry study showed no clear evidence that the organic farmers in the study had more diverse hedges than their conventional counterparts (this matches the finding for target fields in section 3), although organic farms generally contained higher numbers of berries. Farmers in agri-environment schemes had hedges containing greater numbers of berry-producing species. Berry numbers decreased differentially over the period of the study dependent on species and, in one case, management. Berry stocks of some species persisted into December. Using bird data collected on 11 farms during the period of the fruit survey it was possible to establish a relationship between berry abundance and density of berry-eating bird species on hedgerows (r^2 =0.48, n=13, P<0.01).

Table 7.1. Mean winter ± SD bird density and species richness on organic and conventional farms in 2000/01 and 2002/03. N = number of farm pairs. Density is expressed as birds per hectare. P_w indicates the probability level of a Wilcoxon signed rank test. P_{MAM} indicates probability level of the variable farm type (organic or conventional) when added to a model of significant habitat predictors. Note that sample sizes for species richness include some sites where site area data were missing (hence sample sizes are lower for density estimates). Significant values (P≤0.05) are in bold.

Species	2000/01					2002/03				
	ORG	CON	N	P_w	P_{MAM}	ORG	CON	N	P_w	P_{MAM}
Blackbird	0.58±1.81	0.27±0.37	46	**0.04**	0.067	0.56±0.77	0.23±0.20	37	**0.01**	0.077
Bullfinch	0.05±0.10	0.03±0.07	27	0.33	0.084	0.05±0.13	0.01±0.02	30	**0.01**	0.292
Blue Tit	0.28±0.41	0.19±0.29	47	**0.04**	**0.044**	0.24±0.21	0.13±0.16	37	**0.01**	0.176
Carrion Crow	0.23±0.28	0.60±2.60	46	0.11	**0.002**	0.13±0.21	0.09±0.09	37	0.62	0.898
Chaffinch	0.64±0.95	0.51±1.07	47	**0.02**	0.465	0.85±1.34	0.42±0.58	36	0.12	0.314
Dunnock	0.19±0.43	0.14±0.16	47	0.75	0.507	0.25±0.45	0.12±0.11	36	0.26	0.927
Fieldfare	0.68±1.64	0.78±1.62	38	0.51	0.647	1.58±3.03	0.74±1.21	36	0.28	0.855
Goldfinch	0.13±0.27	0.09±0.18	38	0.45	0.367	0.07±0.15	0.05±0.10	31	0.31	0.802
Greenfinch	0.36±0.82	0.14±0.53	39	0.17	**0.042**	0.30±1.04	0.07±0.16	35	**0.05**	0.641
Great Tit	0.19±0.45	0.08±0.12	41	**0.02**	0.180	0.12±0.16	0.06±0.09	37	**0.01**	0.534
House Sparrow	0.04±0.10	0.05±0.20	21	0.75	0.867	0.34±1.74	0.07±0.19	23	0.31	0.830
Jackdaw	0.30±0.38	0.49±1.89	42	0.17	0.337	0.46±1.06	0.14±0.33	31	0.07	0.125
Lapwing	0.39±2.48	0.18±0.56	15	0.23	0.715	0.28±1.25	0.09±0.17	20	0.96	**0.031**
Linnet	0.31±0.86	0.22±1.19	23	**0.05**	0.200	0.52±1.18	0.15±0.37	30	0.23	0.870
Long-tailed Tit	0.18±0.33	0.12±0.19	35	0.24	0.154	0.10±0.16	0.04±0.05	29	**0.01**	0.325
Magpie	0.10±0.17	0.11±0.19	40	0.61	0.483	0.05±0.08	0.03±0.04	35	0.10	0.999
Grey Partridge	0.08±0.50	0.04±0.13	16	0.35	0.613	0.04±0.10	0.03±0.05	21	0.70	0.360
Robin	0.33±0.79	0.23±0.34	47	0.11	0.365	0.29±0.40	0.12±0.13	37	**0.01**	0.142
Reed Bunting	0.08±0.33	0.01±0.02	13	0.27	**0.043**	0.05±0.14	0.01±0.02	22	0.08	0.938
Redwing	0.95±2.84	0.45±2.51	34	**0.01**	0.256	0.87±2.70	0.29±0.49	36	0.08	0.944
Red-legged Partridge	0.04±0.11	0.14±0.50	25	0.19	0.851	0.17±0.44	0.13±0.26	30	0.83	0.387
Rook	0.77±1.47	0.86±2.54	38	0.27	0.528	0.68±1.27	0.28±0.50	31	**0.05**	**0.034**
Skylark	0.28±0.59	0.20±0.32	43	0.71	0.888	0.82±2.15	0.41±0.48	36	0.94	0.620
Stock Dove	0.16±0.42	0.06±0.27	27	**0.01**	0.271	0.13±0.42	0.02±0.04	27	**0.02**	0.295
Starling	1.13±2.67	1.01±3.78	38	0.09	0.473	1.15±1.87	0.42±0.93	34	0.10	0.316
Song Thrush	0.20±0.42	0.11±0.16	44	0.26	0.338	0.23±0.39	0.14±0.12	35	0.17	0.322
Tree Sparrow	0.02±0.06	0.01±0.07	7	0.69	0.376	0.11±0.46	0.00±0.01	9	**0.05**	0.211
Woodpigeon	1.04±1.46	1.20±3.16	46	0.23	0.192	1.89±5.31	0.79±1.39	37	**0.04**	0.646
Wren	0.16±0.17	0.18±0.21	47	0.91	0.871	0.22±0.28	0.11±0.08	36	**0.02**	0.496
Yellowhammer	0.26±0.48	0.25±0.46	42	0.50	0.930	0.42±1.14	0.20±0.28	34	0.90	0.682
Total density	6.31±5.98	4.49±2.59	48	**0.01**	0.236	19.11±34.58	6.23±3.74	37	**0.01**	0.266
Species richness	16.56 ± 5.60	14.85 ± 5.61	52	**0.02**	0.342	21.82 ± 5.45	20.21 ± 5.99	38	**0.04**	**0.038**

(Scientific names of birds are given in Appendix 5)

Discussion and conclusions (birds)

As with the previous extensive study of bird populations on organic farms (Chamberlain *et al.* 1999), there were rather few significant differences in species abundances between organic and conventional farms. Nonetheless, the general patterns were very similar in that all the significant differences involved higher densities on organic and there was a general tendency for species abundances to be higher on organic. Furthermore, overall density and species richness, as tested by the Wilcoxon test, were consistently higher on organic farms. In conclusion, the results support the view that organic farms tend to support larger numbers of individual birds and species, but the differences are not generally very strong. There is little evidence to support the hypothesis that organic farms attract major concentrations of wintering birds (Fuller 1997). Many of the strongly flocking seed-eating species (finches, buntings, sparrows) did not show significantly higher densities on organic farms.

As one might expect, habitat variables were in many cases strongly correlated with species abundances. However, there were several instances where organic farming had an additional (positive) effect. This finding was similar to that of Chamberlain and Wilson (2000) who analysed data from the earlier extensive project to assess whether farm system had an effect on bird abundance within hedgerows independently of hedgerow structure.

8. Bats

Many bat species are in rapid decline (Hutson *et al.* 2001). All British bats are protected by national and European legislation, and pipistrelles are on the short-list of the UK Biodiversity Action Plan. Agricultural intensification has been anecdotally linked to falling bat numbers, but this project is the first large-scale comparison of bat activity on contrasting farming systems. Because bats are highly mobile - which enables them rapidly to select favoured habitat types - and have a high position in the trophic web, they are useful indicators of biodiversity differences between organic and non-organic farms. The one previous study of bats on organic farms reported higher levels of overall bat activity on organic than conventional farms (Wickramasinghe *et al*. 2003). Like the present study it was based on a paired sample of farms (24 pairs compared with 65 in this study) but there was a major difference in the approach. (Wickramasinghe *et al*. 2003) compared bat activity within the same habitats on different farm types, whereas we have assessed bats across farms in proportion to habitat availability**.**

Field methods (bats)

The field surveys were conducted in the months of June, July and August in 2002 and 2003. All surveys were completed before harvest to avoid the potential confounding of farming system with harvest timing. Bat activity was monitored along a transect of approximately 3 km (the precise length being determined by farm size and shape) which began in the ‘target field’. The transect was orientated randomly, and all habitats were therefore sampled in proportion to their availability.

Field workers used heterodyne bat detectors tuned to 25kHz to identify activity by noctule (*Nyctalus noctula*), serotine (*Eptesicus serotinus*), and Leisler’s (*Nyctalus leisleri*) bats. These species were distinguished on the basis of their call characteristics. The number of bat passes, and also the number of feeding calls, heard in each 125 m section was recorded. After each 125 m section, the detector was retuned to 50kHz and the number of pipistrelle bat passes and feeding calls heard within 1 minute was noted. The fieldworkers identified, wherever possible, the species of pipistrelle (*Pipistrellus pipistrellus* or *Pipistrellus pygmaeus*) by rapid retuning of the detector to identify the peak call frequency. Basic habitat details were recorded for each 125 m stretch, including the presence of water, hedgerow and cattle.

Bat activity along the transects was also recorded onto minidisk, using frequency-division ‘Duet’ detectors. The resulting sonograms were analysed using BATSOUND software, and species were identified on the basis of call shape, peak frequency, repetition rate and volume. Any uncertainties were resolved by consultation with additional experienced bat workers. The data were explored using paired analyses (general linear models (GLMs) where data conformed to the assumptions of the models and Wilcoxon tests otherwise). The GLMs adjusted for the effect of year.

Results (bats)

Surveys were completed on 65 farm pairs, 12 of which were visited twice. Sonograms were analysed for a subset of 42 farm pairs. Because it was possible to identify all bat species using the sonograms, these data were used to investigate species diversity and also the activity of species difficult to identify during the field survey.

Species diversity was significantly higher on organic compared with conventional farms (mean Shannon-Weiner indices: organic 0.84 (SE 0.08); conventional 0.49 (SE 0.07), $F_{1,37} = 10.81$, $P = 0.002$). Fig. 8.1 shows the composition based on the number of recorded bat passes of each species. Records from conventional farms were more strongly dominated by common pipistrelles and non-pipistrelle species contributed a higher proportion of records on organic farms.

Activity was greater on organic than on conventional farms (Fig. 8.2) (for all species recorded in the field i.e. serotines, Leisler’s, noctules and pipistrelles, $F_{1,64} = 5.2$, $P = 0.02$). Feeding activity did not differ between farm types for any individual species or for all species combined. Similar results were obtained using the sonogram data. Species which could not be identified during the field survey, but which were evident using the sonograms, also tended to have greater activity on organic compared with conventional farms. These differences were significant for all *Myotis spp*. combined (mean difference=15.2 (SE 13.1) passes*1000/minute, P = 0.01). This was largely due to differences in the activity of Daubenton’s bats (*Myotis daubentonii*) (for this species, mean difference=5.2 (SE 4.5) passes *1000/minute, P = 0.08).

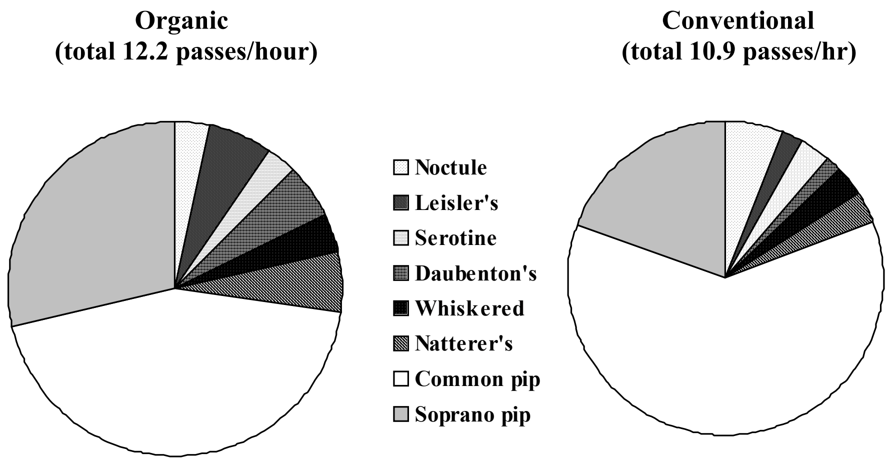


Fig. 8.1. Diversity on organic and conventional farms (proportion of passes/hr. made by each species)

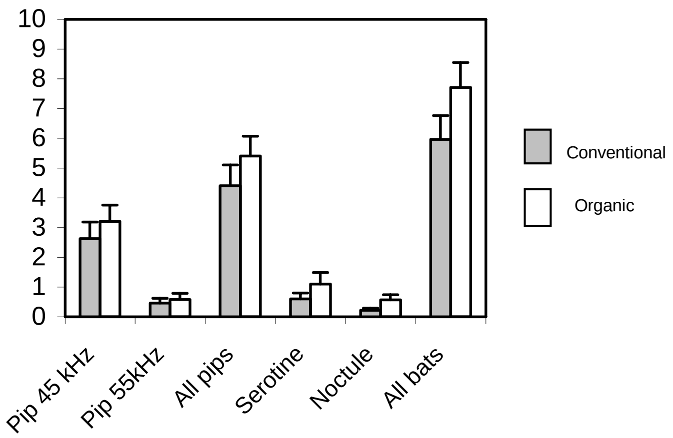


Fig. 8.2 Activity on organic and conventional farms (passes/3km transect).

Cattle were present on a greater proportion of the surveyed organic than conventional farms (59% *vs*. 41%). The presence of cattle on a farm was associated with an increased amount of total bat activity ($F_{1,40}$ = 7.77, P = 0.01) (Fig. 8.3). This effect was in addition to that of system, and there was no significant interaction between system and the presence of cattle. Activity was therefore greatest on organic farms that had cattle. The proportion of the transect for which cattle were present (mean 15% on organic, 8% on conventional) did not predict the amount of bat activity ($F_{1,63}$ = 0.0, P = 0.982). This suggests that the effect of keeping cattle operated at a farm-scale, rather than on a more local level, possibly because dung – and the insects it supports – was spread widely through the holding, and not just restricted to the areas where the cattle were held at the time of the survey.

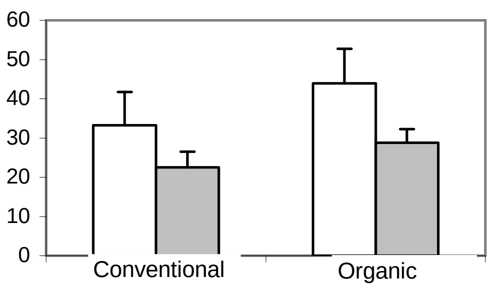


Fig. 8.3. Total bat activity (passes/3km transect) according to farming system and presence of cattle. Cattle=white bars, no cattle=grey bars.

The density of hedgerow along the transect was similar on the organic and conventional farms (20% *vs*. 18%). The total amount of bat activity increased with the amount of hedgerow, but only on organic systems (Fig. 8.4) (hedge*system interaction $F_{1,62}$ = 4.11, P=0.047). The area of woodland was not associated with the amount of total bat activity ($F_{1,59}$ = 0.02, P = 0.876), nor with the type of rotation system ($F_{4,6}$ = 2.02, P = 0.103). There was approximately 50% more open water in the 3 km round the organic farms than the conventional farms, and the presence of water explained some of the system differences in bat activity (adjusting simultaneously for water and system: Water $F_{1,63}$ = 6.6, P=0.01; System $F_{1,63}$ = 3.4, P = 0.07).

<u>Discussion (bats)</u>

There was a general trend for bat activity to be higher on organic than conventional farms. However, the differences were not marked for most species, and we found no evidence that feeding activity was greater on the organic holdings (c.f. Wickramasinghe *et al*. 2003). Organic farms tended to have more water in their surrounding habitat than did conventional farms, and this factor explained some of the difference in bat activity between them. Most of the benefits previously associated with organic farming have been restricted to water-associated species (Wickramasinghe *et al.* 2003): our data suggest that the between-system differences in the habitat mosaics that surround farms may be responsible for some of these effects. The importance of linear features to bats is often emphasised (Russ & Montgomery 2002). That increased hedgerow density was associated with greater bat activity on organic but not conventional farms implies that a difference may exist between farm types in hedgerow quality. This may arise from a structural difference (possibly a result of different management treatments; see section 3) or be related to higher numbers of flying insects around these hedges (possibly a result of adjacent crop management or more livestock). Opportunities may therefore be available to improve habitats for bats on conventional farms by alteration in hedgerow management or adjacent crop management. Similarly, the presence of cattle was associated with increased bat activity on both organic and conventional farms.

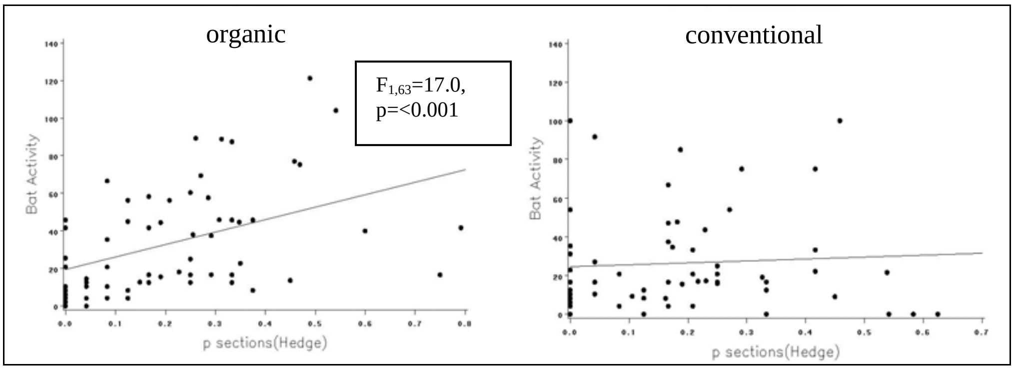


Fig. 8.4 Relationship between bat activity and proportion of transect sections including hedgerow on organic and conventional farms

9. Discussion and conclusions

The extent and range of data collected in this study provide, for the first time, a comprehensive assessment of differences in habitat and biodiversity between organic and conventional cereal farming systems. While many of these differences confirm existing research (e.g. Hole *et al.* 2005), this study brings out the interactive effects of landscape context, farming system and non-cropped habitats in ways not previously possible. This general discussion centres on the five objectives of the project, together with a brief consideration of future research priorities. Account is taken of several issues raised at the workshop (Appendix 6).

Abundance and diversity of species groups on organic and conventional farms (Objective 1)

Across all taxa, diversity (usually measured as species richness) and overall abundance tended to be higher on organic farms but in most cases the difference was quite small and it was not consistently detected in all analyses. The most striking differences were for plants where both species richness and cover of non-crop plants were consistently higher in organic fields (on average there were >80% more species within organic fields). It can be concluded that organic systems are generally associated with slightly higher levels of biodiversity with apparent benefits across a range of taxa. This is consistent with the conclusion of Hole et *al.* (2005).

There are several points to consider in relation to the wider generality of these observations. First, the organic farm sample included virtually all suitable organic farms whereas not all the conventional farmers who were approached agreed to participate. The implications of this are unclear. Second, despite the findings that organic farms tend to display structural features and other practices that encourage biodiversity, organic farmers do also use a range of methods for controlling weeds, pests and diseases which may to some extent limit biodiversity. The balance between these activities will influence the potential for increased biodiversity. Third, each of the workshop discussion groups identified the issue of extent of organic farming as a critical factor determining its potential contribution to biodiversity (Appendix 6). The total area of organic farms relative to conventional is small (currently ca. 2.5% of English farmland is organic) and they tend to be isolated and of smaller size. An increase in size and contiguity of organic farms was thought likely to encourage a greater than linear increase in biodiversity.

Relative extent and potential quality of non-crop habitats (Objective 2)

There were habitat differences between organic and conventional farms at all scales (section 3). These differences related to crop types (more grass on, and in the vicinity of, organic farms), livestock (more on organic) and boundary attributes (hedges were present at higher density, were cut less frequently, and were taller, wider and less gappy on organic). As discussed in section 3, these attributes of organic farms are expected to be broadly beneficial to wildlife.

Genuinely mixed farms have become scarce yet they offer a greater diversity of food resources and habitats for both breeding and wintering birds. Arable organic farms would therefore be expected to offer a wide range of benefits to bird populations. In terms of boundary characteristics, the observed differences in hedgerow structure would also be expected to be associated with higher densities of several breeding birds (these were not studied directly in this project).

Based on data in Green *et al.* (1994) and Macdonald & Johnson (1995) one would expect several breeding species to benefit from taller and wider hedges, though a few (notably whitethroat, linnet, and yellowhammer) prefer short hedges. Overall bird density is predicted to be higher where hedges are taller and contain fewer gaps (Macdonald & Johnson 1995) and where hedgerow density is higher (Macdonald & Johnson 1995, Fuller *et al.* 1997).

The importance of non-crop habitats versus crop management (Objective 3)
In the case of plants and invertebrates there was little evidence that non-crop habitats were driving differences between systems in diversity or abundance. For plants, spiders and carabids, the observed differences were probably caused by factors associated with crop management and were therefore inherent to the system. There was evidence that differences in bird abundance were related to differences in habitat extent. However, for several bird species, effects of system were detected after controlling for habitat. It seems likely that habitat diversity is an important factor affecting bat diversity. The bat transects in the two systems contained overall similar amounts of hedgerow, yet bat activity was greater on organic and relationships with hedgerow density were confined to organic. This suggests that both habitat extent and management system are important to bats.

Our findings suggest that there are considerable benefits associated with the management systems adopted within organic farming. Some, but by no means all, of the benefits of organic farming to biodiversity probably derive from differences in quantity of non-crop habitat. Landscape attributes, non-cropped habitat and crop management all affect biodiversity, but in ways that interact and vary between taxa. Despite the overall differences between the two systems, there remained considerable variation in biodiversity within systems, with some conventional farms performing better than some organic. Further analysis is desirable to identify characteristics of farms that are rich in biodiversity regardless of system.

Effects of organic duration (Objective 4)
It was surprising that so few relationships were detected on organic farms with the time since conversion. In particular, one might have expected effects for plants (Dessaint *et al.* 1997). Whilst this may imply that there was a tendency for the major shift to increased biodiversity to occur almost immediately after conversion it could also reflect our lack of knowledge about pre-conversion management. It is possible that many organic farms prior to conversion were managed with low inputs or in other ways sympathetic to biodiversity (for example the seed bank may have been retained as a consequence of relatively low herbicide inputs). On the other hand, these results may suggest that many fields treated previously with synthetic inputs are able rapidly to regain higher levels of biodiversity. We suggest this is an important area of future research. A major influence towards increased biodiversity after conversion may be the removal of synthetic inputs, herbicides being an obvious example in relation to botanical diversity, which in turn affects the habitats and foods of many other organisms. A major challenge, however, is the restoration of arable weed communities perceived as being of high conservation value, rather than simply an increase in species richness.

Biodiversity aspects of organic systems: Implications for conventional systems (Objective 5)
The main points of relevance to enhancing biodiversity within conventional farms are outlined here in relation to non-crop habitat and factors more intimately bound up with the farming system. In the case of the former we focus on hedges because they are clearly of great importance to farmland biodiversity and there were several striking differences between their characteristic on organic and conventional farms.

There was a greater length of hedge per unit field area on organic farms and those hedges tended to be fuller and taller compared with conventional farms. This difference arises partly because organic fields are smaller than conventional. While it might not be practical to reduce field sizes to create more hedges, options and incentives are available to both organic and conventional farmers to improve quality of hedges, with likely benefits to a range of taxa. It is recognised that in addition to existing management incentives, hedgerow features will be further targeted in new policy measures (including both Cross Compliance and Environmental Stewardship in England) affecting both organic and conventional systems.

Mixed farming systems are important for biodiversity, in the contexts of both conventional and organic farming. There is a greater proportion of stockless arable farms in conventional compared with organic production. There are many ways in which the presence of stock can increase the potential habitats within a farm. Opportunities for direct promotion of mixed farming on organic and conventional systems are limited at present, but it is also recognised that the organic system itself is predisposed towards inclusion of livestock with its associated biodiversity benefits. There is evidence that system benefits may arise from organic farming that may have at least as much to do with inputs as with rotations (the results for plants and invertebrates are relevant here). This raises the possibility that long-term management of field margins in ways that mimic organic treatments could bring considerable benefits; this is different to the widely adopted unsprayed headlands approach because it would involve a commitment to exclusion of synthetic fertilisers and pesticides on the same patches over several consecutive years.

Separating farm structure from farming system was important in terms of recognising the value of different habitat features. However, it needs to be stressed that, in practice, they should not be regarded separately for recommendations. Appropriate farming systems practised on an appropriately structured farm will probably have a more than linear impact compared with improvements in only one of those aspects. For example, for a number of birds and mammals, it is likely that hedges may be regarded foremost as shelter, whereas the surrounding field is the potential source of food; both are essential.

We acknowledge that some uncertainty remains about exactly which elements of organic farming can be transferred into conventional systems with an expectation of biodiversity enhancement. For example, and as noted above, there may be important interactions between quality of non-crop habitat and management of adjacent crops. Furthermore, it is difficult to disentangle the interactions among farming system, management history and landscape context. This could mean, for example, that use of an organic approach in the intensive arable landscapes of eastern England may not generate such high benefits for biodiversity as in other parts of the country. We suggest that the results of this project are incorporated into a wider debate about how best to increase environmental benefits from farming systems. We also suggest the main policy messages are as follows:

- confirmation of the benefits of organic farming for a range of taxa, in line with previous studies;
- evidence of interactions among landscape, non-crop habitats and farming systems in their effects on species;
- implication that increasing hedge length and quality is desirable - these can be enhanced in all farming systems;
- implication that mixed farming is desirable for biodiversity;
- diversity can be encouraged to develop quite rapidly through appropriate management, including organic;

Suggestions for future research on biodiversity and organic farming

A wide range of ideas was raised at the workshop (Appendix 6). It is suggested that the following have the highest priority.

(1) This project focused on arable organic farms. There is a need to examine potential biodiversity benefits of organic farming in a grassland context, including upland and dairy farming.

(2) Long-term experiments are needed to assess rapidity of response to conversion on farms that were previously managed as intensive arable enterprises.

(3) Effects of increasing the size of blocks of land under organic management are poorly understood. Increasing contiguity of organic holdings may result in major gains for farmland biodiversity. Information is needed on relationships between biodiversity and extent of organic management at larger scales.

(4) A better understanding is needed of what makes a farm good for biodiversity – in terms of farming system, landscape context, farmer attitude and business context – and of the constraints to making all farms good for biodiversity.

10 . References

AUDE, E. *et al.* 2004. *Biol.Conserv.*, **118**,467-478.
BROOKS, D.R. *et al.* 2003. *Phil.Trans.R.Soc.Lond*., **B358**, 1847-1862.
CHAMBERLAIN, D.E. & WILSON, J.D. 2000. In *Ecology and Conservation of Lowland Farmland Birds* (eds. N.J. Aebischer *et al.)* pp 57-68. BOU, Tring.
CHAMBERLAIN, D.E. *et al.* 1999. *Biol . Conserv.*, **88**,307-320.
DESSAINT, F. *et al.* 1997. *J. Appl. Ecol*., **34**, 123-130.
FIRBANK, L.G. *et al.* 2003. *J.Env.Manage.* , **67**, 207-218.
FULLER, R.J. 1997 *Proc. Brighton Crop Prot.Conf.– Weeds* pp. 897-906. BCPC. Farnham.
FULLER, R.J, *et al.* 1997. *Ecography*, **20**, 295-307.
GREEN, R.E. *et al.* 1994. *J.Appl.Ecol.*, **31**, 677-692.
HAINES-YOUNG,R.H. *et al.* 2000. *Accounting for nature: assessing habitats in the countryside.* DETR, London
HOLE, D. G. *et al.* 2005. *Biol. Conserv.*, **122**, 113-130.
HUTSON, A.M. 2001. *Global Status Survey and Conservation Action Plan: Microchiropteran Bats.* IUCN, Gland, Switzerland and Cambridge UK.
JACKSON, D.L. 2000. *JNCC Report No. 307.* Peterborough, JNCC.
MACDONALD, D.W., & JOHNSON, P.J. 1995. *J. Appl. Ecol.*, **32**, 492-505.
MARSHALL, E.J.P. 1989. *J.Appl.Ecol*., **26**,247-257.
PERRY, J.N. *et al.* 2003. *J. Appl. Ecol*., **40**, 17-31.
RUSS, J.M. & MONTGOMERY, W.I. 2002. *Biol Conserv.*, **108**,49-58.
SMART, S.M. *et al.* 2003. *J.Env.Manage*., **67**, 239-254.
TILMAN, D. *et al.* 2001. *Science,* **292**, 281-284.
WICKRAMSINGHE, L.P. *et al.* 2003. *J. Appl.Ecol*., **40**, 984-993.
WILSON, J.D. *et al.* 1999. *Agric.Ecosyst. & Environ.*,**75**, 13-30.