British Trust for Ornithology

BTO Research Report No. 154

The Effect of Organic Farming Regimes on Breeding and Winter Bird Populations

Parts I - IV

November 1995

by

British Trust for Ornithology

&

Institute of Arable Crops Research - Rothamsted

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Ministry of Agriculture, Fisheries and Food
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THE EFFECT OF ORGANIC FARMING REGIMES ON BREEDING AND WINTER BIRD POPULATIONS

PART I

SUMMARY REPORT AND CONCLUSIONS

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(*now Oxford University)

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D. Brookes, J. Bater, H. Jones & P.A. Shah (IACR-Rothamsted)

1. INTRODUCTION

1.1 Aims

The broad aims of the project were: (i) to assess whether bird populations on organic farms differed from those on nearby conventional farms, (ii) to examine likely causes of any differences in bird populations, taking account of any differences between organic and conventional farms in non-crop habitat, cropping patterns and farming practices, (iii) to undertake an intensive examination of habitat uses and breeding success of selected bird species on organic and conventional farmland, and (iv) to compare the food resources available to birds on organic and conventional farmland.

1.2 Structure

The project consisted of three parts: (i) a comparison of breeding and winter bird populations on pairs of organic and conventional farmland plots, (ii) an intensive study of skylarks to compare territory distribution, timing of breeding, breeding success and nestling growth rates, (iii) a comparison of invertebrate abundance, seed availability and flora in organic and conventional fields. Parts (i) and (ii) were conducted by the British Trust for Ornithology and part (iii) by the Institute of Arable Crops Research, Rothamsted.

1.3 Rationale of the project

Organic farming systems are commonly thought of as ones where chemical pesticides and synthetic fertilisers are not used, but this definition is too narrow. Different methods of crop and livestock production are used which lead to patterns of land-use and farm structure that can be strikingly different to those on conventional farmland in the same region. It was the aim of this project to assess what, if any, potential benefits might accrue to bird populations from organic farming in its broadest sense. The project was not designed to assess the effect of the use or non-use of agrochemicals in particular field types. The definition of organic farms used in the project was that they should at least conform with the requirements of United Kingdom Register of Organic Food Standards (UKROFS). Organic farms still under conversion were excluded from the analyses, though data were collected from several such sites. The rationale for selection of study areas was that samples should not represent extreme examples of intensive conventional agriculture, nor of organic farmland that was extremely rich in non-crop habitats. The aim was to make comparisons between farms that were within the normal range of variation for organic and conventional systems for the region concerned. It is essential that the results are considered in the context of the types of farms examined. The implications of study site selection are discussed further below (section 5.1).

2. COMPARISON OF BIRD POPULATIONS (BTO) (PART II)

2.1 Study design

The comparison of breeding and winter bird populations was made on a sample of 44 organic and conventional farms. Organic and conventional farms chosen for this part of the study were paired by geographical location and also, as far as possible, in terms of farm area (a minimum farm area of 30 ha was used) and coarse-grained physical features such as amount of non-crop habitat and field size. Nonetheless, some differences remained in these attributes (see 2.3) which to some extent reflect general differences in the physical structure of organic and conventional farmland. Exact pairing by field type was not possible for the scale of study that was necessary to assess whether differences exist in bird populations. In any case, this was not desirable because differences in crop rotation are inherent in the two broad approaches to farming. Surveys were conducted by volunteers using standardised field procedures which permitted direct comparisons of numbers of birds using individual field boundaries and fields on organic and conventional farms. Breeding birds were studied in three years (1992-94), and winter birds were studied in two winters (1992/93 and 1993/94). For purposes of analysis each winter was divided into early (Sept. - Nov.) and late (Dec. - Feb.) periods.

2.2 Bird densities

Bird abundance was expressed as densities for individual species and for all species combined in each field boundary and each field. Densities of individual species were highly skewed in their distribution due to a high proportion of zero counts for all species. Therefore, analysis was performed using a distribution-free randomisation procedure involving resampling the count data within farm pairs. In the majority of species studied, density was consistently higher on organic than on conventional farms. In all habitat/season samples a larger proportion of species attained higher densities on organic than conventional farms. This predominance of higher species densities on organic farms was statistically significant ($P \leq 0.05$) in 3 out of 4 data sets for boundaries in winter, 2 out of 3 data sets for boundaries in summer and 2 out of 4 data sets for fields in winter. For individual species many of the differences in density were not statistically significant, probably because sample size was effectively limited by the large number of zero counts. However, the following account refers only to significant ($P < 0.05$) differences between organic and conventional farms. For field boundaries in the breeding season, 10 out of 18 species were more abundant on organic farms in at least one breeding season. For boundaries in winter, 11 out of 18 species were more abundant on organic farms in at least one winter period. No species was more abundant in boundaries on conventional than organic farms. Differences between densities of birds in organic and conventional boundaries were more marked in winter than in the breeding season. The only field-nesting species for which breeding season field counts were both sufficiently large and accurate to analyse was skylark. Breeding densities of skylarks were higher on organic than conventional fields in 1992 and 1993 but did not differ in 1994. In winter, seven species (woodpigeon, skylark, blackbird, chaffinch, greenfinch, linnet, yellowhammer) were more abundant on organic than conventional fields in at least one winter period, but two (lapwing and fieldfare) were more abundant on conventional fields in at least one winter period. The most striking winter result was that linnet was more abundant on organic farms in the early winter period of both winters examined. The density of all species combined was higher on organic farms for boundaries in 2 of 3 breeding seasons and 3 of 4 winter periods and in fields in 1 of 4 winter periods. In no case was overall density significantly higher on conventional farms.

2.3 Effects of farm structure and farming system

Could the above differences in density have arisen because the samples of organic and conventional farms differed in physical structure? There was no difference between farm types in the proportions of boundary that had hedgerows, woodland or ditches. However, hedges on organic farms tended to be taller, hold more trees and were less frequently trimmed. Fields were slightly larger on conventional farms, more frequently contained winter cereals but less frequently held spring cereals. These characteristics could have contributed to some of the observed differences in bird densities. Further randomisations were, therefore, carried out on various sub-samples of boundaries and fields selected to control for variation in habitat type. These analyses were inevitably based on much reduced sample sizes and consequently fewer significant differences were obtained. For tall hedges, the majority of species were more abundant on organic farms and five species (great tit, dunnock, robin, blackbird, redwing) showed significant differences, with organic farms holding higher densities in each case. Total bird density in tall hedges was consistently higher on organic farms. These results suggest that for some species the higher densities in organic boundaries are a consequence of differences in habitat structure but that this is not the full explanation. Densities of birds on winter stubble fields were compared. Most species were more abundant on organic stubbles but only for fieldfare, which was more abundant on conventional stubbles, was the difference in density significant. Breeding densities of skylarks were higher on organic farms both in winter cereals and in grass fields but the difference was significant only in the cereals.

2.4 Conclusions

It is concluded that the organic farms in the present sample generally held higher densities of birds than the conventional farms, especially in winter, though breeding densities of skylarks were strikingly higher on organic farms. It is likely that this was partially attributable to structural differences (i.e. differences in hedgerow management and crop types) between the two farm types. However, there was evidence that boundaries on organic farms carry higher densities of certain species and of all species combined when differences in physical structure were controlled for. Furthermore, when variation in crop type was controlled, breeding densities of skylarks remained higher on organic fields. It is unlikely that all the differences in bird populations between organic and conventional farms can be accounted for by variations in non-crop habitat structure or in cropping patterns.

3. INTENSIVE STUDY OF SKYLARKS (BTO) (PART III)

3.1 Study design

The intensive study of breeding skylarks was conducted on one pair of organic and conventional farms in Suffolk in 1993 and 1994. The skylark was chosen as an intensive study species because initial observations suggested that densities tended to be much higher on many organic farms than on conventional farmland (this was borne out by the results of the extensive study; see above) and because the species has declined by more than 50% over the last 20 years on lowland farmland. A clearer understanding of the mechanisms underpinning the selection of organic farms by skylarks was, therefore, highly desirable.

3.2 Territory distribution

Territory density was higher on the organic than the conventional farm in both years. This could be explained largely by differences between the two farms in field size, boundary characteristics and cropping practices. The organic farm formed a patchwork of smaller, more open fields whose crop rotations offered the skylarks a high diversity of vegetation in a relatively small area. This pattern of habitat selection is consistent with a model developed in Switzerland which predicts that skylark densities are highest in those areas of farmland with mosaics of vegetation that provide the birds with continuity of structural conditions throughout the breeding season. Rotational and five-year set-aside, grass leys and organic spring cereals held especially high densities of breeding skylarks. Densities on conventional cereals were less than half those on organic cereals and set-aside. In 1993, most occupied territories in conventional winter cereals were abandoned in late April/early May which was probably a response to the rapid growth of the crops which became unsuitable nesting habitat. In 1994, however, there was no such abandonment of conventional cereals, possibly because the crops grew more slowly in the colder and wetter weather in that spring.

3.3 Breeding biology

Nesting activity started simultaneously on both farms in both years but the breeding season was more prolonged on the organic farm. Breeding success, in terms of chicks fledged per nest, was higher on the organic farm in both years. Success of skylarks was highest in organic cereal crops and in set-aside (both on the organic and the conventional farms). In 1993 there were few nesting attempts, and no successful nests, in conventional cereals in striking contrast to organic cereals and set-aside. In 1994, however, nesting attempts were more frequent in conventional cereals than in 1993 and success in conventional cereals was similar to that in organic cereals and organic set-aside. These differences between years may have been a consequence of poor weather in 1994 causing crops to grow more slowly and patchier. Low food availability may have contributed to breeding failures of skylarks in conventional cereals. Evidence for this came from several sources. Growth of nestlings was more erratic, starvation of whole broods more frequent and occurrence of runts more frequent in nests on the conventional farm. Broods at certain stages of development were significantly heavier on the organic farms and the results were indicative that chick body condition was better on the organic farm.

3.4 Skylark diet

Faecal sacs (n=219) were collected from skylark nestlings of mean age 6 days from 28 different nests and these were analysed for invertebrate remains by IACR staff. Coleoptera, especially carabids, formed by far the main component of the diet, but tipulids and spiders were also important parts of the diet. No attempt was made to analyse the diet separately for the organic and conventional farms because the sample size for the conventional farm was too small.

3.5 Conclusions

The intensity of fieldwork required for the work on skylarks made it possible only to study one pair of farms so the generality of the conclusions is unknown. Nonetheless, this work has provided evidence that organic farming systems can provide conditions leading to higher breeding densities and higher breeding success of skylarks than that pertaining on much conventional farmland, especially in winter cereal crops. Organic systems offering a diversity of crops, including rotational grassland and spring cereals, are likely to be high quality breeding habitats for skylarks. The underlying mechanisms are that such systems may provide preferred vegetation structures, and possibly richer food resources, than are available on most conventional farmland.

4. FOOD RESOURCES: INVERTEBRATES AND PLANTS (IACR) (PART IV)

4.1 Study design

Sampling of potential food resources was conducted over three years mainly on cereal fields with more limited sampling of organic grass leys. Study sites were selected from among those where work was conducted on birds, and they included the two intensive skylark study farms. Invertebrates were sampled using a vacuum suction sampler and by soil cores in 1992. Small numbers of invertebrates were trapped by these methods and following the analysis of skylark diet it was decided to concentrate on pitfall trapping in 1994. This approach permitted Carabidae - the major component of the diet of skylark chicks (see 3.4) - to be trapped in sufficient numbers for analysis. In 1992 vacuum samples and soil cores were taken in cereal fields at seven farms in East Anglia (three organic, three conventional and one part organic and part conventional). Three samples were taken at each farm between April and September. Two further sites offered comparisons of organic and conventional cereals and grass leys. Pitfall trapping was carried out between May and July 1994 at seven pairs of organic and conventional farms with two fields sampled at most farms. Weed seeds were sampled post-harvest using a Vortis vacuum sampler and visual estimates of vegetation cover (both crops and weeds) were also made. The work on vegetation was confined to cereals and was carried out in the summer of 1992 and 1993 on the same farms as those from which the vacuum and soil core samples of invertebrates were taken in 1992.

4.2 Invertebrates

Detailed analysis was restricted to invertebrates >5 mm for these are the most likely to constitute food resources for birds. Total numbers of invertebrates trapped by vacuum sampling and soil coring did not differ between organic and conventional cereal fields but higher numbers were trapped on organic grass leys than cereal fields. There were, however, differences in the relative abundance of different invertebrates between farm types: larger numbers of Staphylinidae were vacuum sampled on conventional fields but more *Sitona lineatus* (a weevil) and *Demetrias atricapillus* (a carabid) were vacuum sampled on organic fields. Soil cores produced more immature Diptera and Coleoptera on the organic grass leys and more earthworms in organic cereal fields. Overall relative abundance of carabid beetles, based on pitfall traps, was greater on organic than conventional fields but diversity was higher on conventional cereal fields. Abundances of 12 common carabid species were examined; five species (including the commonest, *Pterostichus melanarius*) were captured more frequently in organic fields and the other seven species showed no significant differences between farming types.

4.3 Plants

Plant abundance and diversity was lower on conventional than organic cereal fields. Crop cover was higher in conventional fields, and cover of non-crop plants and bare ground were higher in organic fields. Non-crop plants in conventional fields were dominated by grasses; dicotyledonous plants were more abundant on organic fields. There was no significant difference in seed abundance between the two systems but grass seeds predominated in the conventional fields and dicotyledonous seeds in the organic. These patterns were evident in both years. Taking a threshold seed size of 0.35 mg as being suitable for skylarks, more plants capable of producing seeds exceeding this threshold were present in organic fields.

4.4 Conclusions

This work indicates that the types of food resources available to birds are likely to differ between organic and conventional fields. There can be differences in the abundance of certain invertebrates on organic and conventional cereal fields, with strong evidence that numbers of several carabid species are higher on the former. The diversity of non-crop plants and seeds and the abundance of dicotyledonous plants and seeds was higher on organic farms. Implications of these findings for bird populations are discussed further below (5.2).

5. CONCLUDING DISCUSSION

5.1 The study design

This study has provided a better understanding of how and why bird populations on organic and conventional farms might differ. The study is unique in Britain and, as far as birds are concerned, represents the most thorough approach to date. However, it is important to acknowledge several aspects of the study design which have implications for the interpretation and generality of the results. Specifically, these concern: (i) the selection of study areas, (ii) the lack of any experimental work, (iii) statistical and sampling problems.

Many organic farms are mixed rotations with legume-based pastures, and manure inputs from livestock, providing nitrogen for subsequent crops. Organic farms that are exclusively livestock holdings occur more frequently than ones that have no livestock component. In arable-dominated areas such as much of eastern England, organic farms are typically strikingly different in their crop composition to most other farmland in the region. In the present study most of the organic farms were mixtures of grass and crops and it did not prove possible to pair these with nearby conventional farms with similar mixtures of fields. In many cases, therefore, the comparison was essentially one of mixed farming (organic) with arable farming (conventional). Furthermore, even though plots were successfully paired in such a way as to avoid gross differences in non-crop habitats, there remained several differences in boundary structures between the samples of organic and conventional farms which reflected different management practices. Indeed, it is a requirement of UKROFS that organic farms are managed in ways that are sympathetic to wildlife and wildlife habitat. Differences in field type and in boundary structure are integral to organic and conventional approaches. It is appropriate, therefore, that they should have been included within this study which sought to describe differences in bird populations associated with the two approaches.

It is highly questionable whether an approach using comparison of paired farms can determine the effects of such specific factors as the use or non-use of chemicals and weed control techniques. It is doubtful whether a sufficient number of replicate plots could ever be identified that were precisely matched for crop type and boundary management to factor out these effects. We believe that adequate control could be achieved only by using experimental approaches. Unfortunately the scale required to undertake such work to obtain sufficient samples of birds for statistical treatment would probably be prohibitively large. However, an experimental approach would be feasible if targeted on selected food resources of birds (see 5.4).

There is great variation in the cropping systems and non-crop habitat structure of both organic and conventional farmland. Therefore, it is inevitable that the findings of any project which adopts a comparative approach will be influenced by the types of study areas selected. In particular, the conventional farms may not have been representative of the surrounding area; there was a tendency to select farms which were not of the most intensive types. This means that the differences in bird populations between organic and conventional farms recorded in this study are likely to be conservative.

Analysis of the bird population data at the scale of individual boundaries and fields rather than at a whole-farm scale was a strength of the study design. Nonetheless, the patchy distribution of most bird species within both the organic and conventional study areas caused considerable analytical problems. The strongly non-normal distribution of the data necessitated use of randomisation, which is an extremely robust way of analysing such data. Nonetheless, there were many cases when apparent differences in density were not identified as statistically significant, probably because the proportion of zeros was so large. This emphasises the difficulty of obtaining adequate sample sizes of birds on farmland to determine whether density differences do exist between treatments.

5.2 How, and why, do bird populations differ on organic and conventional farms?

Previous studies have suggested that organic farming systems can be beneficial to birds (reviewed in PART II of this report) but there has been no previous investigation of how birds respond to organic farming in Britain. There is considerable evidence from this study that bird populations differ on British organic and conventional farms. The main findings were as follows. Breeding densities, and breeding success, of skylarks were especially high on organic cereals whereas conventional cereals were a relatively poor habitat. Many species achieved higher breeding, but especially winter, densities in field boundaries on organic farms and several wintering species were more abundant in organic than conventional fields. The overall density of birds in field boundaries was higher on organic farms.

Some, but not all, of these differences are probably linked to differences in farm structure. For example, when variation in hedgerow structure was controlled in the analyses fewer differences in species densities were apparent between organic and conventional farms than was the case for the full sample of boundaries. It is also likely that the mixed farming regimes operated by most organic farms are broadly beneficial to birds. Such systems will offer a wider range of nesting habitats (for example skylarks nested at high densities in grass leys). The invertebrate sampling also indicated that food resources for ground-feeding species such as starling and thrushes may be higher on leys than cereals.

There were several pieces of evidence that the organic farms benefited bird populations independently of farm structure. First, density of a number of species remained higher on organic farms independently of any effect of boundary structure; furthermore total density in tall hedges was consistently higher on organic farms. Second, skylarks bred at higher density and more successfully in organic than conventional cereals. This may have been related to differences in crop structure and to better insect food resources. Third, many of the species that occurred at higher density in winter on organic farms were field-feeding species, such as tree sparrow, greenfinch, linnet, reed bunting, or field-margin species such as bullfinch and goldfinch. These species will be attracted to areas of high seed resources which are determined more by cultivation and crop production practices than by the physical attributes of the farm. The relatively high densities of wintering seed-eating species on organic farms are consistent with the findings that the diversity of non-crop plants and their seeds, the cover of non-crop plants, and the abundance of dicotyledonous plants and their seeds were greater on organic farms.

We conclude that organic farms often support higher densities of various bird species than conventional farmland, especially in winter, and that the reasons for this are threefold. First, the boundary features of many organic farms exhibit features that are beneficial to birds as a result of sympathetic management, such as reduced frequency of trimming. Second, the mixed enterprises upon which most organic farms are based offer birds diverse nest sites and food resources. Third, organic crop production techniques, including restricted use of agrochemicals and the application of organic manures, can generate richer food resources for several species.

5.3 Policy implications

Some of the species that reach higher densities on organic than conventional farms have declined in lowland English landscapes by more than 50% in recent years, notably skylark and linnet. The current scale of organic farming is unlikely to have a marked effect on the populations of these species at a national level. It is possible, however, that even a modest increase in organic farming could be of local or regional significance for bird populations. This study has shown that differences in bird populations between organic and conventional farmland are especially pronounced in winter. For some farmland bird species, such as linnet, organic farms may be especially important winter feeding areas, effectively acting as 'hotspots' for birds that breed elsewhere. Organic farms could, therefore, contribute to the survival of birds that are distributed over a much wider area of farmland in the breeding season.

Organic farms exhibit some of the features that have become rare on conventional farmland over the last 20 to 30 years. These include (a) rotations incorporating grass leys and legumes, (b) reliance on animal and green manures produced within the farm, rather than on synthetic fertilisers and (c) very little use of chemical pesticides. To some extent, organic farming reverses the trends in agricultural intensification that have occurred in recent decades. The results of this project, therefore, broadly support the hypothesis that the large declines in farmland birds have been caused by agricultural intensification which has affected birds, at least partly, through reduction in food availability. The results obtained from the project are all the more interesting because most organic farms exist as small patches in an otherwise conventionally managed landscape.

Expansion of organic farming would almost certainly benefit bird populations at a local scale. It must be stressed, however, that organic farming embraces a variety of techniques and that these are not necessarily all beneficial to bird populations. Incorporation of some of the attributes of organic farming into otherwise conventional farming systems could also enhance bird populations. The value of organic farms to birds probably lies in the combination of diverse crops (especially the presence of grass leys), reduced pesticide inputs and unintensive management of non-crop habitats (see 5.2). Some bird species may benefit from each of these factors while others may benefit from just one or two. Integration of these attributes into conventional farming systems is likely, in the broadest sense, to benefit birds and other wildlife.

Organic farming, variable though it is, forms one end of a spectrum of farming systems in Britain. In assessing the opportunities available for enhancing wildlife populations on farmland, we believe that organic farms should be considered in the context of this wider variation in farmland which includes various set-aside, ESA-related, low-input and extensification approaches. For example, rotational set-aside may, for the time being, offer excellent prospects for enhancing the breeding success of skylarks and the winter survival of seed-eating birds, simply because it is currently available on a massive scale. Such initiatives, however, may be ephemeral and should not be regarded as a substitute for encouraging longer-term commitment to organic farming.

5.4 Future work

Organic farms offer opportunities to gain further detailed insights into the factors underlying the large declines in several farmland bird species in recent decades. Study of these factors might suggest new ways of ameliorating deleterious effects of modern conventional farming. We suggest that future studies of declining farmland birds should consider using comparative autecological studies on organic and conventional farmland. Detailed recommendations for further work on skylarks are given in PART III of this report.

The present study has indicated that several potential food resources are more abundant on organic farms. One should be cautious, however, in drawing conclusions about the implications of these findings for birds without knowing more about (a) preferences shown by birds for particular species of invertebrates and (b) the availability of these food resources. Clearly, more work is needed on the links between possible food resources and the use that birds make of organic farmland; detailed recommendations for further work on avian food resources are given in PART IV of this report. In particular, the diets of a wider range of bird species need to be assessed on different types of farmland and this work should be coupled with further examination of the distribution of preferred foods across a large sample of farms. There is much variation within both organic and conventional fields in invertebrate abundance: this was evident from the relatively small numbers of farms that were examined in the present study. We suggest that an efficient approach would be to identify patches that are strongly utilised by birds; to quantify food resources available within these preferred areas; and to compare these food resources with those available within randomly selected, but similar, patches. This would achieve better integration of the work on birds and food resources as well as tackling the problem of patchiness in both the distribution of birds and their food. We suggest that an experimental approach should be adopted alongside this observational approach whereby changes in the abundance of selected invertebrates and plants were examined in relation to variation in chemical inputs and other management practices. This would control for duration of chemical-free treatments and for crop type. Duration of organic status is potentially an important factor influencing communities of plants and animals which requires further study. Experimental manipulation of crop structure should also be considered, particularly in relation to its probable effects on nest site selection and food availability for birds such as skylark.

Finally, we repeat that there is much variation in farming practices within organic systems. This probably contributes to the considerable variation in bird populations and their food resources that exists among organic farms. It would be valuable to explore these relationships further with the aim of isolating more clearly those components of organic systems and practices that are of particular benefit to bird populations.

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THE EFFECT OF ORGANIC FARMING REGIMES ON BREEDING AND WINTER BIRD POPULATIONS

PART II

A Comparison of Breeding and Winter Bird Populations on Organic and Conventional Farmland

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SUMMARY

1. The bird communities on a total of 44 organic and conventional farms were surveyed over three breeding seasons and two winters in order to ascertain whether organic and conventional farms differed in the size of their associated bird populations. Previous studies have suggested that organic farming may have beneficial effects on bird populations.

2. Organic and conventional farms were paired on the basis of geographical location, and as far as possible on physical features. Each farm was visited four times per breeding season and three to six times per winter. All birds present were counted at each field boundary and in each field. In addition, data were collected on boundary and field characteristics. Due to the highly non-normal distribution of the data, differences between organic and conventional farms were analysed using randomisation, a procedure which involved resampling the count data within farm pairs.

3. Bird density was higher on organic farms in the majority of species studied. In all habitat/season samples a larger proportion of species attained higher densities on organic than conventional farms. This predominance of higher species densities on organic farms was statistically significant ($P \leq 0.05$) in seven out of 11 habitat/season samples. The density differences for individual species were significant ($P < 0.05$) in a number of species, although only a small number showed consistent significant differences between years. Out of a total of 48 significant results, 46 showed that the density on organic farms was greater than the density on conventional farms. There were more species showing significant differences in the winter than the breeding season and in field boundaries than in open fields. The combined density of all species recorded was significantly higher on organic farms in the majority of cases. Species diversity did not differ between farm types.

4. The structure of the habitat (where structure is defined as the type of crop, and non-crop factors such as hedgerows) differed between farm types: organic farms had significantly higher, wider hedges with less frequent trimming, more trees, smaller fields and less winter cereal than conventional farms.

5. In order to determine the effect differences in farm structure (rather than chemical inputs) had on bird density, further randomisations were carried out on selected species, but considering only very specific habitat types to control for variations in habitat features between farm types. This tended to decrease the magnitude and significance of the differences between farm types, thus indicating that the physical structure of the farm is an important factor in determining bird density. However, the combined density of all species recorded still tended to show large differences between farm types.

6. It is concluded that the sample of organic farms in the present study tended to have a greater density of birds than the conventional farms, particularly in the winter. This may have been due to differences in the physical structure of the farms for some individual species, but when considering all species combined, there was evidence to suggest that non-physical management (i.e. chemical input) did affect the bird community.

1. INTRODUCTION

Since the advent of long-term population monitoring in the 1960s, many species of British farmland birds have shown dramatic declines in both range and population size (O'Connor & Shrubb, 1986; Tucker & Heath, 1994). Fuller *et al.* (in press) report that of 28 species identified as primarily associated with farmland, 24 have shown a contraction in range, and 15 out of 18 species which could be accurately censused showed a decrease in population size. These declines are far greater than those observed in any other habitat. Similar declines have also been detected elsewhere in Europe (Møller, 1983; Hustings *et al.*, 1990; Tucker & Heath, 1994).

The period of decline of many of these species occurred at a time when substantial changes in the management of farmland were taking place. Increased mechanisation and use of chemical fertilizers has resulted in the overall decrease of diversity in farm land use due to changes in the cropping regime, particularly the increase in cereal farming, the switch from spring to autumn-sown cereals, intensification of grassland management, particularly in terms of chemical fertilizer input, and a simplification in crop rotations (Fuller *et al.*, in press). Removal of non-crop habitats, such as farm woods, hedgerows and farm ponds has also contributed to the decline in habitat diversity (Moore, 1986). Additionally, the diversity and amount of pesticides used on farmland increased markedly from the late 1960s (O'Connor & Shrubb, 1986).

These changes in farm management may have affected the bird community in a number of ways. The general loss of habitat diversity will tend to reduce available niche space and therefore reduce the diversity of the bird community. Hedgerow removal is particularly serious for birds, as the majority of farmland bird species will use hedges for nesting (O'Connor, 1984), but even for ground-nesting species, hedges may provide an important food source e.g. the grey partridge (Potts, 1986). The switch from spring to autumn-sown cereals has led to a much shorter period when stubble is present, which is likely to have consequences for winter food availability for many farmland species. Stubble has been identified as holding important food sources for corn buntings, due both to the presence of weeds and spilt grain. The loss of winter stubbles is strongly implicated as a reason for this species' serious decline (Donald & Evans, 1994). Direct toxic effects of pesticides probably no longer have a major effect on bird populations (Potts, 1986), but pesticide use may have effects on birds' food supplies. This may either be due to a direct depletion of food supplies for both invertebrate-feeding (e.g. Rands, 1986) and seed-eating birds (e.g. Donald & Evans, 1994), or herbicides may have an indirect effect on insect populations by removing essential plants (Southwood & Cross, 1969). Increased pesticide use has been strongly implicated as a major factor in the decline of the grey partridge (Potts, 1986).

In recent years, a greater interest in 'green' issues and a growing awareness of possible environmental damage caused by intensive farming has seen a growth in the number of farms run organically (Lampkin, 1990). Organic management typically involves no synthetic pesticide input, and use of crop rotations and organic manures to enrich the soil, rather than using chemical fertilizers. Organic farming embraces a holistic approach to the management of farmland which includes enhancement through perceived sympathetic management of non-crop habitats such as hedgerows and ponds. Implicit in the philosophy of organic farming is the reversal of many of the trends towards intensification outlined above which may have led to the declines in populations of farmland birds. Therefore, organic farms may be expected to benefit farmland birds in a number of ways.

A number of studies have considered the effect of specific management practices on birds (Lack, 1992), particularly in relation to pesticide use (e.g. Somerville & Walker, 1990; Greig-Smith *et al.*, 1992). Studies on the effects of the more holistic management of organic farms on wildlife are, however, rare. In insects there is some evidence that organic farms support a greater number of species (Dritschillo & Wanner, 1980) and a higher number of individuals of certain species (Moreby *et al.*, 1994) than conventional farms. Also the number of weed species and weed cover have been shown to be higher on organic farms (Moreby *et al.*, 1994).

The only European study to date carried out on the effects of organic farming on birds was that of Braae *et al.* (1988) in Denmark. This study found that 16 species were recorded in larger numbers on organic farms. A more detailed parallel study of yellowhammers found that their density was significantly higher on organic farms in both the breeding season and winter (Petersen & Nøhr, 1992). Also, the numbers of fledglings associating with adults were significantly higher on organic farms, indicating either that reproductive success was higher on organic farms, or that conditions on organic farms were especially favourable for recently fledged birds. The authors concluded that the differences observed between farm types were due to pesticide input reducing food resources in conventional farms, an analysis of arthropod samples showing that food items important to birds were more abundant on organic farms (Hald & Reddersen, 1990). Two fairly small-scale studies in America also found that organic farms held higher numbers of birds than conventional farms (Ducey *et al.*, 1980; Gremaud & Dahlgren, 1982).

The conclusions reached from the above studies are questionable (Sears, 1990). In the Danish study, inappropriate statistical analyses were used which may have produced spurious results. In one American study, no statistical analyses were presented (Ducey *et al.*, 1980). Also, in all studies the influence of variation in factors not associated with the management system (e.g. farm size, proximity to woodland, amount of non-crop habitat) which may have affected the bird community was not dealt with adequately. This problem was overcome by Moreby *et al.* (1994) in their study of insects and plants, by pairing organic and conventional fields on the basis of field size, aspect, and boundary type in order to remove variation caused by differences between farms which were not associated with the management system.

The study presented here assesses the benefits of organic farming to birds by surveying the number of all species of birds in a country-wide sample of farms of each type (organic and conventionally managed). It is an improvement on previous studies in a number of aspects. Firstly, each organic farm was paired with a nearby conventional farm in order to control for the geographic variation in bird community composition, but also pairing was carried out as far as possible on the basis of the physical features of the farm. Secondly, the survey included detailed information on various habitat features (boundary and field characteristics) so any differences detected between farming systems could be attributed to specific management practices, particularly the effects of physical attributes of farms (e.g. hedge structure, field use, field size) as opposed to the effects of chemical management (pesticide and fertilizer input). This was important because it was not possible to pair farms exactly in terms of their physical attributes.

2. METHODS

2.1 Farm selection

In this study, organic farms were chosen from lists of farms provided by the Soil Association and Organic Farmers and Growers which meet the requirements of the United Kingdom Register of Organic Food Standards (UKROFS). Farms only appear on these lists after a transitional period of organic management with no pesticide input. This transitional period depends on individual farms but is at least two years. Though some data were collected from farms under conversion to organic regimes these were not used in the analysis.

In total some 22 fully organic farms were surveyed, although the number varied between seasons. Each organic farm was paired with a nearby conventional farm for a comparison which controlled for geographical variation in bird populations. Farm pairs were also matched as far as possible in terms of shape, area, field sizes, and areas of non-crop habitat in an attempt to control for habitat features which may have an effect on bird populations independently of farming system. The procedure of farm selection ensured that the organic farms were not compared with the most intensive conventional systems. It proved impossible, however, to pair the farms exactly in terms of crop type. Indeed this was considered undesirable because one objective of the study was to make overall comparisons between bird populations associated with organic and conventional systems. The selection of the paired conventional farm was usually carried out on the recommendation of the corresponding organic farm's owner. The total number of farms in each category (boundaries or fields) in each breeding season and winter of the study is shown in Table 1. It should be stressed that the samples are partially overlapping from year to year, only a few farms having been surveyed in all seasons.

2.2 Bird and habitat census

Bird census methods were based on mapping techniques employed in the British Trust for Ornithology's Common Birds Census (Marchant *et al.*, 1990). For each farm a minimum of four census visits (approximately one per month from April) was carried out in each breeding season and a minimum of three in the winter (although most farms had six census visits, again one per month from September). At each visit the observer recorded the number of birds (or pairs in the breeding season) of all species located in each field boundary and on each field of the farm whilst walking a set route. For the field survey, observers were requested to invest proportionately more time, and if possible take a route through the centre of a field, if that field was particularly large or had a dense crop. In addition to bird counts, data were collected on numerous habitat characteristics of fields (crop types and other field usage) and field boundaries (boundary type, number of trees per boundary and, for hedges, dimensions and whether there was regular trimming). A single observer visited each pair of farms within any one season. Visits to the farms within each pair were carried out within a week of one another and were matched as far as possible for time of day and weather. No surveys were carried out in excessively wet or windy weather. (The exact instructions given to volunteers are given in Appendix I).

In the following analyses bird density is used, either per 100 m (for field boundaries) or per hectare (for fields). Although all species present were recorded in the census, this paper only presents separate analyses for the most commonly occurring species (Table 2) in addition to analysing the combined density of all species recorded. Certain species were omitted from the results as it was thought that the method could not accurately survey the numbers present. This included all swifts, hirundines, woodpigeons and house sparrows within the breeding season. Only skylarks were censused on fields during the breeding season, partly because most other open field breeders will be scarce, and partly because skylarks are the only breeding species that can be surveyed accurately by counting singing males. Also, fields containing sugar beet in the winter were omitted from the analyses as this crop has a particularly dense cover at this time. In analysing bird density, all boundaries under 100 m in length and all fields under a hectare in size were omitted. This will remove potentially misleading results where a high bird density is recorded due to the sample unit being small. Furthermore, on organic farms, external boundaries were omitted from the analyses because many of these were adjacent to conventionally managed farmland.

When analysing the bird density in the breeding season, it was assumed that most birds recorded would be territory holders and therefore would be sedentary during the survey period. However, in the winter most birds do not maintain territories and are more likely to be dispersive. Therefore numbers recorded on a farm may fluctuate from day to day according to the conditions. Accurate controls for possible seasonal effects (e.g. by incorporating date as a continuous factor in a general linear model) are not possible due to the limitations imposed by the distribution of the data (see below). An attempt has been made to take into account possible seasonal variation by dividing the data set into early and late winter. In the early period, from September to November, the weather will still be fairly mild and food supplies will be high for a number of species, particularly those feeding on berries. In the later period (December to February) conditions are likely to be much colder and food will be harder to find. Thus there are likely to be differing constraints on bird distributions in these two periods.

2.3 Statistical methodology

Ideally, the basic unit of analysis used would be bird density per field or per field boundary. This would make best use of the data and permit analyses relating field or boundary characteristics to bird density. However, a problem with the data gathered was that there were many fields and field boundaries with zero counts and the distribution of data was non-normal (Figure 1; see also Appendix II). There are no transformations which would normalise this type of distribution so parametric tests were not possible. Considering mean bird density per farm would normalise the data but this is undesirable for a number of reasons: much information would be lost; there would be reduced possibilities to relate habitat variables to bird density; and, there are only a small number of farms in some seasons. A further alternative would be to use a rank test, but this is undesirable when a single rank is shared among many data.

A useful technique to deal with data which do not conform to the requirements for standard statistical tests is randomisation (Manly, 1991; Crowley, 1992). This involves randomly re-sampling a test statistic describing the data a large number of times in order to determine the probability of occurrence of a test statistic at least as extreme as that observed (Manly, 1991). For example, the test statistic chosen may be the mean difference in bird density between organic and conventional farms. A random re-allocation of the data points between farm types is then performed a large number of times and a new mean difference is calculated from each newly created data set. The proportion of mean differences from the randomly generated data sets exceeding the observed mean difference is effectively equivalent to the significance level produced in a more standard test (Manly, 1991).

In the following analyses randomisations were carried out (without replacement) on bird densities per individual boundary or field averaged per visit using SAS programming (SAS Institute, 1989). 999 randomisations of the whole data set were considered adequate. The paired nature of the data was maintained, resampling being carried out within every farm pair for each of the 999 iterations. In the early analyses, the test statistic was calculated for each species in the following way: The mean bird density per boundary or field was determined for each individual farm. The sum of means for organic and conventional farms was then calculated. The test statistic was then taken as the difference between the sum of means (organic-conventional), divided by the total sum of means (organic+conventional) in order for the difference between farm types to be in relation to the overall abundance of each particular species. This will be referred to as the density index from here onwards. (The densities per sample unit averaged over all farms are presented in Appendix II).

With the exception of boundary length, field area and number of trees per boundary, all habitat variables were recorded on a categorical basis (including hedge height). Basic paired comparisons of habitat variables were carried out using t-tests (or ANOVA with boundary lengths and field areas). Further randomisations were then carried out on selected species, but this time only data from specific habitat types (e.g. only tall hedges with trees) were analysed in order to control for possible effects of habitat structure.

In addition to density, species diversity was also analysed, using the Shannon-Weiner index (Krebs, 1980) as a measure of diversity, which was calculated thus:

$$\text{diversity} = \Sigma - p_i \ln p_i$$

where p_i is the proportion the ith species contributes to the total number of individuals of all species. This index takes into account both the numbers of species recorded, and of the number of individuals recorded, higher indices indicating higher diversity. The calculation of diversity indices was carried out at the farm level, thus the problems of large numbers of zero values were avoided and a parametric analysis could be carried out.

3. RESULTS

3.1 Breeding season field boundaries

The density indices for the 18 commonest species and the total of all species in each breeding season, and the corresponding significance levels produced from the randomisation tests described above are shown in Table 3. In each year a majority of species (46/54 cases overall) showed higher densities on organic than conventional farms; this predominance of higher densities on organic was statistically significant ($P<0.01$) in 1992 and 1994 (sign tests). Whilst only a few individual species show significant differences between organic and conventional farms, all those which were significantly different had positive indices (i.e. organic > conventional), although there was one species, the long-tailed tit, which showed nearly significant differences ($P<0.07$) in the other direction in one year. However, the overall trend was for bird density to be higher on boundaries from organic farms, with 46 out of 54 cases having a positive index. This was reflected in the analysis of total density (i.e. the density of every species recorded, not just the 18 selected species), which showed significant differences in two out of three breeding seasons.

The significance level of a randomisation test did not necessarily relate to the magnitude of the index when comparing between species. For example, there was a significant difference between organic and conventional farms in blue tit density in 1992, when the density index was 0.14. However, the turtle dove had an index of 0.50 but the difference in density between farm types was not significant. This effect occurs for two reasons. Firstly, the variance of the data will be important. For example, if there is a small number of high values within a farm type, this will increase the mean density and therefore increase the magnitude of the index. However, when the randomisation procedure is carried out, there will be a reasonably high probability that all of these high value data points will be resampled into the same data set, thus the resampled test statistic may equal or exceed the observed test statistic and a non-significant result is likely. Therefore sets with a large range of values are less likely to produce significant differences.

Secondly, the number of zeros within a single farm will affect the outcome of the randomisation test. For example, with a fairly scarce bird such as the turtle dove, it is likely that birds will only be recorded in a small proportion of the boundaries on each farm. Therefore when the randomisation procedure is carried out there is a high probability of resampling these data points into the same data set and a non-significant difference is likely to result, as described above. Therefore it is possible to have an index of ± 1.0 (birds only recorded on one farm type) and still not have a significant difference. In such cases the number of boundaries occupied will be very low. These effects do not invalidate the statistical methods, but scarce species are less likely to exhibit significant differences.

3.2 Winter field boundaries

The density indices for the 18 most common species and for total species recorded on field boundaries in each winter of the survey are shown in Table 4. More species showed a significant difference in density between farm types in the winter than in the breeding season, and there was also more consistency in the results between years within each species (e.g. both bullfinch and great tit showed a significant or nearly significant difference in each period in each year). In common with Table 3, all significant differences had positive indices (organic > conventional). There was a tendency for indices to have positive values (60/72 cases overall). In the two winters, both in early and late periods, the majority of species attained higher densities on the organic farms and this was statistically significant ($P<0.01$) in three of the four data sets (sign tests). The density of all species combined was significantly higher on organic farms in both early winter periods and in one (of two) late winter periods.

There was a tendency for a greater number of significant or nearly significant differences to be observed in the early winter period. In 1992 ten individual species showed significant differences in density between farm type in the early winter, and five in the late winter. In 1993 the corresponding figures were five and three. Therefore the differences between organic and conventional farms appear to be more pronounced in the early winter period.

3.3 Fields

In the breeding season only skylarks were surveyed on open fields as it was thought that no other species could be accurately censused. The density indices for skylarks breeding on open fields in each year are shown in Table 5. Skylark density was significantly higher on organic farms in two out of three years.

For the winter survey of open fields the 17 most common species were analysed. The density indices of these species and of all species combined, and the corresponding significance levels calculated from randomisation tests are shown in Table 6. As in the analysis of field boundaries, the data were divided into early and late winter.

There was a tendency for the density on organic farms to be greater than the density on conventional farms, with a positive density index in 11 to 15 out of 17 individual species in each period. In two of the four periods the predominance of positive indices was significant at $P\leq0.05$ (sign tests). However, few significant differences were detected between farm types, with a significant difference being detected in six species in early winter 1992 and only one species each in the late winter 1992 and early winter 1993, and two species in the late winter 1993. In contrast to the field boundary results, two of the significant results (fieldfare and lapwing) had a negative density index (conventional>organic); and there was also another species, the mistle thrush, which showed a nearly significant difference ($P<0.07$) in the same direction. There was some consistency between periods, with linnet density being significantly higher on organic farms in two of the four periods. Two other seed-eaters, chaffinch and greenfinch, also showed consistently high positive indices, although the difference was significant in only two instances. The density of total species was significantly higher on organic farms only in the 1992 early winter, although positive indices were shown for the other three periods.

3.4 Habitat characteristics

In the results presented so far, there has been strong evidence to suggest that the density of many species of birds is higher on organic than on conventional farms. However, it can not be concluded that organic farm management per se affects bird populations unless other habitat features are controlled for. Organic farmers may tend to be 'environmentally friendly' and therefore general farm management (e.g. hedge maintenance or upkeep of non-crop habitat such as farm woods) may be expected to differ between organic and conventional farms.

Both field area and boundary length were analysed with a two-factor ANOVA, taking farming type (i.e. organic or conventional) and farm pair (geographic location) as the factors. There was no significant difference in the length of field boundary between farm types in any year (Table 7a). However, there were highly significant differences in field size in three out of five samples of farms (Table 7b), with conventional fields being larger than organic fields. In the analysis of bird density

(Tables 3-6) small boundaries and fields were omitted from the analysis as it was deemed that as boundary/field size decreased, there was likely to be a decrease in the accuracy of density estimates. Omitting small fields and boundaries did not alter the significant differences observed in field/boundary size between farm types; indeed in one case the differences were accentuated (Table 8).

There is some evidence that higher bird densities occur in shorter hedgerows, mainly due to the proximity of hedge intersections (Lack, 1988). Boundary unit length did differ significantly between farm types in one year after boundaries under 100 m had been omitted (Table 8). In the analyses of bird density the nearest hedge intersections would have been at least 100 m apart, so it seems likely that their influence would have been small. Differences in boundary unit length between farm types are unlikely to have affected the results of this study.

The significant differences detected in field size between farm types may present more of a problem in interpreting the bird density results if an increase in field size resulted in a reduction in the accuracy of the census. However this problem was minimised as observers were requested to spend proportionately more time censusing larger fields (see Appendix I). Also the magnitude of the differences in field size between farm types in absolute terms were not particularly great. The impact of variations in field area between farm types was probably therefore minimal.

Table 9 shows some simple comparisons of selected habitat features between organic and conventional farms. Most of the boundary features were recorded as categorical data, so straight forward parametric tests were not possible. Also, the high variation in the frequency of different categories on different farm types, and the preponderance of zero frequencies for many categories, meant that categorical analyses tended to be inaccurate. Instead a simple analysis was undertaken whereby the proportion of boundaries of each different category was determined, and paired t-tests were then carried out on selected categories between farm types (after transforming the proportions using the arcsine square root function). Certain categories are only applicable to hedges, so the proportions calculated in these farms consider hedge boundaries only. For the analysis of density of trees per boundary, t-tests were carried out on non-transformed data. If both farms within a pair had zero frequencies for a particular category, that pair was dropped from the analysis. There was evidence for differences in the proportion of trimmed hedges, the proportion of low and thin hedges and the number of trees per boundary between organic and conventional farms. There was no significant difference in the occurrence of hedges, ditches or woodland edge between farm types.

The type of crop in a field may affect its use by birds (Lack, 1992). Stubble fields may be particularly important as a winter food source for seed eaters (Donald & Evans, 1994; Wilson *et al.*, 1995), and grass is important for invertebrate feeders (Lack, 1992). Following the methods used in Table 9, the difference in the percentage occurrence of selected field types per farm pair was tested to assess whether field management differed between organic and conventional farms (Tables 10 and 11). A problem with fields in the winter is that their status may change markedly over the course of the season. For this reason, data were considered from the second and fifth census visit per farm, these two visits always occurring within the early and late winter periods respectively. It was deemed that less seasonal change would occur to fields in the breeding season so only data from the first visit was analysed. Note that sample sizes differ between early and late periods because farm pairs with a total frequency of zero for a particular field type were dropped, and also in some cases less than five census visits were carried out.

In the winter, there was a significantly higher percentage of bare till fields on organic farms and a higher percentage of winter-sown cereal fields on conventional farms in early 1992 only (Table 10). Interestingly, this period showed the most significant differences in bird density between farm types (Table 6). The only significant result detected in the breeding season was a higher percentage of spring-sown cereal fields on organic farms in 1993 (Table 11). However, sample sizes tended to be small in these analyses.

3.5 Controlling for the effects of habitat structure

Some of the habitat features which differed in occurrence between farm types are known to affect farmland bird communities. For example, taller hedges tend to hold more bird species whose primary nesting habitat is woodland (Lack, 1992); also it is known that higher numbers of birds tend to be found in hedges which have trees (Green *et al.*, 1994; Parish *et al.*, 1994). As more tall hedges and a greater number of trees per boundary occurred on organic farms, then it is perhaps not surprising that higher numbers of birds were recorded on organic farms. Therefore these features need to be controlled for in an analysis in order to separate any such effects of habitat structure from effects of the farming system. Ideally, this would be carried out by using a general linear model to analyse the effect of a number of habitat features on bird density. This was not possible due to the distribution of the data (see, for example, Figure 1), so a randomisation procedure was necessary. It is possible to carry out randomisations on any test statistic which adequately describes variation in the data set under scrutiny, including mean squares from analyses of variance or general linear models (Manly, 1991). This approach was attempted here, but was found to be impracticable due to the complexity of the analysis and subsequent interpretation of the results, a problem exacerbated by the lack of literature on such complex randomisations. It was therefore decided to take a more straight forward approach.

In order to achieve this, a repeat analysis of the randomisations presented in Tables 3 and 4 was carried out. However, the analyses were restricted to two specific habitat types: (i) hedges of a minimum height of 2 m and with the presence of trees, and (ii) hedges with a maximum height of less than 2 m with no trees. These analyses controlled for some of the differences observed in boundary features between farm types. The analyses were restricted to birds which showed significant results in the analysis of all boundaries, and to total density.

The density indices of selected species occurring in tall hedges with trees are shown in Table 12. The analysis was restricted to species that showed significant differences in density between farm types in the analysis of all boundaries, and to total density for each case. Fewer significant differences were found in this smaller sample, but all the differences significant at $P<0.05$ remained in favour of higher densities on organic farms. Four of the five species showing significant differences (dunnock, robin, blackbird and redwing) were birds that eat substantial numbers of ground-living invertebrates. Though not significant, some species showed opposite trends to those shown in the results from all boundaries (Tables 3 and 4). For example, yellowhammer in the 1992 breeding season, goldfinch in the early winter of 1992/93 and bullfinch in the late winter of 1992/93 were all more abundant in organic boundaries in the full sample but were more abundant in conventional boundaries in the sample of tall hedges with trees. Total density in tall hedges was consistently higher on organic than conventional farmland. The density indices for species occurring in short hedges without trees are shown in Table 13 (only the 1992 sample of farms had sufficient numbers of this habitat for an analysis to be carried out). Again, the number of significant results was reduced relative to the results from all boundaries, but the proportion of significant differences and the proportion of positive indices were lower than in the analysis of tall hedges. Furthermore, in contrast to tall hedges, the total density was lower in organic than in conventional short hedges.

These results would seem to suggest that at least for some species the differences found between farm types in the analysis of all boundaries were partly attributable to differences in habitat structure between organic and conventional farms. However, there is a problem in interpreting these results as sample sizes are inevitably much smaller than those in the analysis of all boundaries, both in terms of the number of farms and the number of boundaries per farm. This may result in a lower likelihood of observing a significant result, even when differences in the observed means are high, especially if the data still have a high proportion of zero counts. Note that 11 individual cases from Tables 12 and 13 had an index of 1.00 (i.e. no birds recorded on conventional farms) but showed no significant differences.

In order to control for possible effects brought about by differences in field use (i.e. crop type) between farm types, a repeat analysis of the randomisations presented in Tables 5 and 6 was carried out on specific field types. In the winter, only birds occurring on stubble fields were analysed. In the breeding season, skylarks occurring only on grass fields (combining both temporary and permanent fields) and skylarks occurring only on winter cereal fields were analysed separately. In common with Tables 12 and 13, the analysis was restricted birds which showed significant differences in density between farm types in the analysis of all fields, and to total density for each case.

In stubble fields in the winter, the only species to show a significant difference in density between farm types was the fieldfare (Table 14), which showed a significantly higher density on conventional farms, in common with the result from the full data set (Table 6). The majority of other results had high positive indices, but none were significant. In common with Tables 12 and 13, the small sample sizes should be taken into account when interpreting these results.

There was no significant difference in skylark breeeding density on grass fields between organic and conventional farms, although high positive indices were shown in both years (Table 15). A problem in interpreting this result, apart from the small sample size involved, is that observers typically did not distinguish between grazed and ungrazed grass. As the presence of grazing is one factor known to affect the use of fields by skylarks, then this may have affected the results, particularly if the proportion of grazed and ungrazed grass fields differed between farm types. The density indices of skylarks breeding in winter cereals were very similar to those of birds breeding on grass fields, but in both years the difference between farm types was significant (Table 16). These results indicate that either differences in chemical input or differences in crop structure, rather than differences in crop type, lead to a higher density of skylarks on organic farms.

3.6 Species diversity

Previous analyses have compared the densities of individual species and of all species combined in the different farm types. However, it is also useful to know if organic farms support a greater number of species, for example, due to a greater diversity of prey types being available. Tables 17 and 18 show the results of general linear models carried out on the differences in diversity index between farm types for birds recorded on field boundaries in the breeding season (Table 17) and in the winter (Table 18). The pairing of the farms was taken into account in the models, as was the total length of the boundary per farm, as the number of species recorded may have been related to farm size in some way.

There was no evidence of a difference in species diversity between organic and conventional farms in either the breeding season or winter of any year. There was a significant effect of farm pair in some cases, which is not surprising as the diversity of bird communities is likely to vary with geographic location. Additionally, there were two cases which showed a significant effect of total boundary length per farm; thus diversity may increase with increasing farm size.

A repeat analysis was carried out on results from open fields in the winter only (only skylarks were surveyed on open fields in the breeding season), taking total field area as a measure of farm size in the model (Table 19). A very similar pattern to that observed in field boundaries was shown for species diversity on open fields, there being an apparent effect of farm pair (location) in most years, but no effect of farm type.

4. DISCUSSION

In the great majority of species, mean density was higher on organic than on conventional farms. However, for individual comparisons, the difference in mean density is not reliably indicative of an effect of farm type due to the highly non-normal distribution of the data (Figure 1), and, with the exception of total density, the very large variances surrounding the means (see Appendix II). Randomisation tests, the only reliable indicators of differences in such data, showed that many of the observed differences were significant. The density on organic farms was greater than on conventional farms in 46 out of 48 significant results. Perhaps most importantly, the total density of all species (a less variable measure) recorded on organic farms exceeded the density on conventional farms in the majority of cases, and the difference was often significant. Total density was never significantly higher on conventional farms.

Although many species exhibited significant differences in density between farm types, few species showed consistently significant results between years. This, in part, was due to having partially overlapping samples, with only a few farms having been surveyed in every year. Also, some variation may have been caused by particular conditions in any one year, such as differences in weather or food abundance which in turn may have caused fluctuations in overall population size between years. If populations levels are high then a greater proportion of the population may be forced to settle in less preferred habitats, thus differences in density between areas of differing quality may not be large. Conversely, in years when populations are low, and there is consequently less competition, fewer birds will be forced into habitats of lower quality and therefore differences between habitat types may be more apparent. Such density dependent variation in habitat use could lead one to draw very different conclusions about habitat requirements, and the relative importance of different habitats, depending as to when censuses were undertaken (O'Connor, 1986).

In the winter, greater differences were observed in field boundaries than in fields, and the differences were more consistently in favour of organic farms. As many species occurred at higher densities on conventional fields, there is an indication that organic fields are not necessarily better for birds than conventional fields in the winter. Organic management could potentially increase winter food supplies for both seed-eating birds (more stubble fields and a greater number of weeds) and invertebrate-feeding birds (more weeds as cover and food for invertebrates, less disturbance of the soil in stubble fields, and fewer pesticides). There was, however, little evidence to suggest that organic farms held higher densities of birds in the latter group, with only the blackbird showing significantly higher densities on organic farms in one year. Indeed, two earthworm feeders, lapwing and fieldfare, had significantly higher densities on conventional farms, a surprising result given that Brooks *et al.* (1995) found significantly higher earthworm density on organic fields. There is evidence that lapwings occur at higher densities on larger fields (Tucker, 1992), thus this effect may merely be a consequence of differences in field size between farm types. More significant is the fact that seed-eaters tended to occur at higher densities on organic farms, particularly the greenfinch and linnet, which may be indicative of a greater abundance of weeds due to the absence of herbicides.

Field boundaries may have shown greater differences between farm types than did fields due to more accurate sampling, and possibly because more of the wintering species analysed from the boundary survey would have been sedentary species. Thus boundary counts may have been less variable than field counts where many of the species form large flocks. The different food resources exploited in field boundaries and fields may have also been important. Birds foraging in fields are feeding mainly on soil invertebrates and seeds, but in hedgerows the emphasis will be more on shrub invertebrates and berries. The abundance of the shrub invertebrates is likely to be affected by pesticide input, either directly by spraying hedge bottoms, or by spray drift from fields. This will probably affect the smaller passerines such as robins, dunnocks and the tits, all of which showed some significant differences between organic and conventional farms. The abundance of berries on hedgerows of different farm types is less likely to be directly affected by pesticide input, but differences in physical management of hedgerows between organic and conventional farms may affect their abundance (see below). Organic farms tended to have larger hedges with more trees which were subject to less regular trimming compared to conventional farms. This may be of benefit by providing a greater abundance and diversity of food items for birds such as the redwing (feeding on berries) and the bullfinch (feeding on buds and seeds), in addition to providing better cover.

There was a tendency for more species to show significant differences in the early winter than in the late winter. This may be associated with decreasing food supplies. In the early part of the winter when the weather is still fairly mild, food stocks, particularly berries and seeds, will be relatively high and birds may distribute themselves according to food abundance. However, as food becomes increasingly scarce and less predictable, the differences in farm types may be lessened, particularly if food is depleted at a greater rate within the better quality habitat. This effect may also be amplified by birds becoming increasingly dispersive as conditions become harsher.

The breeding season field survey showed significant differences in the density of the only species analysed, the skylark, in two out of three years. In a companion study, Evans *et al.* (1995) found that nesting density was higher on an organic farm than on a paired conventional farm, and that this difference could be largely explained by differences in field size, boundary characteristics and cropping regimes. Measures of reproductive success associated with diet (nestling weight, nestling survival rates and clutch size) were also higher on the organic farm, indicating that the main prey, insects, were either more abundant, more accessible, or both on organic farms (Dritschillo & Wanner 1980). Evans *et al.* (1995) also found that differences between farm types were greater in 1993 than in 1994, which may have been due to differences in the weather between years. A parallel result was found in this study, with 1994 showing no significant difference in skylark density between farm types.

There was no significant difference in species diversity between farm types. As organic farms are typically more diverse in habitat and field type than conventional farms (Lampkin, 1990), this seems rather surprising. This result may be partly a consequence of the pairing procedure used in this study, as the most intensive examples of conventional farmland were excluded. A similar result using the Shannon-Weiner index to measure diversity has been found for insects (Dritschillo & Wanner 1980). For the common species, most farms will have at least some suitable habitat, so many species will be found on all farms, although their densities may differ. Less common species probably will always occur at fairly low densities and so will contribute little to the magnitude of a diversity index where they do occur.

4.1 Physical or chemical management?

Organic farming differs from conventional farming not only in pesticide and chemical input, but also in the physical management of the farm, as shown in this study (Tables 9-11). Differences in both the chemical and physical management of a farm may affect bird density. Both hedgerow structure and field types differed between farm types in a way likely to increase bird density on organic farms.

When variation in both hedge height and the occurrence of trees in a hedge was controlled for, the number of significant differences decreased compared to results from the full data set, and in some cases the density on conventional farms exceeded the density on organic farms. Therefore, there is an indication for some species that hedgerow management, rather than pesticide input, causes the observed difference in bird density between farm types. The combined density of all species on organic farms exceeded the density on conventional farms in every season for tall hedges, although again fewer significant results were observed than in the complete data set. There was a tendency for a higher number of positive indices and more significant results to occur in predominantly invertebrate feeding, rather than predominantly seed-eating species, suggesting that hedge structure has a greater effect on seed availability and pesticide input has a greater effect on the abundance of invertebrates.

In short hedges without trees, the density on organic farms exceeded the density on conventional farms, although no conventional farms had significantly higher densities. The reason for this may be associated with the relative amounts of good and poor quality hedgerow within a farm. Tall hedges with trees tend to hold relatively high numbers of species and a high density of individuals (Green *et al.*, 1994; Parish *et al.*, 1994). Organic farms had more high quality hedgerow (Table 9), so on these farms birds may be preferentially using tall hedges, an option which is less likely to be available on conventional farms with fewer good quality hedges. The only species which had a higher density on organic farms in short hedges without trees was the yellowhammer, a species known to prefer this type of hedgerow (Green *et al.*, 1994).

When variations in winter field usage were controlled by analysing only birds in stubble fields no significant differences were detected between farm types, with the exception of one species, the fieldfare, which had a higher density in conventional farms. However, the magnitude of the density indices were still high and positive in the majority of cases. Also, in the breeding season, skylarks showed high and sometimes significant differences in density between farm types when the analysis was restricted to only certain field types. Skylark densities were significantly higher in organic winter cereals than in conventional winter cereals. This density difference is likely to be either a response to better food availability or a more suitable crop structure (i.e. a less dense or shorter crop) or both.

These restricted analyses inevitably resulted in a large reduction in sample sizes, which may reduce the likelihood of detecting a significant difference, even when the magnitude of the density index is very high. The specific habitat analysed could have been refined still further if sample sizes had allowed. For example, other factors known to affect bird density, such as hedge width or the type of adjacent fields and hedges (e.g. Parish *et al.*, 1994; Green *et al.*, 1994), could then have been taken into account. These results can therefore only act as a rough indication of the relative effects of physical and chemical management on bird density across farm types. Despite some indications in individual species that habitat structure was more important, the overall indication was that pesticide management still has major effects independently of farm structure, particularly in larger hedges and, for skylarks, in fields. Further work, however, is needed to determine the wildlife benefits that might accrue from reduced pesticide inputs (Fuller, 1995).

4.2 How representative were the survey farms?

When farms were selected, an attempt was made to pair organic and conventional farms on the basis of geographic location, but also on other factors such as farm size, field type and the distribution of non-crop habitats. Whilst this was achieved fairly accurately for the first two factors, there were sometimes substantial differences in overall land-use between farm pairs. There was particularly poor pairing for field type, in that the proportion of arable fields and pasture fields were not well matched within farm pairs. Additionally, no account was taken of the length of time a farm had been under organic management in the analysis. The extent to which the time a farm has been under organic management affects the bird community is not known, but it seems likely that if there is an effect, it will be to increase the farm's suitability to birds.

A further problem in the pairing procedure was that selection of the conventional farm pair was carried out largely on the recommendation of the organic farm's owner. Apart from the less accurate pairing this may have produced, the organic farmers may have chosen (albeit unintentionally) conventional farms which were operated in a more environmentally friendly way than a typical conventional farm. Indeed, the very fact that conventional farmers allowed such a survey to take place on their land may indicate that they are more interested in wildlife than a typical conventional farmer, and so the farm may have been managed in a way beneficial to birds. Therefore, the conventional farms surveyed in this study may not be representative of the majority of conventional farms in the country.

The extent to which closer pairing by crop type would have affected the results must remain unknown. However differences in the cropping regime are part of the overall difference between organic and conventional farming systems, organic farms typically having a greater diversity of land-use than conventional farms (Lampkin, 1990). Both the failure to take into account the time a farm had been under organic management, and the possibility that conventional farms surveyed were better than average for birds, would tend to decrease the differences between organic and conventional farms rather than cause inflated densities on organic farms. Therefore, the farm selection procedure can be regarded as being a conservative one, with potential differences between farm types being minimised. Given this, the differences in density are all the more striking, and a more stringent selection procedure, using older organic farms more closely paired for field type with conventional farms, may have produced even greater differences.

4.3 Density as an indicator of habitat quality

Throughout this study, there has been an implicit assumption that higher bird density reflects better habitat quality. This is not necessarily the case as social dominance factors may affect the distribution of animals, and a large proportion of a given population may be non-breeders or unsuccessful breeders in less favoured habitats (van Horne, 1983; Vickery *et al.*, 1992). However, most of these strictures apply to situations where territorial behaviour is affecting breeding density. Many of the significant results in this study were observed during the winter when territories are no longer defended in the majority of species. In the absence of territorial exclusion, birds are more likely to distribute themselves in an Ideal Free manner (Fretwell & Lucas, 1969), thus higher densities will be observed in areas of greater resource abundance. Therefore, density is likely to be a good indicator of habitat quality for the majority of species in the winter.

In the breeding season, density may be less indicative of habitat quality if there is unequal exploitation of resources within species (i.e. an Ideal Despotic Distribution - Fretwell, 1972). However, even within species which show marked differences in dominance between individuals, higher nesting density is typically observed in the better quality habitat, e.g. great tit (Krebs, 1971) and blackbird (Hatchwell *et al.*, in press).

In order for firmer conclusions to be drawn on the quality of habitat on each farming system, more detailed information on the survival and productivity of individual species is needed. This has been carried out in a companion study of the skylark (Evans *et al.*, 1995), the results of which parallel this study very well, with a higher productivity occurring on the high density organic farms. Therefore, most of the evidence presented indicates that density is likely to reflect habitat quality on different farm types. It is concluded that the results of this study indicate that organic management is beneficial to the farmland bird community, the greatest effects being on field boundaries in the winter.

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6. REFERENCES

Braae, L., Nøhr, H. & Petersen, B.S. (1988). *Fugelfaunen pa konventionelle og økologiske landbrug*. Miljøprojekt 102, Miljøministeriet, Miljøstyrelsen.

Brooks, D., Bater, J., Jones, H. & Shah, P.A. (1995). *Invertebrate Food Sources for Birds in Organic and Conventional Farming Systems*. BTO Research Report No 154. PART IV. To MAFF & WWF UK on Organic Farming and Birds.

Crowley, P.H. (1992). Resampling methods for computation-intensive data analysis in ecology and evolution. *Annu. Rev. Ecol. Syst.* 23:405-447.

Donald, P.F. & Evans, A.D. (1994). Habitat selection by corn buntings *Miliaria calandra* in winter. *Bird Study* 41:199-210.

Dritschillo, W. & Wanner, D. (1980). Ground beetle abundance in organic and conventional corn fields. *Environmental Entomology* 9:629-631.

Ducey, J., Rauscher, J., Wiederspan, C., Miller, L., Koehler, A. & Mazour, D. (1980). *A Biological Comparison of Organic and Chemical Farming*. University of Nebraska, Lincoln.

Evans, J., Wilson, J.D. & Browne, S. (1995). *Habitat Selection and Breeding Success of Skylarks* Alauda arvensis *on Organic and Conventional Farmland*. BTO Research Report No. 154. PART III. To MAFF & WWF UK on Organic Farming and Birds.

Fretwell, S.D. (1972). *Populations in a Seasonal Environment*. Princeton University Press, Princeton.

Fretwell, S.D. & Lucas, H.J. (1969). On territorial behaviour and other factors influencing habitat distribution in birds. *Acta Biotheoretica* 19:16-36.

Fuller, R.J. (1995). *The Effect of Organic Farming Regimes on Breeding and Winter Bird Populations. Summary Report and Conclusions*. BTO Research Report No. 154. PART I. To MAFF & WWF UK.

Fuller R.J., Gregory, R.D., Gibbons, D.W., Marchant, J.H., Wilson, J.D., Baillie, S.R. & Carter, N. (in press). Population declines and range contractions among lowland farmland birds in Britain. *Conservation Biology*.

Green, R.E., Osborne, P.E. & Sears, E.J. (1994). The distribution of passerine birds in hedgerows during the breeding season in relation to characteristics of the hedgerow and adjacent farmland. *J. Appl. Ecol.* 31:677-692.

Greig-Smith, P., Frampton, G. & Hardy, T. Eds (1992). *Pesticides, Cereal Farming and the Environment: The Boxworth Project*. HMSO, London.

Gremaud, J.K. & Dahlgren, R.B. (1982). Biological farming: impacts on wildlife. In: *Workshop on Midwest Agricultural Interfaces with Fish and Wildlife Resources* (ed. R.B. Dahlgren), pp38-39. Iowa State University, Ames.

Hald, A.B. & Reddersen, J. (1990). *Fugelføde i kornmarker - insecter og vilde planter.* Miljøprojeckt 125, Miljøministeriet, Miljøstyrelsen.

Hatchwell, B.J., Chamberlain, D.E. & Perrins, C.M. (in press). The reproductive success of blackbirds *Turdus merula* in relation to habitat structure and choice of nest site. *Ibis.*

van Horne, B. (1983). Density as a misleading indicator of habitat quality. *J. Wildlife Man.* 47:893-901.

Hustings, F., Post, F. & Schepers, F. (1990). Are corn buntings *Miliaria calandra* disappearing as breeding birds in the Netherlands? *Limosa* 63:103-111.

Krebs, J.R. (1971). Territory and breeding density in the great tit *Parus major. Ecology* 52:2-22.

Krebs, C.J. (1980). *Ecology: the experimental analysis of distribution and abundance.* Harper and Row, New York.

Lack, P. (1988). Hedge intersections and breeding bird distribution in farmland. *Bird Study* 35:133-136.

Lack, P. (1992). *Birds on Lowland Farms.* HMSO, London.

Lampkin, N. (1990). *Organic Farming.* Farming Press, Ipswich.

Manly, B.F.J. (1991). *Randomization and Monte Carlo Methods in Biology.* Chapman and Hall, London.

Marchant, J.H., Hudson, R., Carter, S.P. & Whittington, P. (1990). *Population Trends in British Breeding Birds.* British Trust for Ornithology, Tring.

Møller, A.P. (1983). Changes in Danish farmland habitats and their populations of breeding birds. *Holarctic Ecology* 6:95-100.

Moore, N.W. (1986). *The Bird of Time.* Cambridge University Press, Cambridge.

Moreby, S.J., Aebischer, N.J., Southway, S.E. & Sotherton, N.W. (1994). A comparison of the flora and arthropod fauna of organically and conventionally grown winter wheat in southern England. *Ann. Appl. Biol.* 125:13-27.

O'Connor, R.J. (1984). The importance of hedges to songbirds. In: *Agriculture and the Environment* (ed D. Jenkins), pp117-123. ITE, Cambridge.

O'Connor, R.J. (1986). Dynamical aspects of avian habitat use. In: *Wildlife 2000: Modelling Habitat Relationships of Terrestrial Vertebrates.* (ed. J. Verner, M.L. Morrison & C.J. Ralph), pp235-240. University of Wisconsin Press.

O'Connor, R.J. & Shrubb, M. (1986). *Farming and Birds.* Cambridge University Press, Cambridge.

Parish, T., Lakhani K.H. & Sparks, T.H. (1994). Modelling the relationship between bird population variables and hedgerow and other field margin attributes. I. Species richness of winter, summer and breeding birds. *J. Appl. Ecol.* 31:764-775.

Petersen, B.S. & Nøhr, H. (1992). *Pesticiders indflydelse pa gulspurvens levelvilkar.* Miljøprojekt 1, Miljøministeriet, Miljøstyrelsen.

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

Rands, M.R.W. (1986). The survival of gamebird (Galliform) chicks in relation to pesticide use on cereals. *Ibis* 128:57-64.

SAS Institute (1989). *SAS/STAT Users Guide.* Version 6. Cary, North Carolina.

Sears, E.J. (1990). *A Research Review of Current Information on the Effects on Birds of Organic and Low Input Farming.* RSPB Research Report.

Somerville, L. & Walker, C. (eds) (1990). *Pesticide Effects on Terrestrial Wildlife.* Taylor and Francis, London.

Southwood, T.R.E & Cross D.J. (1969). The ecology of the partridge III. Breeding success and the abundance of insects in natural habitats. *J. Anim. Ecol.* 38:497-509.

Tucker, G.M. (1992). Effects of agricultural practices on field use by invertebrate feeding birds in winter. *J. Appl. Ecol.* 29:779-790.

Tucker, G.M. & Heath M.F. (1994). *Birds in Europe: Their Conservation Status.* BirdLife Conservation Series no. 3. BirdLife International, Cambridge.

Vickery, P.D., Hunter, M.L. & Wells, J.V. (1992). Is density an indicator of breeding success? *Auk* 109:697-705.

Voous, K.H. (1977). *List of Recent Holarctic Bird Species.* British Ornithologists' Union, London.

Wilson, J.D., Evans, A., Poulsen, J.G. & Evans, J. (1995). Wasteland or oasis? The use of set-aside by breeding and wintering birds. *British Wildlife* 6:214-223.

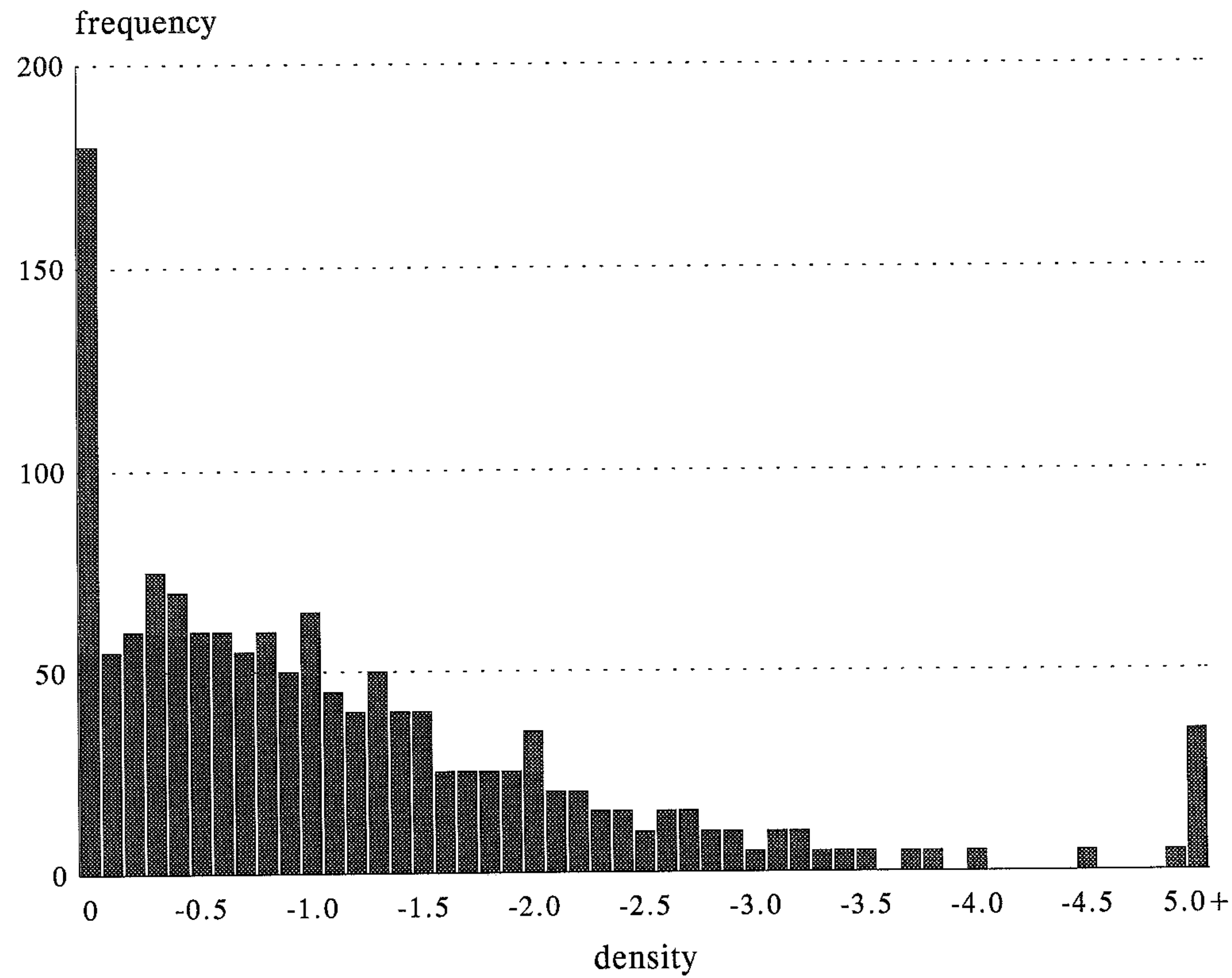

Figure 1. The frequency distribution of the density (per 100m) of all birds recorded per field boundary in the 1992 winter.

Table 1. The number of pairs of farms of each category censused in each season.

year	season	field boundaries	fields
1992	breeding season	7	7
	winter	18	18
1993	breeding season	18	17
	winter	17	18
1994	breeding season	13	13

Table 2. Species selected for individual analysis of differences in density between organic and conventional farms. The seasons used (s=breeding season, w=winter) and whether results were considered from open fields (f) or field boundaries (b) is shown.

species	season	field/boundary
red-legged partridge	w	f
partridge	w	f
lapwing	w	f
wood pigeon	w	f/b
stock dove	w	f
turtle dove	s	b
skylark	s/w	f
wren	s/w	b
dunnock	s/w	b
robin	s/w	b
blackbird	s	b
	w	f/b
fieldfare	w	f/b
song thrush	s	b
	w	f/b
redwing	w	f/b
mistle thrush	w	f
whitethroat	s	b
long-tailed tit	s/w	b
great tit	s/w	b
blue tit	s/w	b
starling	w	f
tree sparrow	s/w	b
chaffinch	s	b
	w	f/b
greenfinch	s	b
	w	f/b
goldfinch	s	b
	w	f/b

Table 2. cont.

species	season	field/boundary
linnet	s	b
	w	f/b
bullfinch	s/w	b
yellowhammer	s	b
	w	f/b
reed bunting	s/w	b

Table 3. The differences in the densities (pairs/100 m) of selected species occurring in **field boundaries** between paired organic and conventional farms in the **breeding season**. The sum of means have been divided by the total for both farms for each species. Negative values indicate conventional > organic. P values calculated from randomisation tests.

SPECIES (no. farms)	1992 (14)	1993 (36)	1994 (26)
turtle dove	0.50	0.24	0.60
wren	0.09	-0.03	0.07
dunnock	0.22**	0.08	0.10
robin	0.14	0.12**	0.17**
blackbird	0.11	0.03	0.16**
song thrush	-0.11	0.07	0.43**
whitethroat	0.09	-0.02	0.16
long-tailed tit	0.07	-0.27(*)	0.08
blue tit	0.14**	0.01	0.05
great tit	0.35**	0.09	0.10
tree sparrow	-0.16	0.36**	0.14
chaffinch	0.03	0.09	-0.01
greenfinch	0.27	0.05	0.14
goldfinch	0.03	0.20	0.03
linnet	0.29	-0.08	0.04
bullfinch	0.31	-0.04	0.49**
yellowhammer	0.25**	0.08	0.01
reed bunting	0.53**	0.05	1.00
total density	0.12**	-0.02	0.10**

boundaries < 100 m not included. **P < 0.05, (*)P < 0.07.

	1992	1993	1994
Species where O > C	16	13	17
Species where C > O	2	5	1
Sign test for species densities	P < 0.01	NS	P < 0.01

Table 4. The differences in the density (individuals/100 m) of selected species occurring in **field boundaries** between paired organic and conventional farms in the **winter**. Differences were calculated as (sum of mean densities per organic farm - sum of means per conventional farm) divided by the total mean (organic+conventional) for each species. P values calculated from randomisation tests.

SPECIES (no. farms)	1992 Sept-Nov (34)	1992 Dec-Feb (36)	1993 Sept-Nov (34)	1993 Dec-Feb (34)
wren	0.06**	0.08	0.03	-0.07
dunnock	0.17(*)	0.07	-0.04	-0.07
robin	0.07	0.06	0.05	0.04
blackbird	0.42**	0.08	0.03	0.01
fieldfare	-0.23	0.08	0.45(*)	0.23
song thrush	0.07	0.04	0.20	0.16
redwing	0.20	0.42**	0.68**	0.68**
long-tailed tit	0.20	0.18	0.16	-0.02
blue tit	0.23**	0.17**	0.07	0.07
great tit	0.28**	0.17**	0.18**	0.20(*)
tree sparrow	0.75**	0.52	0.04	-0.22
chaffinch	0.39**	0.24	0.15	0.21
greenfinch	0.33	-0.18	-0.33	-0.24
goldfinch	0.36(*)	-0.59	0.72**	0.25
linnet	0.57	0.98**	0.64	0.06
bullfinch	0.39**	0.52**	0.36**	0.49**
yellowhammer	-0.03	0.04	0.11	-0.01
reed bunting	0.60**	0.20	0.01	1.00
total density	0.21**	0.10	0.26**	0.15**

boundaries <100 m not included. **P<0.05 (*)P<0.07.

Species where O>C	16	16	16	12
Species where C>O	2	2	2	6
Sign test for species densities	P<0.01	P<0.01	P<0.01	NS

Table 5. The differences in the densities (pairs/ha) of skylarks occurring in **fields** between paired organic and conventional farms in the **breeding season**. The sum of means have been divided by the total for both farms. Negative values indicate conventional > organic. P values calculated from randomisation tests.

	1992	1993	1994
(no. farms)	(14)	(36)	(26)
density index	0.66**	0.29**	-0.04

fields <1.0 ha not included. **P<0.05 (*)P<0.07.

Table 6. The differences in the density (individuals/ha) of selected species occurring in **fields** between paired organic and conventional farms in the **winter**. Differences were calculated as (sum of mean densities per organic farm - sum of means per conventional farm) divided by the total mean (organic+conventional) for each species. P values calculated from randomisation tests.

SPECIES (no. farms)	1992 Sept-Nov (36)	1992 Dec-Feb (36)	1993 Sept-Nov (32)	1993 Dec-Feb (32)
red-legged partridge	0.33	0.45	-0.07	0.11
partridge	0.12	0.58	1.00	1.00
lapwing	-0.45	0.10	-0.05	-1.00**
stock dove	-0.08	-0.86	0.08	0.97
wood pigeon	0.28	0.58**	-0.05	0.13
skylark	0.62**	0.37	0.48	-0.02
blackbird	0.17	0.03	0.22	0.29**
fieldfare	-1.00**	0.00	-0.09	0.44
song thrush	0.33	-0.31	0.11	0.25
redwing	1.00	0.13	0.14	0.16
mistle thrush	-0.82(*)	0.32	0.93	-0.48
starling	0.48	0.28	-0.24	0.44
chaffinch	0.72**	0.37	0.08	0.43
greenfinch	0.99**	0.97	0.74	0.81
goldfinch	0.37	0.04	0.18	-0.12
linnet	0.77**	1.00	0.89**	0.36
yellowhammer	0.94**	0.31	-0.46	-0.39
total density	0.40**	0.27	0.12	0.23

fields <1.0 ha not included. **P<0.05 (*)P<0.07.

Species where O>C	13	15	11	12
Species where C>O	4	2	6	5
Sign test for species densities	P=0.05	P<0.05	NS	NS

Table 7. Mean (±SD (n)) field boundary length (a) and field area (b) on organic and conventional farms. Data were transformed using log(x+1) for the ANOVA. (*)P<0.07, **P<0.05, ***P<0.01.

(a) boundary length (100m)

sample	organic	conventional	ANOVA
1992 breeding season	1.94±0.99 (189)	1.90±1.15 (232)	$F_{1,407}=0.02$
1992 winter	1.19±1.11 (603)	1.88±1.18 (641)	$F_{1,1206}=0.53$
1993 breeding season	1.97±1.12 (531)	1.93±1.15 (518)	$F_{1,1015}=0.63$
1993 winter	1.90±1.10 (541)	1.98±1.13 (522)	$F_{1,1030}=2.06$
1994 breeding season	2.02±1.17 (382)	2.12±1.16 (327)	$F_{1,683}=3.51$(*)

(b) field area (ha)

sample	organic	conventional	ANOVA
1992 breeding season	4.37±2.41 (66)	5.61±4.09 (65)	$F_{1,117}=0.26$
1992 winter	4.13±2.83 (166)	4.17±3.56 (147)	$F_{1,281}=0.44$
1993 breeding season	3.90±2.64 (195)	4.50±3.51 (180)	$F_{1,339}=7.71$***
1993 winter	3.75±2.38 (169)	4.66±3.86 (150)	$F_{1,294}=16.23$***
1994 breeding season	4.05±2.43 (120)	5.04±3.90 (100)	$F_{1,219}=9.76$***

Table 8. Mean (±SD (n)) field boundary length (a) and field area (b) on organic and conventional farms, omitting boundaries <100 m and fields <1.0 ha. Data were transformed using log(x+1) for the ANOVA. (*)P<0.07, **P<0.05, ***P<0.01.

(a) boundary length (100m)

sample	organic	conventional	ANOVA
1992 breeding season	2.24±0.49 (154)	2.30±1.04 (176)	$F_{1,316}$=0.33
1992 winter	2.24±1.03 (498)	2.26±1.11 (485)	$F_{1,945}$=2.86
1993 breeding season	2.23±1.06 (443)	2.29±1.07 (398)	$F_{1,807}$=2.46
1993 winter	2.19±1.03 (439)	2.25±1.06 (399)	$F_{1,805}$=2.65
1994 breeding season	2.60±1.12 (323)	2.41±1.07 (271)	$F_{1,568}$=4.08**

(b) field area (ha)

sample	organic	conventional	ANOVA
1992 breeding season	4.72±2.20 (61)	6.22±3.92 (58)	$F_{1,105}$=2.68
1992 winter	4.40±2.70 (158)	4.66±3.52 (641)	$F_{1,254}$=2.28
1993 breeding season	4.20±2.56 (178)	4.96±3.43 (161)	$F_{1,303}$=8.79***
1993 winter	4.16±2.29 (161)	5.09±3.88 (133)	$F_{1,261}$=16.97***
1994 breeding season	4.24±2.34 (114)	5.42±3.84 (92)	$F_{1,182}$=12.61***

Table 9. Mean differences in selected habitat variables between organic and conventional farms. Negative values indicate conventional > organic. Sample sizes (farm pairs) are given in brackets, means having been calculated per farm for all variables. P values calculated from paired t-tests. Percentages were transformed using arcsine(sqrt.).

habitat variable	1992b	1992w	1993b	1993w	1994b
%boundary=hedge	8.61 (7)	-4.39 (18)	-2.19 (18)	-1.23 (17)	-6.43 (13)
%trimmed hedges	-23.69 (5)	-25.29** (15)	-29.06** (15)	-10.40 (9)	-18.89 (8)
%hedges width<2m	-2.27 (6)	-7.20 (15)	-11.71** (15)	-4.24 (13)	-9.94** (12)
%hedges height<2m	-17.32 (5)	-19.15** (12)	-22.56** (10)	-30.91** (12)	-26.11** (10)
live trees/100m	0.00 (7)	0.00 (18)	0.21 (15)	0.36 (17)	0.29(*) (11)
dead trees/100m	0.00 (7)	0.00 (18)	0.35** (12)	0.12 (16)	0.42(*) (11)
total trees/100m	0.00 (7)	0.00 (18)	0.59** (12)	0.31 (16)	0.84** (8)
%boundary with woodland edge	-5.01 (5)	2.24 (12)	0.58 (14)	-0.85 (9)	4.02 (8)
%boundary with ditch	3.74 (5)	-3.16 (13)	-2.55 (12)	-0.25 (10)	-1.67 (10)

Boundaries < 100 m not included. **P<0.05 (*)P<0.07.

Table 10. Mean differences in the percentage occurrence of selected crop types on organic and conventional farms during the winter. Negative values indicate conventional > organic. Sample sizes (farm pairs) are given in brackets, means having been calculated per farm for all variables. P values calculated from paired t-tests. Percentages were transformed using arcsine(sqrt.).

	1992		1993	
	early	late	early	late
stubble	0.18 (13)	7.62 (11)	1.79 (8)	8.19 (6)
permanent grass	-2.59 (15)	-0.23 (14)	-8.75 (15)	-4.38 (12)
bare till	10.53** (11)	13.66 (8)	-0.97 (11)	6.49 (7)
winter cereal	-24.42** (7)	-15.97 (8)	-4.29 (7)	-6.88 (8)

Fields < 1.0 ha not included. **P<0.05.

Table 11. Mean differences in the percentage occurrence of selected crop types on organic and conventional farms during the breeding season. Negative values indicate conventional > organic. Sample sizes (farm pairs) are given in brackets, means having been calculated per farm for all variables. P values calculated from paired t-tests. Percentages were transformed using arcsine(sqrt.).

	1992	1993	1994
winter cereal	-46.52 (5)	-10.40 (12)	-9.97 (9)
spring cereal	17.60 (5)	19.04** (11)	9.84 (6)
permanent grass	12.50 (6)	-3.06 (17)	-0.45 (12)

Fields < 1.0 ha not included. **$P<0.05$.

Table 12. The differences in the densities (birds/100 m) of selected species occurring in **tall hedges (>2 m) with trees** between paired organic and conventional farms. n=number of farms. The sum of means have been divided by the total for both farms for each species. Negative values indicate conventional>organic. P values calculated from randomisation tests.

year	n	species	density index
1992 breeding season	10	dunnock	0.13
		blue tit	0.19
		great tit	0.32**
		yellowhammer	-0.48
		reed bunting	1.00
		total density	0.12(*)
1992 winter (Sept-Nov)	24	wren	0.11
		dunnock	0.37**
		blackbird	0.17**
		blue tit	-0.01
		great tit	0.12
		tree sparrow	0.54
		chaffinch	0.25
		goldfinch	-0.71(*)
		bullfinch	0.43(*)
		yellowhammer	-0.55(*)
		total density	0.08
1992 winter (Dec-Feb)	24	redwing	0.64**
		blue tit	0.10
		great tit	0.27
		linnet	-1.00
		bullfinch	-0.37(*)
		total density	0.13**
1993 breeding season	16	robin	0.89**
		long-tailed tit	-0.78
		tree sparrow	1.00
		total density	0.37

Table 12 cont...

year	n	species	density index
1993 winter (Sept-Nov)	14	fieldfare	-0.81
		redwing	-0.95
		great tit	0.46
		goldfinch	1.00
		bullfinch	0.49
		total density	0.22
1993 winter (Dec-Feb)	14	redwing	1.00
		great tit	0.84
		bullfinch	1.00
		total density	0.36
1994 breeding season	10	robin	0.01
		blackbird	0.03
		song thrush	1.00
		bullfinch	1.00
		total density	0.23

Boundaries <100 m not included. **$P<0.05$ (*)$P<0.07$.

Table 13. The differences in the densities (pairs/100 m) of selected species occurring in **short hedges (<2 m) without trees** between paired organic and conventional farms. Only data from 1992 were available on organic farms for this category. n=number of farms. The sum of means have been divided by the total for both farms for each species. Negative values indicate conventional>organic. P values calculated from randomisation tests.

year	n	species	density index
1992 breeding season	10	dunnock	-0.41
		blue tit	-0.87
		great tit	-1.00
		yellowhammer	0.35**
		reed bunting	1.00
		total density	-0.29
1992 winter (Sept-Nov)	24	wren	-0.27
		dunnock	0.18
		blackbird	-0.31
		blue tit	0.37
		great tit	-0.51
		tree sparrow	1.00(*)
		chaffinch	-0.08
		goldfinch	-0.51
		bullfinch	-0.36
		yellowhammer	-0.69
		total density	-0.08
1992 winter (Dec-Feb)	24	redwing	0.02
		blue tit	-0.45
		great tit	-0.42
		linnet	1.00
		bullfinch	1.00
		total density	-0.30

Boundaries<100m not included. **P<0.05 (*)P<0.07.

Table 14. The differences in density (birds/ha) of selected species occurring in **stubble fields** in the **winter** between organic and conventional farms. n=number of farms. The sum of means have been divided by the total for both farms within a farm pair for each species. Negative values indicate conventional>organic. P values calculated from randomisation tests; no differences were significant.

season	n	species	density index
1992 (Sept-Nov)	18	skylark	0.19
		fieldfare	-1.00**
		chaffinch	0.86
		greenfinch	1.00
		linnet	-0.45
		yellowhammer	0.95
		total density	0.63
1992 (Dec-Feb)	12	woodpigeon	-0.10
		total density	-0.27
1993 (Sept-Nov)	14	linnet	0.49
		total density	0.19
1993 (Dec-Feb)	14	lapwing	0[1]
		blackbird	0.26
		total density	0.11

Fields <1.0 ha not included. **P<0.05.
[1]No birds were recorded on stubble fields.

Table 15. The differences in skylark density (pairs/ha) occurring in **grass fields** in the **breeding season** between organic and conventional farms. n=number of farms. The sum of means have been divided by the total for both farms within a farm pair. Negative values indicate conventional>organic. P values calculated from randomisation tests; no differences were significant.

year	n	density index
1992	8	0.99
1993	32	0.23

Fields <1.0 ha not included.

Table 16. The differences in skylark density (pairs/ha) occurring in **winter cereal fields** in the **breeding season** between organic and conventional farms. n=number of farms. The sum of means have been divided by the total for both farms within a farm pair. Negative values indicate conventional>organic. P values calculated from randomisation tests.

year	n	density index
1992	12	0.99**
1993	14	0.40**

Fields <1.0 ha not included. **$P<0.05$.

Table 17. F ratios calculated from a general linear model of the effect of farming system, farm pair (geographical location) and total boundary length on Shannon-Weiner diversity indices calculated for birds in field boundaries in the breeding season. Interactions are not shown, but none were significant.

model variable	1992	1993	1994
farm system	$F_{1,4}=0.25$ NS	$F_{1,14}=0.22$ NS	$F_{1,10}=2.78$ NS
farm pair	$F_{6,4}=1.20$ NS	$F_{16,14}=3.32$ **	$F_{12,10}=2.20$ NS
total length	$F_{1,4}=0.01$ NS	$F_{1,14}=0.43$ NS	$F_{1,10}=5.93$ **

**P<0.05.

Table 18. F ratios calculated from a general linear model of the effect of farming system, farm pair (geographical location) and total boundary length on Shannon-Weiner diversity indices calculated for birds in field boundaries in the winter. No interactions were significant.

model variable	1992 (early)	1992 (late)	1993 (early)	1993 (late)
farm system	$F_{1,12}=3.89$ NS	$F_{1,15}=0.02$ NS	$F_{1,13}=2.39$ NS	$F_{1,11}=0.03$ NS
farm pair	$F_{16,12}=8.14$ ***	$F_{17,15}=2.54$ **	$F_{16,13}=3.93$ **	$F_{13,11}=1.54$ NS
total length	$F_{1,12}=3.06$ NS	$F_{1,15}=0.02$ NS	$F_{1,16}=15.92$ ***	$F_{1,11}=3.54$ NS

**P<0.05 ***P<0.01.

Table 19. F ratios calculated from a general linear model of the effect of farming system, farm pair (geographical location) and total field area on Shannon-Weiner diversity indices calculated for birds in fields in the winter. No interactions were significant.

model variable	1992 (early)	1992 (late)	1993 (early)	1993 (late)
farm system	$F_{1,12}=0.69$ NS	$F_{1,14}=0.20$ NS	$F_{1,13}=0.32$ NS	$F_{1,11}=0.03$ NS
farm pair	$F_{16,12}=4.06$ ***	$F_{16,14}=2.59$ **	$F_{15,13}=4.52$ ***	$F_{13,11}=2.61$ (*)
total area	$F_{1,12}=3.67$ NS	$F_{1,14}=1.05$ NS	$F_{1,13}=0.12$ NS	$F_{1,11}=0.13$ NS

**P<0.05, ***P<0.01.

APPENDIX I: Instructions to observers.

Below is an exact copy of the field work instructions provided to all field workers on the project.

FIELDWORK SUMMARY

The fieldwork is summarised in four parts, below, with detailed instructions following on subsequent pages. All fieldwork will be carried out on two study plots; one on an organic farm, and one on either a nearby conventional farm, or a conventional part of the same organic farm. Once on the farms, the precise area and boundary of each study plot is yours to decide, subject to the constraints set out in these instructions.

1. MAPPING CENSUSES of the distribution of birds during the breeding season on each study plot. This fieldwork uses similar methodology to that applied in the Common Birds Census (CBC). The main difference is that a MINIMUM OF FOUR VISITS (rather than 8-10 as in the CBC) will be made to each plot between 15 April and 15 July. All data should be recorded on copies of a 1:2500 base map, with one copy used per visit.

2. Completion of a HABITAT MAP and FIELD BOUNDARY HABITAT FORM for each plot during the mapping season. These will identify the crop in each field, and describe the field boundaries and any areas of non-crop habitat on the plot. These data should be easily collected in the course of mapping visits, or by asking the farmer. Completion of the HABITAT MAP and FIELD BOUNDARY HABITAT FORM is a key part of the project because it enables all fields and field boundaries on the plots to be given a unique code number which will assist greatly my analysis of the bird populations which you record on the plot.

3. COUNTS of birds using the plots during the remainder of the year. This will require monthly visits to each plot between September and March inclusive. Counts of birds will be made for each field, and for each field boundary. Any changes in the state of fields (e.g. harvesting, ploughing, sowing) between counts or since the end of the mapping censuses should also be noted. FIELD COUNT and FIELD BOUNDARY COUNT forms will be provided on which all these data should be recorded.

4. Completion of a FARMING PRACTICE QUESTIONNAIRE covering previous cropping, fertiliser, pesticide and farmyard manure inputs, cultivation and sowing techniques. This questionnaire should be completed with the help of the farmer.

INSTRUCTIONS - BREEDING SEASON MAPPING

a) The Plots

Your fieldwork will involve a minimum of FOUR visits to all parts of both plots, recording all contacts with birds (identified by sight or sound) on 1:2500 base maps. These maps are called VISIT MAPS. A special advantage of the mapping method is that it shows the approximate location of every bird detected. Maps can be compared in detail between years to show the preferred sites of each species in relation to habitat, and effects of habitat change. The area you choose as your plot can include any type of arable, horticultural or grass farmland, provided that it is more or less typical of the farm which you are covering. Where small woods and copses occur among fields, they should be included as part of the plot, but should not exceed 10% of the plot area. Each plot should be at least 30 hectares (75 acres) in size, and preferably 50 hectares (125 acres) or more.

In general, large plots are preferable to small ones, and plots approximately square or rounded are much better than plots which are long and thin. Plot boundaries must be clearly discernible features. You must be able to walk the entire boundary, so use field edges on farmland rather than draw imaginary lines across open fields. Areas known to be particularly rich in birds, such as shelter belts, should be avoided as plot boundaries wherever possible.

Please decide on your organic farm plot first. **Then, when choosing your conventional farm plot, please try to ensure that it matches the organic farm plot as closely as possible in terms of shape, area, field sizes, crop types and areas of non-crop habitat.** You will use the same plots for your counts of birds outside the breeding season.

b) The Mapping Visits

The basis of the breeding season fieldwork is the MAPPING VISIT, involving full coverage of all parts of the plot. Normally, each visit should be completed within a few hours; partial visits are to be avoided if at all possible. If it is possible for you to cover both plots in one fieldwork outing then please feel free to do so. However, if you do this, please alternate between visits the plot which is covered first. This will guard against any apparent differences between the plots being due to the time of day that you visit them! **For the minimum four visits to a plot, the ideal distribution is: the first in mid-late April, the second in early May, the third in late May or early June, and the fourth in late June or early July.** The ideal would be to match each pair of visits, conventional and organic, for time of day (within an hour), time of year (within a week), and weather. Of course, the unpredictability of the weather and the other calls on your time will rarely allow pairings to be very precise.

Carry the visit map attached to a clipboard. Use a brightly coloured ballpoint pen or, in wet weather, a pencil. You will need binoculars, but no other equipment. Morning is generally the best time to make a census visit, since activity and song output are usually at their greatest. If possible, aim to start fieldwork within two hours after sunrise. Do not start before sunrise. Cold, windy or wet days are to be avoided since the activity and detectability of the birds are much reduced. However, please try not to allow persistently bad weather during the season to prevent you from carrying out your full complement of visits. It is better to make a relatively inefficient visit than to miss a visit entirely or submit data from only a partial visit.

The aim of each visit is to mark on the map the location and movements of every bird present during the visit, but to record each individual once only. The lists of ACTIVITY CODES and SPECIES CODES show how this can be done. **It is essential that the standard codes are used for species and activities.** Please take special note of the section describing dotted and solid lines between registrations, since proper use of these symbols is essential for easy and accurate analysis of your maps. As you enter the plot, record the date and your start time on the visit map. On completion, note your finishing time. Make a brief note of the weather and the extent of your coverage during the visit. At the end of the mapping season (by the end of July), all visit maps should be returned to me for analysis. Copies will be returned to you for your future reference.

About 3-4 hours are required for thorough coverage of the average farmland plot. Progress can be quite fast, since the number of birds detectable from any one point is usually rather limited, but the route should take the observer at least once along every major internal field boundary as well as completely around the perimeter of the plot. Accurate placing of the registrations on the map is usually made easy by the network of field boundaries. Take care not to damage crops and hedgerows. If there is no path next to a hedge that must be walked, the best alternative is the first set of tractor wheel-tracks (tramlines), usually about 5m from the hedge. Frequent use of binoculars is essential for an efficient census on farmland, since typically most of the birds in view will be some distance away. Sequential movements of individual birds should be recorded carefully. Coverage should be as even as possible, but more time should be allowed for areas where bird density is higher. The direction and, if possible, starting point of the route should be varied between visits.

Please do not conduct intensive nest-searching. However, please record all active nests you happen to find during normal census work. Do not spend time nest-searching to the detriment of mapping the birds, except for those species (Grey Heron, Rook, Sand Martin, House Martin, Swallow, Woodpigeon, Magpie, Jackdaw, Carrion Crow, House Sparrow, Starling) for which nest counts give an accurate estimate of the numbers present. As with all nest-finding it is essential to keep disturbance to a minimum.

An Optional Extra

Four visits to each plot is the **minimum** requirement. If you have the time and enthusiasm, please feel free to carry out extra pairs of visits to your study plots during the mapping season. The greater the number of visits, the more valuable the data. If you can achieve 9-10 visits on either (or both) of your plots, and you can repeat the exercise in 1993, and further seasons, please ask John Marchant at The Nunnery to register you with the farmland CBC. This will more than double the value of your fieldwork.

INSTRUCTIONS - HABITAT MAP AND FIELD BOUNDARY HABITAT FORM

Information on the nature of the habitat within each plot is an essential complement to the data you collect on the numbers and distribution of birds. During the mapping season, we therefore need you to complete a full HABITAT MAP. This should be done on one of the 1:2500 base maps, and should describe the permanent skeleton of the plot - including field boundaries, tracks and lanes, buildings, gardens, scrub, copses, permanent pasture, streams and standing water - together with a note of the crop being grown in each field. The following four items should be included on the HABITAT MAP.

A. The plot boundaries should be clearly marked.

B. **Each field and each field boundary unit (a unit is any length of field boundary between intersections) on the plot should be marked with a unique number. Please use a separate sequence of consecutive numbers from 1 upwards for fields and field boundary units respectively. Each number will then identify a particular field or field boundary unit on the count forms.**

C. The crop being grown in each field on the plot should be identified. A list of letter codes for different crops is provided below. Please mark each field on the habitat map with the appropriate code. To each of the codes, please add (c) if the field is farmed conventionally, (o) if the field is farmed organically, or (t) if the field is in transition from conventional to organic standards. For example, WW(o) = organic winter wheat. If you are in any doubt as to the identity of a crop, seek the help of the farmer. Please also note on the habitat map the presence of any bird scaring devices (e.g. scarecrows, bangers) on fields.

Crop Codes

WW	Winter Wheat	CS	Cereal Stubble
WB	Winter Barley	OS	Other Stubble
SW	Spring Wheat	BD	Bare (Deep Ploughed)
SB	Spring Barley	BS	Bare (Shallow Ploughed)
O.	Oats		
C.	Carrots		
PO	Potatoes	LG	Ley Grass
B.	Beet	PG	Permanent Grass
R.	Other Roots	SA	Set Aside Grass
OR	Oilseed Rape	UG	Unknown Grass
BR	Other Brassica		
LS	Linseed		
P.	Peas		
BN	Beans		
M.	Maize		
UC	Unknown Crop		

D. Each copse or woodland block on the plot should be described (approximate canopy height and species composition, shrub layer species composition, ground composition and any dominant species in the field layer).

The second important requirement is that detailed information be recorded on the structure of all field boundaries on the plot. A FIELD BOUNDARY HABITAT FORM is provided for this purpose to avoid the need for lengthy descriptions of field boundary structure on the habitat map. This form uses the same numbering system to enable cross reference between field boundary units and the habitat map. Codes for each boundary character (e.g. height, width) are given at the bottom of the form. These codes should be entered in the appropriate boxes for each boundary unit. **Please note that a FIELD BOUNDARY HABITAT FORM can be used for field boundary units 1-9, 10-18 or 19-27. Please tick the number sequence being used (or delete the two sequences not being used) when completing the form.**

Habitat information can usually be collected in the course of normal mapping visits, but make a special visit if you wish. Please ensure that all habitat information ends up on a single, separate habitat map, rather than scattered on several visit maps. The HABITAT MAP and FIELD BOUNDARY HABITAT FORM should be returned with the VISIT MAPS by the end of July.

INSTRUCTIONS - FIELD COUNTS AND FIELD BOUNDARY COUNTS

Your fieldwork will involve monthly visits (September-March inclusive) to both plots, recording all birds using each field and each field boundary unit on the plot. To collect this information, walk all the field boundaries keeping separate notes of birds in the centre of fields, near the edge of fields, and in the field boundaries themselves. These data should be recorded on the FIELD COUNT FORMS and FIELD BOUNDARY COUNT FORMS provided. As in the mapping visits, it is important that your coverage of the plot is complete and thorough. Sometimes, it may be impossible to detect smaller birds in the middle of the field from the perimeter walk. In this case, you should also walk one diagonal of the field. Edge totals refer to all birds recorded within 5m of the field boundary. Any boundary strip is treated as part of the field boundary. Centre totals refer to all other birds recorded on the field. Insert these totals on the FIELD COUNT FORM and mark each total 'E' (edge) or 'C' (centre) as appropriate (e.g. Red-legged Partridge 23C,3E Blackbird 4E). Similarly, for field boundary counts all you need to record is a total count for each species present in each field boundary unit, and enter these totals on the field boundary count form. Each bird seen should be assigned to either a field count (E or C) or a field boundary count, according to where it was **first** recorded. Birds flying over the plot but not using it should not be recorded. Hunting kestrels, feeding swallows and singing skylarks are examples of observations of flying birds which clearly **are** using the plot. Birds recorded in locations on the plot that cannot be categorised as either 'field' or 'field boundary' should be recorded in the extra column to the left of the species name.

As with the FIELD BOUNDARY HABITAT FORM, the FIELD COUNT and FIELD BOUNDARY COUNT forms are designed to be used with the numbering system used on the habitat map to allow cross-referencing between the map and the forms. Again, please tick the number sequence being used (or delete the other two) when you are completing the form.

One potential problem with this aspect of the fieldwork is that birds may move between fields and hedges during the course of the visit, thus introducing the possibility of double-recording of individuals or flocks of birds. To some extent, this problem is unavoidable. However, we would ask you to take careful note of the flight directions and likely landing points of birds that you disturb whilst censusing, and thereby to try and ensure that birds are only included in the count for the first field or field boundary in which they are detected.

During each visit it is also important that you should note any change in the state of a field or field boundary since the previous visit. The baseline from which to record these changes will be the HABITAT MAP completed during the mapping season. Changes will be largely the result of routine farm operations on fields such as harvesting, stubble burning/incorporation, manuring, deep or shallow ploughing, sowing, and hedge trimming. Space is provided on the FIELD COUNT and FIELD BOUNDARY COUNT FORMS to use the crop codes and field boundary habitat codes to record any such changes.

Other general guidelines for this part of the fieldwork are essentially the same as for the mapping visits. As with the mapping fieldwork, please feel free to carry out extra pairs of visits to the plots to conduct counts if you wish to do so. The additional information will be very valuable. Please return FIELD COUNT and FIELD BOUNDARY COUNT FORMS to me as soon as you have completed the plot visits for that month.

INSTRUCTIONS - FARMING PRACTICE QUESTIONNAIRE

This questionnaire can either be completed by you, in consultation with the farmer, or can be left with the farmer for completion and collected later. One form should be completed for every field on the plot. The farmer is under no obligation to complete the questionnaire. However, it should be impressed upon him that data on inputs to fields and cultivation techniques employed are extremely valuable to the project, and that the fullest possible answers to the questions asked will be greatly appreciated. There is space on the questionnaire to insert the code number of each field as marked on the HABITAT MAP. Please return all completed questionnaire forms to me in October.

APPENDIX II: Mean Bird Densities on Organic and Conventional Farms.

In the following tables mean bird density per boundary is presented. Density indices were actually calculated from the sum of means per farm rather than the mean of each sampling unit (field boundary or field) over the whole data set, so the standard deviations presented here will tend to be more extreme than the actual deviations per individual farm, but the data still give a good indication of the high variability in bird density. The density index can still be calculated by multiplying the mean per species by the number of farms in the sample and then calculating the difference between farm types (organic-conventional) divided by the sum of farm types (organic+conventional). Exact duplication of density indices presented in the text is not likely due to rounding errors.

Table I: Mean (±SD) boundary density (pairs/100m in the breeding season, individuals/100m in the winter) per farm of selected species and total species on organic and conventional farms. Original densities have been multiplied x 10^2 for presentation purposes.

(a) 1992 breeding season

	organic	conventional
no. farms	7	7
no boundaries	168	194
species		
turtle dove	0.38±2.34	0.17±1.18
wren	8.42±16.34	7.05±14.81
dunnock	5.50±11.15	3.28±7.16
robin	6.18±13.29	4.65±10.59
blackbird	9.37±15.60	7.05±11.54
song thrush	0.79±2.81	0.98±3.96
whitethroat	3.80±8.27	3.17±7.92
long-tailed tit	0.96±4.05	0.81±2.89
blue tit	9.86±16.47	6.96±13.26
great tit	5.22±12.36	2.68±6.43
tree sparrow	0.20±1.71	0.21±1.28
chaffinch	12.88±16.74	12.70±16.83
greenfinch	1.19±3.96	0.73±3.08
goldfinch	0.84±3.74	0.74±3.19
linnet	0.69±3.17	0.49±2.49
bullfinch	0.68±3.54	0.46±2.45
yellowhammer	6.20±11.20	3.84±9.07
reed bunting	1.81±5.82	0.64±3.60
total density	97.85±89.92	78.98±73.54

(b) 1992 winter

	Sept.-Nov.		Dec.-Feb.	
	organic	conventional	organic	conventional
no. farms	17	17	18	18
no boundaries	490	479	513	505
species				
wren	8.46±19.78	7.63±17.17	6.42±13.99	5.20±11.89
dunnock	9.18±21.28	7.26±27.74	9.17±22.16	6.22±17.94
robin	17.11±25.29	14.05±26.55	13.10±23.52	10.14±17.94
blackbird	27.24±69.79	11.48±44.70	21.77±35.72	18.56±38.57
fieldfare	8.38±74.13	10.87±138.92	15.12±164.39	9.92±90.22
song thrush	4.34±15.05	2.74±11.54	5.62±15.47	4.32±12.25
redwing	18.50±116.42	10.47±72.50	19.50±100.39	5.84±38.26
long-tailed tit	5.99±37.46	5.60±39.45	6.57±29.28	4.76±33.79
blue tit	17.82±37.21	13.00±36.47	16.41±38.43	12.11±28.06
great tit	7.08±20.13	5.88±21.21	8.38±22.16	5.90±18.55
tree sparrow	1.87±22.63	0.35±5.68	3.37±29.82	1.08±20.62
chaffinch	30.24±99.11	13.81±51.97	29.19±103.10	19.58±208.42
greenfinch	16.08±103.61	7.86±72.31	3.67±22.06	4.88±36.43
goldfinch	2.96±22.29	1.71±11.15	1.78±28.29	8.09±115.59
linnet	6.06±77.24	1.79±26.49	6.16±78.87	0.02±0.64
bullfinch	2.81±12.61	1.00±7.42	2.06±11.97	0.76±6.05
yellowhammer	8.09±39.35	8.25±53.30	5.81±32.35	5.36±42.36
reed bunting	1.00±8.14	0.34±4.86	2.081±8.53	1.93±40.94
total density	276.06±434.13	190.22±373.34	283.78±825.76	211.14±521.48

(c) 1993 breeding season

	organic	conventional
no. farms	18	18
no boundaries	460	414
species		
turtle dove	0.15±1.36	0.09±0.99
wren	9.06±17.02	9.13±16.31
dunnock	4.77±11.14	3.86±9.15
robin	9.85±15.62	7.24±13.15
blackbird	10.21±14.64	8.52±13.33
song thrush	1.35±4.86	1.07±4.67
whitethroat	1.67±5.47	1.70±5.57
long-tailed tit	0.43±2.78	0.82±3.84
blue tit	7.25±12.64	6.64±11.97
great tit	5.36±11.35	3.71±8.11
tree sparrow	0.74±4.23	0.36±2.44
chaffinch	15.33±21.57	13.83±18.40
greenfinch	1.83±5.66	1.49±6.30
goldfinch	0.92±4.26	0.57±3.04
linnet	1.76±7.70	1.82±7.96
bullfinch	0.36±2.11	0.48±3.15
yellowhammer	6.36±12.31	5.24±10.53
reed bunting	0.29±2.11	0.25±2.02
total density	96.33±88.87	92.47±113.38

(d) 1993 winter

	Sept.-Nov.		Dec.-Feb.	
	organic	conventional	organic	conventional
no. farms	17	17	15	15
no boundaries	445	411	312	297
species				
wren	7.77±17.83	7.73±16.45	4.01±11.19	4.51±11.16
dunnock	6.61±16.55	7.71±21.36	6.63±17.76	7.60±21.27
robin	17.36±27.93	14.84±24.07	11.77±21.54	9.77±18.62
blackbird	25.72±53.63	17.73±47.90	20.68±33.30	16.66±27.44
fieldfare	57.25±520.17	18.35±105.05	8.54±59.24	5.44±48.69
song thrush	5.32±40.33	2.30±12.62	3.32±10.98	1.85±7.08
redwing	100.94±1043.63	12.64±66.16	24.93±180.89	4.48±27.89
long-tailed tit	7.41±39.60	5.82±35.47	2.32±31.40	2.41±19.41
blue tit	17.30±39.85	15.65±40.42	15.64±36.54	10.70±28.69
great tit	10.22±28.48	6.22±17.62	10.26±32.33	5.16±18.18
tree sparrow	1.54±17.33	1.21±14.26	0.11±1.49	0.18±3.16
chaffinch	34.15±283.65	19.59±63.23	21.23±74.16	13.06±56.43
greenfinch	1.71±12.26	3.42±19.12	2.38±13.41	4.40±27.66
goldfinch	8.87±93.57	1.41±9.53	9.06±109.17	0.27±2.68
linnet	4.58±79.40	0.76±7.77	6.71±96.30	1.41±16.68
bullfinch	1.75±8.98	0.74±5.02	2.04±9.22	0.75±4.83
yellowhammer	5.59±30.79	3.97±17.25	3.50±22.97	3.62±17.81
reed bunting	0.13±1.43	0.18±2.23	0.54±6.42	0.00
total density	399.18±1665.22	220.61±465.90	214.75±425.65	140.98±244.70

(e) 1994 breeding season

	organic	conventional
no. farms	13	13
no boundaries	331	275
species		
turtle dove	0.33±2.84	0.07±1.12
wren	8.59±13.62	7.23±13.51
dunnock	5.33±10.71	4.45±8.77
robin	10.21±16.12	7.07±12.79
blackbird	11.56±15.93	7.95±13.65
song thrush	2.22±7.27	0.94±3.87
whitethroat	1.51±5.19	1.03±3.76
long-tailed tit	0.88±3.47	0.71±3.61
blue tit	8.35±16.61	7.34±13.04
great tit	5.39±11.89	3.83±9.41
tree sparrow	0.29±2.69	0.24±2.37
chaffinch	13.82±17.05	13.88±19.25
greenfinch	2.13±7.68	1.56±6.57
goldfinch	1.04±4.40	0.98±4.72
linnet	1.31±5.32	1.05±4.66
bullfinch	0.67±3.16	0.24±1.73
yellowhammer	5.40±11.42	5.33±11.84
reed bunting	0.06±1.11	0.00
total density	97.30±86.34	77.19±67.80

Table II: Mean (±SD(n)) skylark density (pairs/ha) per field on organic and conventional farms in the breeding season. Original densities have been multiplied x 10^2 for presentation purposes.

year	organic	conventional	no. farms
1992	24.57±52.75 (61)	4.39±7.19 (58)	12
1993	5.27±9.75 (178)	2.60±5.08 (161)	34
1994	2.94±5.80 (121)	3.23±6.77 (98)	26

Table III: Mean (±SD) field density (birds/ha) per farm of selected species and total species on organic and conventional farms in the winter. Original densities have been multiplied x 10^2 for presentation purposes.

(a) 1992

	Sept.-Nov.		Dec.-Feb.	
	organic	conventional	organic	conventional
no. farms	17	17	18	18
no fields	161	129	174	140
species				
red-legged partridge	2.85±15.60	1.49±6.66	2.81±11.16	1.09±6.23
grey partridge	0.72±6.20	0.98±5.55	0.77±5.06	0.28±1.96
lapwing	0.32±3.07	1.21±12.20	3.31±37.59	2.08±14.88
stock dove	0.33±2.65	0.34±2.78	1.25±8.81	27.29±312.89
wood pigeon	44.01±204.19	23.95±124.65	66.86±256.75	18.30±96.73
skylark	16.68±59.93	3.74±19.42	22.00±77.50	11.72±67.28
starling	89.65±495.56	30.32±149.15	76.66±349.99	42.86±130.67
blackbird	1.28±5.69	0.78±4.27	3.97±11.22	4.13±19.47
fieldfare	0.00	0.27±2.16	15.49±124.20	14.97±69.69
song thrush	0.53±4.53	0.24±2.03	1.00±7.89	2.04±12.14
redwing	3.66±30.62	0.00	13.54±104.49	13.17±66.90
mistle thrush	0.18±1.95	1.56±13.97	2.31±20.27	0.85±3.44
chaffinch	23.83±164.58	4.92±23.14	16.84±99.46	9.06±47.41
greenfinch	47.85±469.83	0.08±0.86	28.92±207.97	0.23±2.84
goldfinch	4.46±30.43	5.05±50.03	2.65±27.59	1.54±17.01
linnet	31.27±188.70	6.89±54.99	2.52±22.19	0.00
yellowhammer	34.11±367.86	1.19±6.77	3.31±21.82	1.84±12.90
total density	421.85±969.84	180.16±538.77	395.18±945.68	219.14±467.92

(b) 1993

	Sept.-Nov.		Dec.-Feb.	
	organic	conventional	organic	conventional
no. farms	17	17	18	18
no fields	160	140	132	123
species				
red-legged partridge	1.48±9.21	2.45±13.24	0.89±9.88	0.72±4.63
grey partridge	0.56±7.12	0.00	0.21±2.46	0.00
lapwing	3.80±36.37	4.89±41.37	0.00	9.89±107.83
stock dove	0.12±0.53	0.09±0.92	2.52±28.33	0.00±0.36
wood pigeon	46.05±198.61	56.85±251.71	81.75±216.30	59.79±265.81
skylark	25.09±129.43	5.71±28.98	8.70±42.77	5.50±42.33
starling	67.26±341.63	96.43±371.12	212.66±1086.61	55.39±150.53
blackbird	5.50±16.25	3.69±15.36	15.79±44.67	7.57±22.30
fieldfare	52.70±398.99	61.76±486.50	125.63±750.01	31.65±156.26
song thrush	0.67±3.44	0.89±7.79	3.45±18.58	1.45±6.40
redwing	53.13±623.32	26.22±195.09	107.28±873.18	69.88±699.56
mistle thrush	20.63±247.23	0.94±4.62	0.78±3.68	1.63±7.36
chaffinch	13.97±85.77	12.57±59.74	62.29±397.62	17.74±114.60
greenfinch	12.96±135.07	0.94±8.47	2.21±22.47	0.17±2.05
goldfinch	60.57±8.72	1.18±8.19	0.40±4.80	0.48±3.98
linnet	56.29±491.99	1.76±17.50	6.57±47.73	1.20±13.52
yellowhammer	1.09±7.08	3.06±18.68	0.29±3.50	0.51±1.79
total density	507.46±1577.43	347.83±978.15	728.08±2004.41	354.78±862.36

Appendix III: Scientific names of species mentioned in the text. Following Voous (1977).

Red-legged partridge *Alectoris rufa*

Grey partridge *Perdix perdix*

Lapwing *Vanellus vanellus*

Stock dove *Columba oenas*

Woodpigeon *Columba palumbus*

Turtle dove *Streptopelia turtur*

Swift *Apus apus*

Skylark *Alauda arvensis*

Wren *Troglodytes troglodytes*

Dunnock *Prunella modularis*

Robin *Erithacus rubecula*

Blackbird *Turdus merula*

Redwing *Turdus iliacus*

Song thrush *Turdus philomelos*

Mistle thrush *Turdus viscivorus*

Fieldfare *Turdus pilaris*

Whitethroat *Sylvia communis*

Blue tit *Parus caeruleus*

Great tit *Parus major*

Long-tailed tit *Aegithalos caudatus*

Starling *Sturnus vulgaris*

House sparrow *Passer domesticus*

Chaffinch *Fringella coelebs*

Greenfinch *Carduelis chloris*

Goldfinch *Carduelis carduelis*

Linnet *Carduelis cannabina*

Bullfinch *Pyrrhula pyrrhula*

Corn bunting *Miliaria caladra*

Reed bunting *Emberiza schoeniculus*

Yellowhammer *Emberiza cintrinella*

British Trust for Ornithology

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THE EFFECT OF ORGANIC FARMING REGIMES ON BREEDING AND WINTER BIRD POPULATIONS

PART III

Habitat Selection and Breeding Success of Skylarks *Alauda arvensis* on Organic and Conventional Farmland

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SUMMARY

1. The habitat selection, territory density, nesting success and diet of skylarks breeding on one organic farm and one conventional farm in north Suffolk were investigated during a two-year study to investigate the impact of organic farming practices on skylark breeding populations.

2. Territory density was higher on the organic than on the conventional farm and this difference could be explained largely by differences between the two farms in field size, boundary characteristics and cropping. Rotational and five-year set-aside, short-term grass leys and spring cereals (confined to the organic farm) were the most attractive field types to skylarks. Overall mean density on conventional cereals was less than half that on organic cereals, organic set-aside and conventional set-aside.

3. Densities of territorial male skylarks remained constant throughout the breeding season on all field types, with the exception of conventional winter cereals in 1993, when most territories were abandoned in late April and early May. In 1994, territory densities showed no such reduction. Possible reasons for this difference include differences in crop structure and growth rate due to differences in weather conditions between the two years.

4. Nesting activity commenced simultaneously on both farms but the timing varied between crops. On the organic farm nesting was earliest in set-aside but later on spring cereals. On the conventional farm nesting was earliest on winter cereals and set-aside but latest on sugar beet.

5. Breeding success (mean chicks fledged/nest) was higher on the organic farm than on the conventional farm in both years. On both farms, however, success was higher in 1993 than 1994 probably due to poor weather in the second year. In 1993 there were few nesting attempts, and no successful nests, on conventional cereals in striking contrast to organic cereals and set-aside. In 1994, however, nesting attempts were more frequent in conventional cereals than in 1993 and success in conventional cereals was similar to that on organic cereals and organic set-aside. These differences between years may have been a consequence of the fact that conventional crops grew more slowly and were patchier in 1994 than in 1993.

6. Broods on the organic farm were significantly heavier than broods of the same age on the conventional farm. A condition index, which examined body mass in relation to body size, tended to be greater on the organic farm but not significantly so.

7. Both rotational and non-rotational set-aside have great potential as nesting and feeding habitats for skylarks, but successful nesting on set-aside depends on farmers refraining from cutting close to the ground surface or cultivating set-aside between late April and the end of June.

8. Recommendations are made for further research on the ecology of skylarks on arable farmland.

1. INTRODUCTION

The skylark is a characteristic species of lowland farmland and other open habitats. It tends to avoid tall structures, for example trees and tall hedges, and rather than deliver its song from a raised perch, it usually does so either from the ground or in flight. The nest is a simple cup of woven grass lined with finer material, usually in a shallow depression in the soil. Both nest-building and incubation are carried out by the female. Clutch size is usually three or four (exceptionally two or five) with incubation beginning after the last egg is laid and lasting 11 days. Clutches laid later in the season tend to be larger. The young hatch synchronously and are tended by both parents. They leave the nest at 8-10 days old and fledge at 18-20 days, becoming independent at about 25 days old. Individual pairs make up to three, or exceptionally four, nesting attempts in one year. Territory size varies greatly according to different habitat characteristics, but most territories cover 0.25-2 ha. Pairs may shift or abandon their territories during the course of the season if vegetation structure becomes unsuitable. The above information is summarised from Cramp (1988).

Common Birds Census (CBC) data show a 54% decline of the breeding population of skylarks on British farmland between 1968 and 1991 (Fuller *et al.*, in press). The current population estimate of 1.35 million breeding pairs on British farmland (Gibbons *et al.*, 1993) implies a loss of over 1.5 million breeding pairs in 22 years. Similar declines have been reported in Denmark, Sweden, Germany and Switzerland (Busche, 1989; Zbinden, 1989; Hustings, 1992; Jacobsen, 1992). These declines have often been attributed to the intensification of arable agriculture in recent decades.

Analysis of farmland CBC plots in the early 1960s indicated that breeding skylarks preferred areas where cereal and root crops were predominant to areas which comprised mainly pastures and leys (Williamson, 1967). More recently, O'Connor and Shrubb (1986) showed that skylark population fluctuations during the period 1975-83 were positively correlated with the percentage of grassland in England and Wales which was ley grass under five years old. Both arable and grassland habitats have experienced changes in the latter half of this century. There has been a dramatic switch from spring- to autumn-sown cereals since the 1960s, which has led to a large-scale reduction in the area of stubble available for skylarks and other seed-eating passerines during the winter. At the same time, increased pesticide usage and improved harvesting methods have reduced the quantities of cereal and weed seeds available in stubbles, changes which have already been implicated in the decline of the cirl bunting *Emberiza cirlus* (Evans & Smith, 1994, 1995). Cereal grain and leaves are important components of the diet of skylarks, spring sown grain in particular being an important source of food in early spring when other food is scarce (Green, 1978). Changing farming practices have also led to a reduction in the area of ley grassland. This, combined with intensification of grazing, mowing and fertilising regimes, may have contributed to the decline in the British skylark population. Busche (1989) describes severe declines of skylark populations in Germany as a consequence of such changes.

In Britain, the first detailed study of the population ecology and breeding biology of skylarks took place in the Ravenglass dune system in Cumbria (Delius, 1963, 1965). More recently, detailed studies of the breeding biology and ecology of skylarks on farmland were carried out in Switzerland in the 1980s (Schläpfer, 1988; Jenny, 1990a,b,c). This research suggests that highest densities are reached when crop diversity is high so that different crop types provide suitable nesting habitat throughout the season. Where habitat is homogeneous over large areas, for example in intensively farmed areas, the overall density is lower and the distribution is often clumped. The reasons for this are unknown. Schläpfer (1988) found that dense vegetation exceeding 30-35 cm high was avoided and suggested that the reason for this was hindrance of movement at ground level. Poulsen (1993) found that winter cereals tended to support low territory densities (<0.03 ha^{-1}) with higher densities on spring cereals and grassland (0.03-0.10 ha^{-1}) and the greatest concentrations on five-year set-aside land (0.28 ha^{-1}).

Census work during the 1992 breeding season, as part of the BTO's Organic Farming and Birds Project, on 11 pairs of organic and conventional farms, plus two farms with a mixture of organically and conventionally managed fields, showed higher densities of territorial male skylarks on organic cereal and grass fields in comparison with conventional counterparts (Wilson, 1995). One reason for this difference may be that organic cereals provide a more suitable nesting habitat for skylarks (see Schläpfer, 1988) because they are less heavily fertilised and are often sown later and less densely than conventional cereals (Lampkin, 1990). Similarly, organic grass is often short-term ley, which may provide a more suitable vegetation structure for nesting than the dense, heavily fertilised swards of herbage seed, silage or permanent grass on conventional farms. In addition, food availability may be greater on organic farms due to the withdrawal of pesticide inputs and the retention of rotational practices such as undersowing. The latter favours invertebrates that only overwinter successfully in undisturbed soils, for example sawfly larvae, which have been shown to form a large proportion of the diet of skylark chicks (Barker, 1992). Finally, the greater crop diversity associated with organic crop rotations may provide better opportunities for repeat nesting attempts than exist on conventional farms and also contribute to a greater diversity and abundance of invertebrate food sources for skylarks.

Given the findings of the 1992 breeding season census work, we decided to initiate a more detailed investigation of habitat selection, nesting success, diet and chick condition on organic and conventional farms in order to understand better the apparent benefits of organic farming systems for breeding Skylarks. The work took place during the 1993 and 1994 breeding seasons on one pair of farms in East Anglia. This report documents the results of this work and makes recommendations for further work in this field.

2. METHODS

2.1 Study area

Two study plots in Suffolk were used, one at Village Farm, Market Weston (TL9878), the other at Hall Farm, Coney Weston (TL9678). The Village Farm plot, which has been at Soil Association organic standards for over 20 years, comprised 12 fields with a total area of 46 ha. At Hall Farm, which is under a conventional regime, 13 fields with a total area of 133 ha were studied. In 1993, Village Farm grew winter and spring cereals, one short-term grass/clover ley, three fields under MAFF five-year set-aside grassland and one field of naturally regenerating oat stubble under the new rotational set-aside (RSA) regulations. In 1994, no winter cereals were grown, the winter triticale stubble had been under-sown with clover and two fields had been left fallow after ploughing (Figure 1). In both 1993 and 1994, Hall Farm grew winter cereals, sugar beet and peas, under an intensive pesticide and fertiliser application regime. In 1993, one field was sown with perennial ryegrass under RSA regulations. In 1994, however, linseed was sown as a set-aside crop (Figure 2). A full list of crops and field types is given in Table 3.1

2.2 Territory mapping

Identical methods were used in both years. Each study plot was visited on 12 occasions between mid-March and mid-June. On each occasion the location of all singing male skylarks was recorded on 1:2,500 maps. Particular attention was paid to plotting the start and end points of song-flights. These were found to be good indicators of the 'core' territories of paired males. Any subsequent nest was usually found within an area defined in this way. All mapping visits were made in the morning, between 6am and midday. In areas of high territory density, song frequency (i.e. song output per individual) was higher than in areas where territory density was very low (unpublished data). Consequently, there was less likelihood of detecting a single isolated territory on every visit than there was of detecting one with many others nearby.

Table 3.1 **Areas (ha) of crops and field types on Hall and Village Farms in 1993 and 1994.**

	CONVENTIONAL (HALL FARM)		ORGANIC (VILLAGE FARM)	
	1993	1994[1]	1993	1994
Spring barley	0	0	3.3	4.5
Spring wheat	0	0	5.0	4.8
Spring oats	0	0	4.5	7.0
Winter barley	25.5	31.1	0	0
Winter wheat	35.8	9.8	7.8	0
Winter oats	14.5	16.1	0	0
Winter triticale	0	0	2.0	0
Peas	9.8	7.0	0	0
Sugar beet	36.3	31.3	0	0
Linseed	0	26.8	0	0
Ley	0	0	3.5	3.5
Fallow	0	0	0	9.0
Rotational set-aside	11.0	0	4.8	2.0
5-year set-aside	0	0	15.8	15.8

[1] One field of 10.8 ha that had been surveyed in 1993 was not surveyed in 1994 by mistake.

2.3 Field characteristics

In both years, vegetation height and percentage ground cover were recorded at 10 points on a diagonal transect across each field. The points on each transect were evenly spread, so that the distances between each point and between the start and end points and the respective field corners were all equal. Measurements were taken on three occasions - mid-April, mid-May and mid-June. At each location, height was measured using a tape measure, and percentage ground cover (including both crop and weeds) was estimated by eye with the aid of a 50 cm × 50 cm quadrat divided into a 5 × 5 cm grid. Mean values were then calculated for each field for each of these months and graphs plotted of mean vegetation height versus mean percentage cover.

An index of field boundary structure was calculated by dividing the perimeter of each field into sections, according to the following numerical categories (0=no vertical structure, 1=low hedge/wall/bank, 2=tall hedge/wall/bank, 3=hedge with trees or line of trees, 4=woodland edge, or boundary of other unsuitable habitat such as gardens, scrub, buildings etc.). The length of each section was multiplied by its category score and the sum over all sections divided by the perimeter length to give a 'boundary index' for that field. Values range from 0 (no vertical structure in field boundary) to 4 and provide a crude index which can be used to examine the influence of the field boundary on the attractiveness of the field to skylarks. An index of field shape was calculated by expressing the actual perimeter of each field as a proportion of the minimum perimeter for a field of the same area (i.e. the perimeter if the field was circular).

2.4 Location of nests

In 1993, several techniques for locating skylark nests were tested. By far the most productive technique for finding nests was found to be to watch skylark activity for a minimum period of 45-60 minutes per field in any one day and look for evidence of nesting activity. Thus, in 1994, this was the only technique employed and the majority of nests were found by watching the female carrying nesting material and subsequently discovering a partially completed nest cup. A few others were found at the egg and chick stage. All but the most distant nests were located within an hour of noting the first evidence of nesting behaviour.

At any stage of the nesting period, it is essential to make the visits to the nest as brief as possible. This is particularly important during nest-building and incubation, when the female is more likely to desert the nest. Searches for nests during these stages were therefore very brief in order to cause as little disturbance as possible, both to the nest being searched for and to any others in the vicinity. Subsequent visits to the nest were usually made after a period of observation, when the parents were known to be absent.

2.5 Nest checks

The same protocol was followed in both years. Nests were visited on a daily basis, at approximately the same time of day, to record clutch or brood size and ring and measure chicks. Each chick was fitted with a BTO ring on the right leg and a single colour-ring on the left leg. In 1993, red rings were used for chicks hatched on Village Farm and yellow rings for chicks hatched on Hall Farm. In 1994, orange rings were used for chicks hatched on Village Farm and light blue rings for chicks hatched on Hall Farm. From three to nine days old, tarsus length of each chick was measured daily to an accuracy of 0.1 mm using vernier callipers, and mass was recorded to an accuracy of 0.1 g using a Pesola balance. In 1993, all measurements were recorded by the same observer. In 1994, two observers were involved, the second in the latter stages of the breeding season. All measurements of any individual brood, however, were taken by a single observer.

Faecal sacs were collected, preserved in 70% alcohol and analysed at the Institute of Arable Crops Research at Rothamsted.

2.6 Data analysis

All analyses were carried out using release 6 of the SAS statistical package.

3. RESULTS

3.1 Factors affecting territory density

Throughout both seasons densities of skylarks were consistently higher overall on the organic farm ($P<0.05$, Mann-Whitney tests comparing densities estimated on individual visits). Densities on conventional cereals and sugar beet (only present on conventional) were markedly lower than those on organic cereals, grass leys (only present on organic) and set-aside. Densities on conventional cereals were less than half those on organic cereals and set-aside (Figure 3).

Densities of territorial skylarks throughout the two seasons are shown for selected crop types in Figure 4. On the conventional farm in 1993 densities were consistently high on rotational set-aside. Densities were lower on the conventional winter cereals, and were especially low on winter wheat. Densities in conventional cereals declined rapidly after late April/early May, falling virtually to zero. There was no such decline in densities on organic cereals where densities were considerably higher throughout the breeding season. In 1994 there was no seasonal decline in skylark density in conventional cereals. Numbers remained relatively constant and densities in winter barley and winter oats were slightly higher than in 1993. There was no rotational set-aside on the conventional farm in 1994. On the organic farm there was an increase in densities on spring barley and spring oats towards the end of the 1994 breeding season.

There were differences in field structure between the two farms, for example the conventional fields were larger than the organic fields (Respective medians 9.75 ha, 4.00 ha; Mann-Whitney $P<0.001$). In 1993, ordination by Principal Components Analysis (PCA) was used to examine relationships between field structure and skylark abundance. PCA was undertaken on the following four field variables: field type (organic = 1, conventional = 2), boundary index, shape index, and field area. The first three principal components (PCs) together explained 96.2% of the total variance in field structure (54.1%, 26.3% and 15.8% respectively). PC1 was positively correlated with all four variables and reflects a gradient from open fields with relatively short boundaries (negative scores) to enclosed fields with relatively long boundaries (positive scores). In other words, PC1 reflects the basic differences in field structure between the organic and the conventional farm. PC3 reflects a gradient from open fields with relatively long boundaries (negative scores) to enclosed fields with relatively short boundaries (positive scores). PC2 has no obvious interpretation. The scores for all three PCs along with the percentage vegetation cover (arcsine-square root transformed) and vegetation height were entered into least-squares multiple linear regression analyses to explain variation in the density of singing male skylarks on the same sample of fields at each visit. All densities were log (+0.1) transformed to give a better approximation to a normal distribution. The analyses explained between 36.2% (visit six) and 61.8% (visit three) of variation in the density of singing male skylarks, with PC1 by far the most important predictor variable in all cases (Table 3.2). As expected, PC1 was inversely related to skylark density with a coefficient varying from −0.296 to −0.474. PC3 also predicted a significant proportion of variation in skylark density (9.7% - 15.7%) on some visits.

Again, this component was inversely related to skylark density with a coefficient varying from −0.361 to −0.463. PC2 was uncorrelated with skylark density. In no case did vegetation cover or vegetation height emerge as a significant predictor of skylark density. In summary, therefore, the skylarks were strongly associated with small, open fields and tended to avoid fields that were enclosed by tall boundaries such as hedges.

3.2 Seasonal changes in vegetation structure

Figures 5 to 7 compare the vegetation data collected in 1993 and 1994 for all fields containing a crop type common to both years. The solid line indicates the stage at which Schläpfer (1988) suggested crops become unsuitable for nesting skylarks. We have extrapolated this line back (hatched), assuming that even the tallest cereal crops (c. 100 cm) remain tolerable if overall vegetation cover is very sparse and ground level movement remains relatively unhindered. The box at the origin demarcates fields which are too bare of vegetation to provide adequate cover for nesting skylarks. In the following discussion, we refer to crops as being 'suitable' and 'unsuitable' for nesting skylarks according to their position with respect to these threshold lines.

Figure 5 compares the 1993 and 1994 data for April and shows a very similar pattern of growth between years, the only difference being the degree of variability in percentage cover between individual fields of conventional cereals in 1994. In both 1993 and 1994, all the conventional cereals and some of the set-aside fields were 'unsuitable' in May but the height and percentage cover of conventional winter barley was more variable and sugar beet growth was less advanced (Figure 6). There are three notable differences between the vegetation data for June 1993 and June 1994 (Figure 7). The first is the marked difference in the growth of the sugar beet between years, being much more advanced in 1993 than in 1994. The second is that some of the set-aside fields have once again become 'suitable' having been cut and begun to regrow. The third is the difference in the organic spring cereals which showed a much higher percentage ground cover in 1994 than those in 1993, although the height was similar in both years. In both years, the organic spring cereals became 'unsuitable' in June, later than all other cereals.

Table 3.2 **Relationship between skylark density and field and vegetation structure in 25 fields, March-June 1993. Skylark density on each visit is the dependent variable and field structure (as shown by principal components), vegetation cover and vegetation height are independent variables. Only statistically significant predictors (at P<0.05) are shown.**

Source	% Variance Explained	Regression Coefficient	Visit
TOTAL	47.8		1 (March)
PC1	43.4	−0.4711	1
TOTAL	52.9		2 (March)
PC1	31.7	−0.3940	2
TOTAL	61.8		3 (March)
PC1	38.4	−0.4039	3
PC3	11.3	−0.3809	3
TOTAL	54.2		4 (March)
PC1	26.6	−0.3445	4
PC3	9.7	−0.3612	4
TOTAL	44.0		5 (April)
PC1	26.9	−0.3281	5
PC3	14.3	−0.4833	5
TOTAL	36.2		6 (April)
PC1	24.4	−0.2957	6
PC3	14.8	−0.4665	6
TOTAL	51.2		7 (April)
PC1	44.8	−0.3595	7
TOTAL	56.5		8 (May)
PC1	50.3	−0.4136	8
TOTAL	56.9		9 (May)
PC1	53.3	−0.4342	9
TOTAL	60.1		10 (May)
PC1	53.6	−0.4735	10
TOTAL	44.1		11 (June)
PC1	30.1	−0.4073	11
TOTAL	51.1		12 (June)
PC1	31.5	−0.3901	12
PC3	15.7	−0.4378	12

3.3 Breeding season

A total of 41 nesting attempts was recorded in both 1993 and 1994. In 1993, the first clutch was initiated on 31 March and the last two on 11 June. In 1994, however, the first clutch was initiated much later, on 18 April, probably due to the unusually cold weather in the first half of the month. The last clutch was initiated on the 20 June, again later than the previous year. This may have been due to the delay in the start of the breeding season leading to a later finish, which was made possible by the long spell of warm, dry weather that lasted through most of June and the second half of July. Figure 8 shows the seasonal distribution of clutches in 1993 and 1994. In cases where the exact date was not known, the date of clutch initiation was estimated by extrapolation from the age of chicks or appearance of eggs, assuming an 11 day incubation period and four days from initiation to completion of the clutch. In both years, most clutches were laid in the last two weeks of April and the first two weeks of May.

Of 29 nesting attempts with known clutch size in 1993, one had two eggs, 16 had three and 12 had four (mean = 3.38±0.56SD). Of 26 nesting attempts with known clutch size in 1994, 19 had three eggs and seven had four (mean = 3.27±0.45SD). Larger clutches were laid later in the season (medians 121.5 and 143.5 for clutch sizes 3 and 4 respectively; Mann-Whitney $P<0.01$). In both years, mean clutch size was very similar to those recorded in other studies (Delius, 1965; O'Connor & Shrubb, 1986; Poulsen, 1993).

Figure 9 compares the mean clutch initiation date (±SE) for 1993 and 1994 on four field types: set-aside (organic and conventional), organic spring cereals, conventional winter cereals and sugar beet (1993) or grass verges (1994). Mean clutch initiation dates did not differ significantly between years (medians 126.5 and 128 for 1993 and 1994 respectively; Mann-Whitney $P>0.05$). Nesting activity commenced simultaneously on both farms but there were some differences in the timing of breeding between different field types. In both years, clutch initiation on the organic farm was earliest on the set-aside fields and much later on the spring cereals. On the conventional farm, clutch initiation was earliest on the conventional winter cereals and rotational set-aside. In 1993, later clutches were recorded on sugar beet, whereas none were recorded on sugar beet in 1994. Any attempts later in the season were recorded in the rough grass on the field margins but were not as late as those recorded on the organic spring cereals.

The much colder, wetter weather experienced early in the 1994 season meant that the conventional crops germinated more slowly than in 1993 and did not provide sufficient cover for nesting skylarks until approximately two weeks later than in 1993. This may have affected the mean clutch imitation date on conventional cereals, which was significantly later in 1994. The organic set-aside fields already provided sufficient cover for nesting skylarks at the start of the breeding season, while later on in the season, the weather conditions improved and the germination of the organic spring crops was relatively unaffected. Hence, the mean clutch initiation date on these fields was very similar between years.

3.4 Nesting success

Nesting success was higher on the organic farm than on the conventional farm in both years. The overall mean number of chicks fledged per nest (inclusive of all total failures) was 1.79 in 1993 and 0.89 in 1994 on the organic farm compared with 1.39 in 1993 and 0.36 in 1994 on the conventional farm. The lower productivity on both farms in 1994 reflects the poor weather conditions experienced early in the season. The effect was relatively greater on the conventional than the organic farm. In 1994, productivity on the conventional farm declined by 74% relative to 1993, but on the organic farm productivity dropped by 50% between the two years.

Figure 10 shows the mean number of chicks fledged per nest on each of seven field types in 1993 and 1994 and clearly demonstrates the greater productivity in 1993. The two most striking differences between the two years was the relative success of skylarks nesting on conventional winter cereals and conventional sugar beet in 1994 and 1993 respectively. In 1993, few nesting attempts were recorded on conventional cereals and no chicks fledged. In 1994, however, productivity was similar to that on organic spring cereals, organic set-aside and organic grass ley. Conversely, productivity on conventional sugar beet fields in 1993 was high due to a few successful late-season nesting attempts, whereas in 1994 no nesting attempts were recorded. Sugar beet grew much more slowly in 1994 due to the poor weather early in the season and was frequently sprayed and hoed. Thus, the crop would not have provided suitable nesting cover until later in the season and there would have been a higher probability of nest losses due to farming operations.

Table 3.3 shows the number of nest failures due to different causes. A much higher proportion of nests failed in 1994 than 1993, principally due to predation and starvation. The main causes of failure in 1993 were predation and farming operations. Of the five lost to farming operations, three were crushed by a tractor during the cutting of conventional rotational set-aside, one was destroyed by harrowing on an organic cereal field and one was trampled by farm workers hand-weeding an organic cereal field. No nests failed due to farming operations in 1994. The fact that there was no conventional rotational set-aside may have made a difference to losses of this nature on the conventional farm. In addition, the conventional farmer was managing the organic farm, causing a slight difference in the management regime between the two years. However, it may simply have been chance that no losses due to farming operations were recorded, since harrowing as a means of weed control continued to take place.

Table 3.3 Causes of nest failure on the organic (Village) and conventional (Hall) Farm in 1993 and 1994.

	1993		1994	
	Organic	**Conventional**	**Organic**	**Conventional**
Predation	4	2	8	6
Farming operations	2	3	0	0
Desertion	0	1	2	1
Starvation	0	1	0	3
Successful nests	17	11	14	7
Total nests found	23	18	24	17
Total nests failed (%)	6 (26%)	7 (39%)	10 (42%)	10 (59%)

3.5 Chick condition

Mean chick mass per brood was plotted against age separately for each farm in order to compare growth rates under the two regimes (Figure 11). On the organic farm the growth curve followed a pattern already documented in other small passerines, namely relatively slow growth in the first three days after hatching, followed by a rapid increase between four and eight days of age, before slowing down again as the chicks became old enough to leave the nest (O'Connor, 1984). The growth curve for broods on the conventional farm did not show this pattern, rather growth seemed to take place in short bursts throughout the nestling period. At five and eight days of age, broods on the organic farm were significantly heavier than broods of the same age on the conventional farm ($U=35$, $U=61$; Mann-Whitney $P<0.05$).

An index of condition of birds can be derived by examining residuals of mass on a measure of intrinsic body size (e.g. tarsus length) at a given age (e.g. Ormerod & Tyler, 1990). Birds with a higher than expected mass for their size are interpreted as being in good condition and birds with unexpectedly low masses as being in poor condition. However, the data for individual chicks within the same brood are not independent. Thus, for each age from three to nine days inclusive, the logarithm of mean brood mass was regressed on the logarithm of mean brood tarsus length using the least squares method. Log_{10} transformation was carried out because mass is not directly proportional to linear size and the regression may be expected to be based on some exponential relationship. The resulting regression equation:

$$\log_{10}\text{mass} = \log_{10}a + b\log_{10}\text{tarsus}$$

was rearranged to give:

$$\text{mass} = a \times \text{tarsus}^{b}$$

and expected mean chick masses for each brood were calculated from this equation.

The regression lines for each age explained between 98.8% (day 3) and 34.7% (day 9) of the variation in mass. The condition indices derived from these regressions ranged from +6.35g (day 6) to −9.75g (day 8). The mean condition index for all ages except three days was greater on the organic farm than the conventional farm (Figure 12), and the difference became more pronounced with age, but none of the individual differences was significant (Mann-Whitney $P>0.05$ for all ages).

These results may be affected by the fact that most of the successful nests on the conventional farm in 1993 were on a field of rotational set-aside which received no fertiliser or pesticide inputs during the breeding season. When the same data are re-cast according to the two dominant vegetation types (organic and conventional set-aside grass versus organic and conventional cereals), the mean mass of chicks in broods reared on set-aside was consistently heavier than chicks in broods of the same age reared on cereal fields (Figure 13). Moreover, this difference was significant for broods of three, four and five days of age (Mann-Whitney $P<0.05$). At all ages, except three and nine days for which the sample size was very small, the condition index for broods reared on set-aside was always positive, whereas for broods reared in cereal fields it was always negative (Figure 14), however there was no significant difference at any age (Mann-Whitney $P>0.05$).

4. DISCUSSION

Winter cereal crops have become an increasingly dominant feature of the lowland farmland landscape since the 1960s. In 1974, winter cereals comprised 35% of the total area of land in arable production (Chapman *et al.*, 1974), whereas in 1989-90, this had risen to 67%, more than 30% of lowland farmland (Davis *et al.*, 1990). During the same period, the British skylark population has declined by over 50%. Recent research indicates that winter cereals are a poor habitat for breeding skylarks and that changes in farming practices may therefore have contributed to their decline (Schläpfer, 1988; Jenny, 1990a,b; Busche, 1989; Poulsen, 1993).

Poulsen (1993) recorded very low territory densities on winter cereals in Hampshire and Dorset. During the present study, overall densities on the conventional farm were much lower than those on the organic farm and during the 1993 breeding season there was a dramatic fall in the number of skylark territories on conventional cereals. Schläpfer (1988) suggested that skylarks avoid vegetation which becomes too tall and dense to permit easy access to the ground and which restricts movement on the ground. Modern, heavily fertilised winter cereals usually grow rapidly from early April onwards and reach the height and extent of ground coverage that might be expected to deter skylarks by late April and early May, at exactly the time when most pairs would normally lay their first clutches. In 1994, no such abandonment of territories was observed and, on certain conventional winter cereal fields, skylark territory densities were similar to those observed on the organic farm. However, the first half of the 1994 breeding season was unusually cold and wet, affecting both the timing of clutch initiation and vegetation growth. The conventional crops in particular grew more slowly, showed less vegetative (leaf) growth and were much patchier than in 1993. The difference in the results between the two years may therefore be due to this difference in vegetation characteristics. It is possible that there is a critical period at the beginning of the season, before the first clutch is laid, during which birds will abandon a territory, but that once the female has laid a clutch the pair will remain on that territory at least until the end of that nesting attempt. The conventional cereal field where skylark densities were highest in 1994 had been rotational set-aside in 1993. Skylarks on the conventional farm which nested on set-aside were much more successful than those on conventional cereals. Another possible reason for the difference in results between the two years may be that the adults and juveniles from the successful nests in 1993 returned to the same field the following year. Past experience may cause birds to remain on their territory throughout the following breeding season despite unfavourable changes in vegetation height and density. Delius (1965) found that skylarks were extremely site-faithful, although he found no evidence to suggest that a successful breeding season increased the likelihood of a bird returning to the same site the following year.

Despite the difference in territory densities and territory occupation between the two years, both years saw very low productivity on the conventional farm. Productivity of nests that were built in winter cereals was particularly low. In 1993, only four nesting attempts were recorded in 76 ha of conventional winter cereals, from which no chicks fledged. This finding was very similar to that of Poulsen (1993), who found no nests in 580 ha of winter cereals even though territories were present at a density of 0.035 ha^{-1} in late April and May. In 1994, a much higher number of nesting attempts was recorded on conventional winter cereals, reflecting the higher territory density on this crop type and possibly its more suitable vegetation structure compared with 1993. The majority of these attempts were unsuccessful, but the few that were successful meant that the productivity in 1994 was much higher than in 1993 when no chicks fledged on conventional cereals.

Three reasons can be suggested for the breeding failure of skylarks in winter cereals. Firstly, the vegetation may become very tall and dense in the course of a nesting attempt, restricting movement and making provisioning of the chicks more difficult. Secondly, the microclimate of nests in this tall, dense vegetation may be detrimental to the survival of the chicks by being too cool and wet. Finally, there is evidence (Jenny, 1990a; Poulsen, 1993; Tucker, 1993) that the availability of invertebrate foods for Skylarks is much lower in winter cereals than on meadow or set-aside grasslands, again affecting brood provisioning.

Organic management produces a slower growing, shorter, sparser crop and there is evidence from other studies (Hald & Reddersen, 1990; Moreby *et al.*, 1994) that organic cereal fields hold higher densities of certain groups of invertebrates than conventional fields. Consequently, we might expect Skylarks on organic farms to benefit from amelioration of all three of the problems mentioned above, for conventional winter cereals. Accordingly, the present study found that skylark territory densities and breeding success remained higher throughout the breeding season on organic cereal fields than on their conventional counterparts. These findings are supported by those of the extensive part of the BTO's Organic Farming and Birds Project (Chamberlain *et al.*, 1995) and a similar Danish study (Braae *et al.*, 1988), which both provide more general indications that skylarks are present at higher densities on organic than on nearby conventional farms.

One problem with comparing densities and performance of skylarks in the present study is that effects of crop type and crop management could be confounded. In particular, the cereals on the conventional farm were winter sown whereas those on the organic were predominantly spring sown (this tends to be a general feature of the two systems (see Part II)). It would be highly desirable to compare skylark breeding biology on organic and conventional farms that each had reasonable areas of winter- and spring-sown cereals.

Nesting activity of skylarks started simultaneously on the two farms in both years, however in 1994 this occurred two weeks later than in 1993. On both farms, activity peaked in the first two weeks in May as the first broods, which were initiated simultaneously, hatched. On the organic farm there was a second smaller peak in late May/early June, whereas on the conventional farm few nesting attempts were recorded after mid-May. This may indicate that more first broods were successful on the organic farm, leading to greater synchrony (and hence the second small peak in activity) later in the season. A high failure rate, with failures occurring at all stages of the nesting period would lead to a breakdown in synchrony and no such peak in activity. The small number of attempts that were recorded later in the season on the conventional farm were on rotational set-aside, sugar beet or the grass verges of winter cereal fields. This number was particularly low in 1994, when there were no spring cereals or rotational set-aside grassland and the sugar beet, having germinated very slowly due to the cold, wet weather, only became suitable as nesting habitat much later in the season. The second peak in nesting activity on the organic farm occurred on the spring cereal fields. Lack of suitable nesting habitat may therefore lead to the premature termination of the breeding season on most conventional arable farms. Poulsen (1993) recorded successful nests into July, but it is unclear what stage these nests had reached when they were recorded. Delius (1965) recorded new clutches being laid in early July on a dune system, but also noted that skylarks nesting on adjacent arable land abandoned their territories in early June. In East Anglia, we observed skylarks carrying food to nestlings or fledged young throughout July on coastal grazing marshes and in forestry clearings. If truncation of the breeding season is a general phenomenon in agricultural habitats, it may have a considerable effect on the overall productivity of skylarks nesting on arable land. This effect will be two-fold: earlier in the season, clutch size is smaller and the weather is more likely to be cold and wet, resulting in low productivity. Later in the season, when clutch sizes tend to be largest (Delius, 1965; this study), and the weather warmer and drier, the number of nesting attempts possible will be limited by the area of suitable nesting habitat.

The more erratic pattern of growth recorded in broods on the conventional farm suggests that the food supply on this farm was much less predictable. The timing of hatching to coincide with a plentiful supply of invertebrates is critical, for example O'Connor and Morgan (1982) found that spotted flycatchers *Muscicapa striata* grew more slowly and suffered higher losses in cold, wet weather when insect activity is lowest. All documented cases of starvation of whole broods occurred on the conventional farm and there was a greater number of 'runts' in the broods. Skylarks hatch synchronously and their development should also be synchronous allowing the brood to fledge as a unit and maximise productivity (O'Connor, 1975). Thus, the presence of a runt in a brood is an indication that there is a food shortage. There was also a much higher incidence of predation in 1994 than 1993, a factor which can be associated with starvation. Dunn (1977) found that broods of great tits *Parus major* were more heavily predated by weasels *Mustela nivalis* in years when food was scarce because they were attracted by the begging calls of the hungry chicks. Broods on both farms fared badly in cold, wet weather but those on the conventional farm seemed to fare worse, for example all the cases of starvation of whole broods occurred on the conventional farm. If densities of invertebrate prey of skylarks are higher on organic than conventional farms this may have no apparent effect when the weather conditions are relatively benign but may be the difference between success and failure in unfavourable weather, when the adults will have difficulty in maintaining an adequate provisioning rate. Although there was no clear evidence of a strong correlation between chick condition and farm type, the overall pattern suggests that broods on the organic farm were in better condition than those on the conventional farm. When a comparison was made between chicks reared on set-aside and chicks reared in cereal fields, the results suggested that those reared on set-aside were heavier throughout the nestling period between day three and leaving the nest. Once again, the overall pattern suggests that skylark chicks on set-aside were in better condition than those on cereals. Since skylark chicks remain dependent on the adults for up to two weeks after leaving the nest, those chicks which are in poorer condition when they leave the nest may fare worse during this period and after independence and have a lower survival rate. After leaving the nest, the chicks invariably become separated but must still compete successfully for their parents' attention. The better developed a chick is, the more active and more alert it will be and the more likely that it will be able to attract its parents' attention (O'Connor, 1984).

Both Poulsen's and this study found high territory densities and breeding success on set-aside fields. On Hall Farm in 1993, 63% (12/19) of nesting attempts were on a single field of RSA with a sown ryegrass cover, comprising only 8% of the available field area. On the organic farm, and on the farms in Poulsen's study, fields in the final years of the MAFF five-year set-aside scheme were also very attractive to skylarks and had high territory densities and fledging success. The grass/clover ley and the triticale stubble under-sown with clover in this study were attractive early in the season when they had high territory and fledging success, although they became tall and dense later in the season and nesting activity declined. Grassland may prove particularly attractive for skylarks if it is unimproved and 'tussocky' thereby providing access to the ground even when it exceeds the average height thresholds suggested by Schläpfer (1988). Grassland on which there is little or no fertiliser or pesticide input may also be a richer source of invertebrate food for the chicks. This will be important not only when the chicks are in the nest, so that the adults do not have to travel far to find food, but also in the period between the chicks leaving the nest and becoming independent. During this period, when they are learning to search for food, the chicks are flightless and unable to move easily from areas of low invertebrate density to areas of high invertebrate density. Being raised in a crop which has a high density of invertebrates may therefore be crucial to their survival to independence.

Set-aside will occupy 10-20% (0.4-0.8 million ha) of arable land in Britain in coming years and has enormous potential to provide habitat for ground-nesting species such as skylark and grey partridge *Perdix perdix*. It will also provide important invertebrate and seed food resources for a much greater range of farmland birds throughout the year (Wilson *et al.*, 1995), although appropriate management techniques are required to avoid weed control measures, such as cutting and cultivation, taking place at the peak of the breeding season. In 1993, the management rules for RSA resulted in the cutting and ploughing in of most set-aside fields in May and June, which would have destroyed a high proportion of skylark nests. These rules now allow spraying with a herbicide as a means of weed control and this appears to be less disruptive to ground-nesting birds.

Multivariate analyses indicate that field area, field shape and the physical structure of the field boundary all have important effects on skylark density. Thus, when looking for other effects of the two farming regimes on skylark abundance and breeding success, an ideal study would compare farms with very similar field sizes, shapes and field boundary structures. In this study, the organic farm had smaller, more open fields leading to a high vegetation diversity in a relatively small area and indeed there were higher densities of skylarks here than on the conventional farm. This finding is consistent with Schläpfer's (1988) model of skylark habitat selection which predicts that population density will be highest in areas supporting mosaics of vegetation types which offer continuity of suitable structural conditions for the birds throughout the breeding season. There were, however, other important differences between the two farms. Not only was productivity higher but the growth rate of broods was less erratic and their condition better on the organic farm. The better condition of the chicks on the organic farm suggests that they were fed more and their less erratic growth rate suggests that the food supply available was more abundant and predictable. One reason for this may be that the less tall and dense crop structure on the organic farm resulted in greater accessibility of invertebrates enabling higher provisioning rates even though the overall numbers of invertebrates present were similar to those on the conventional farm. However, the differences observed also suggest that the chemical inputs used in a conventional farming regime, such as pesticides and fertilisers, may have an indirect effect on skylark productivity by reducing the availability of invertebrate food for the chicks. Any direct effects of these chemicals on skylarks are unknown and may be difficult to detect. Some species of birds are more susceptible than others to the effects of pesticides, because of differences in ecology, behaviour and physiology, and detecting any effect is often dependent on the reporting of mortality incidents by members of the public (Hart, 1990). More subtle effects may therefore pass unnoticed. Such effects might be detected by monitoring changes at population level, but these may only become clear after several years and even then it is rarely possible to decide unequivocally whether the changes are due to pesticide effects or to other factors such as changes in habitat (Hart, 1990). Although the decline in the skylark population has been linked to changes in agricultural practice, these changes include changes in cropping as well as massive increases in the use of chemicals. The mechanisms involved in the decline are therefore not yet fully understood but the results of this study have gone some way towards furthering that understanding.

5. RECOMMENDATIONS

1. Further work should be carried out on the ecology of skylarks on arable land and should, ideally, be carried out on a larger sample of farms including both organic and conventional systems, ideally with spring- and autumn-sown crops within each system (see above). It would be valuable to maintain work on territory distribution and breeding success at Village and Hall Farms in order to determine the relationship between breeding success and establishment of territories over a longer period. Work should concentrate on chick diet, foraging locations of adult skylarks during nest provisioning.

2. A large-scale survey of the distribution of singing male skylarks on lowland farmland throughout Britain is desirable to allow quantification of preferences for different crop types and phenologies and to assess the scale and timing of territory abandonment on different crop types. Such a survey should take place over two years and be carried out from mid-March to the end of July in each year. Data on the distribution of singing male skylarks should be combined with simple measurements of crop height and ground cover in each surveyed field. Survey methodology could be based on stratified random samples of squares (1 km^2 or tetrad), roadside transects or could use the existing network of Breeding Bird Survey 1 km^2 transects.

3. The establishment of colour-marked populations on two study areas will allow a more detailed examination of the factors affecting skylark breeding success on different crop types. In particular, it will be important to investigate whether there are differences between the attributes (age, pairing, physical condition, prior breeding history) of birds nesting in different crop types and to know the fates of those birds. It will also allow a study of the wintering ecology of skylarks, particularly habitat utilisation, over-winter survival and site fidelity and an investigation of how this relates to breeding success.

4. More detailed work should be carried out to investigate both indirect effects, such as the reduction in the availability of chick food invertebrates, and direct effects, such as activity suppression, of pesticides and inorganic fertilisers on Skylark breeding success. Work on the indirect effects would concentrate on chick diet, chick growth and foraging locations of adults during nest provisioning. Work on the direct effects would involve taking blood samples from the chicks for analysis of chemical residues and radio-tagging them to investigate post-fledging survival. Without a study of this kind, the roles of different aspects of agricultural intensification in the decline of the British skylark population will never be fully understood.

In addition, the results of such a study may identify the key factors in the population declines of a range of farmland species and provide the means to reverse those declines.

5. In the longer term, an ambitious but important experimental study would manipulate the density, height and growth rate of experimental cereal plots through alteration of sowing times and densities and input regimes, and monitor subsequent territory establishment and nesting success, foraging behaviour and diet of skylarks. Individual plots would need to be at least 5-10 ha in size to allow meaningful assessment of skylark densities and the array of plot treatments and replicates should be sited in an area of flat, open, 'prairie-like' cereal farmland. This will help ensure that field boundary structures and variations in field slope and aspect do not confound the effects of experimental treatments.

6. ACKNOWLEDGEMENTS

This work was funded jointly by the Ministry of Agriculture, Fisheries and Food and the World Wide Fund for Nature UK. Thanks are due to Bert and Jane Capon and John Wallace for allowing this work to be carried out on their land and to John Poulsen, Alex Schläpfer and Markus Jenny for invaluable advice on the design and execution of studies of skylarks on farmland. Rob Fuller, Chris Feare and Rowena Langston commented on earlier drafts of the manuscript. Sophie Foulger provided invaluable secretarial support.

7. REFERENCES

Barker, A. (1992). Sawflies and Farmland. *Game Conservancy Ann. Rev.* 24:75-76.

Braae, L., Nohr, H. & Petersen, B.S. (1988). *Fuglefaunaen pa konventionelle og okologiske landbrug*. Miloprojekt 102. Miljoministeriet, Miljostyrelsen, Copenhagen.

Busche, G. (1989). Drastische Bestandseinbussen der Feldlerche *Alauda arvensis* auf Grunlandflachen in Schleswig-Holstein. *Die Vogelwelt* 110:51-59.

Chamberlain, D., Wilson, J.D. & Fuller, R.J. (1995). *A Comparison of Breeding and Wintering Bird Populations on Organic and Conventional Farms*. BTO Research Report No. 154. PART II. To MAFF & WWF UK on Organic Farming and Birds.

Chapman, P.J., Sly, J.M.A. & Cutler, J.R. (1974). *Pesticide Usage Survey Report 11. Arable Farm Crops in England & Wales 1974.* MAFF, London; DAFS, Scotland.

Cramp, S. (ed) (1988). *Handbook of the Birds of Europe, The Middle East and North Africa. The Birds of the Western Palearctic*. Volume V. Oxford University Press.

Davis, R.P., Garthwaite, D.G. & Thomas, M.R. (1990). *Pesticide Usage Survey Report 85. Arable Farm Crops in England & Wales 1990.* MAFF, London.

Delius, J.D. (1963). Das verhalten der Feldlerche. *Z. Tierpsychol.* 20:297-348.

Delius, J.D. (1965). A population study of Skylarks *Alauda arvensis*. *Ibis* 107:466-492.

Dunn, E.K. (1977). Predation of weasels (*Mustela nivalis*) on brooding tits (*Parus* spp.) in relation to the density of tits and rodents. *J. Anim. Ecol.* 46:634-652.

Evans, A.D. & Smith, K.W. (1994). Habitat selection of Cirl Buntings *Emberiza cirlus* wintering in Britain. *Bird Study* 41:81-87.

Evans, A.D. & Smith, K.W. (1995). Conservation of Cirl Buntings in the UK. *Proc. XII Int. Cong. IBCC & EOAC.*

Fuller, R.J., Gregory, R.D., Gibbons, D.W., Marchant, J.H., Wilson, J.D., Baillie, S.R. & Carter, N. (in press). Population declines and range contractions among lowland farmland birds in Britain. *Conservation Biology.*

Gibbons, D.W., Reid, J.B. & Chapman, R.A. (1993). *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991.* T. & A.D. Poyser, London.

Green, R. (1978). Factors affecting the diet of farmland Skylarks, *Alauda arvensis*. *J. Anim. Ecol.* 47:913-928.

Hald, A.B. & Reddersen, J. (1990). *Fugelfode i kornmarker - insekter og vilde planter.* Miljoprojekt 125. Miljoministeriet, Miljostyrelsen, Copenhagen.

Hart, A.D.M. (1990). The assessment of pesticide hazards to birds: the problem of variable effects. *Ibis* 132:192-204.

Hustings, F. (1992). *Bird Census News* 5(2). SOVON, The Netherlands.

Jacobsen, E.M. (1992). *Ynglefuglerapport 1992.* Danish Ornithological Society.

Jenny, M. (1990a). Nahrungsokologie der Feldlerche *Alauda arvensis* in einer intensiv genutzen Agrarlandschaft des schweizerischen Mittellandes. *Orn. Beob.* 87:31-53.

Jenny, M. (1990b). Populationsdynamik der Feldlerche *Alauda arvensis* in einer intensiv genutzen Agrarlandschaft des schweizerischen Mittellandes. *Orn. Beob.* 87:153-163.

Jenny, M. (1990c). Territorialitat und Brutbiologie der Feldlerche *Alauda arvensis* in einer intensiv genutzen Agrarlandschaft. *J. Orn.* 131:241-265.

Lampkin, N. (1990). *Organic Farming.* Farming Press, Ipswich.

Moreby, S.J., Aebischer, N.J., Southway, S.E. & Sotherton, N.W. (1994). A comparison of the flora and arthropod fauna of organically and conventionally grown winter wheat in southern England. *Ann. Appl. Biol.* 125:13-27.

O'Connor, R.J. (1975). Initial size and subsequent growth in passerine nestlings. *Bird-banding* 46:329-340.

O'Connor, R.J. (1984). *The Growth and Development of Birds.* John Wiley & Sons Ltd.

O'Connor, R.J. & Morgan, R.A. (1982). Some effects of weather conditions on the breeding of Spotted Flycatchers *Musciapa striatus* in Britain. *Bird Study* 29:41-48.

O'Connor, R.J. & Shrubb, M. (1986). *Farming and Birds.* Cambridge University Press.

Ormerod, S.J. & Tyler, S.J. (19900. Assessments of body condition in Dippers *Cinclus cinclus*: potential pitfalls in the derivation and use of condition indices based on body proportions. *Ring. & Migr.* 11:31-41.

Poulsen, J.G. (1993). *Comparative Ecology of Skylarks* (Alauda arvensis L.) *on Arable Farmland.* Unpubl. Cand. scient. thesis, University of Aarhus.

Schläpfer, A. (1988). Populationsokologie der Feldlerche *Alauda arvensis* in der intensiv Agrarlandschaft. *Orn. Beob.* 85:309-371.

Tucker, G.M. (1993). Effects of agricultural practices on field use by invertebrate-feeding birds in winter. *J. Appl. Ecol.* 29:779-790.

Williamson, K. (1967). The bird community of farmland. *Bird Study* 14:210-226.

Wilson, J.D. (1995). The effect of organic farming systems on breeding and wintering bird populations. In: *Britain's Birds: the conservation and monitoring review 1991-92* (ed. S. Carter), pp 67-72. BTO/JNCC.

Wilson, J.D., Evans, A.D., Poulsen, J.G. & Evans, J. (1995). Wasteland or oasis? The use of set-aside by breeding and wintering birds. *British Wildlife* 6:214-223.

Zbinden, N. (1989). *Die Entwicklung der Vogelwelt in der Schweiz.* Schweizerische Vogelwarte Sempach, Switzerland.

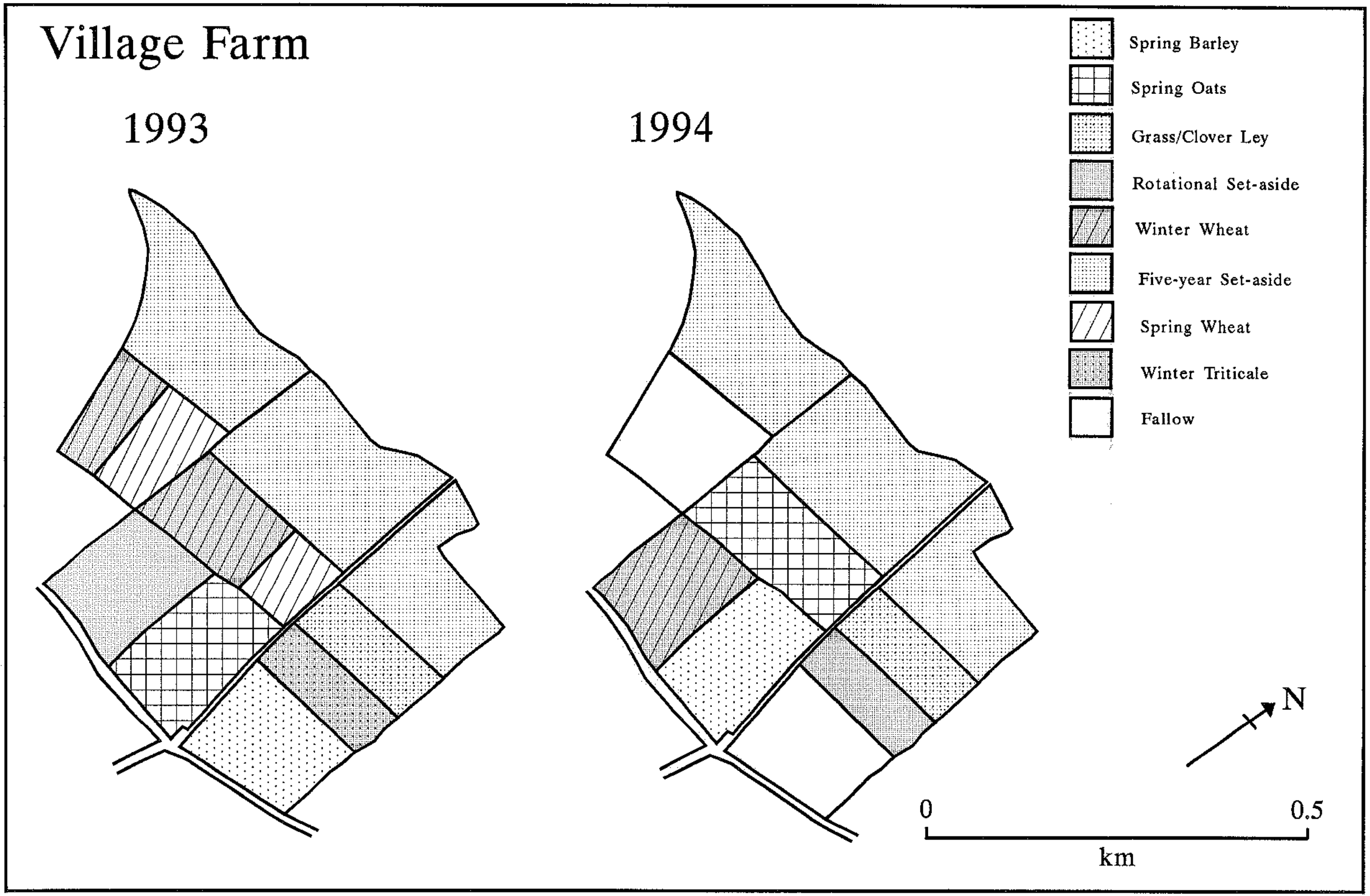


Figure 1 Map of the organic study site showing the differences in cropping patterns between the two years.

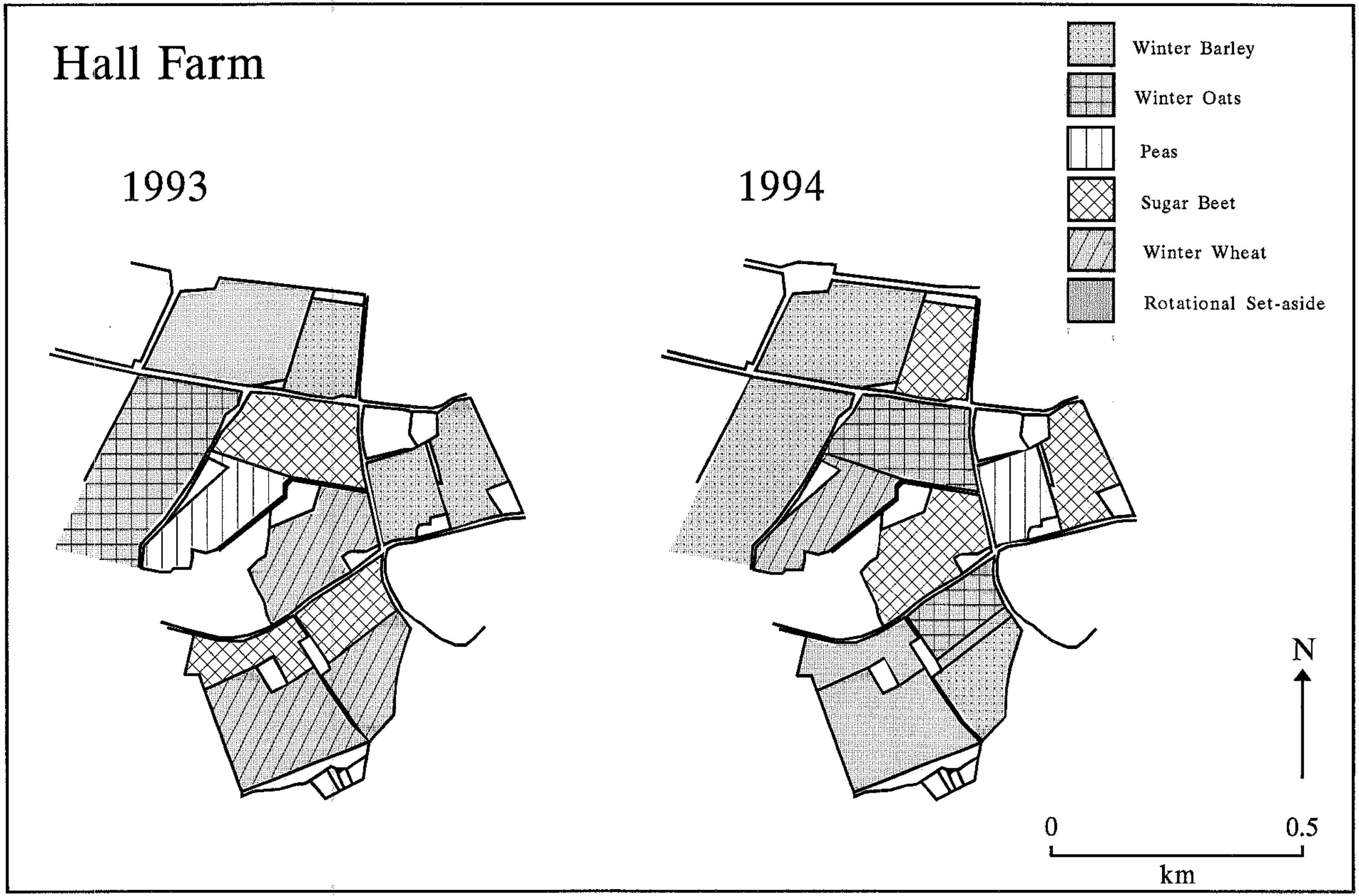


Figure 2 Map of the conventional study site showing the differences in cropping patterns between th two years.

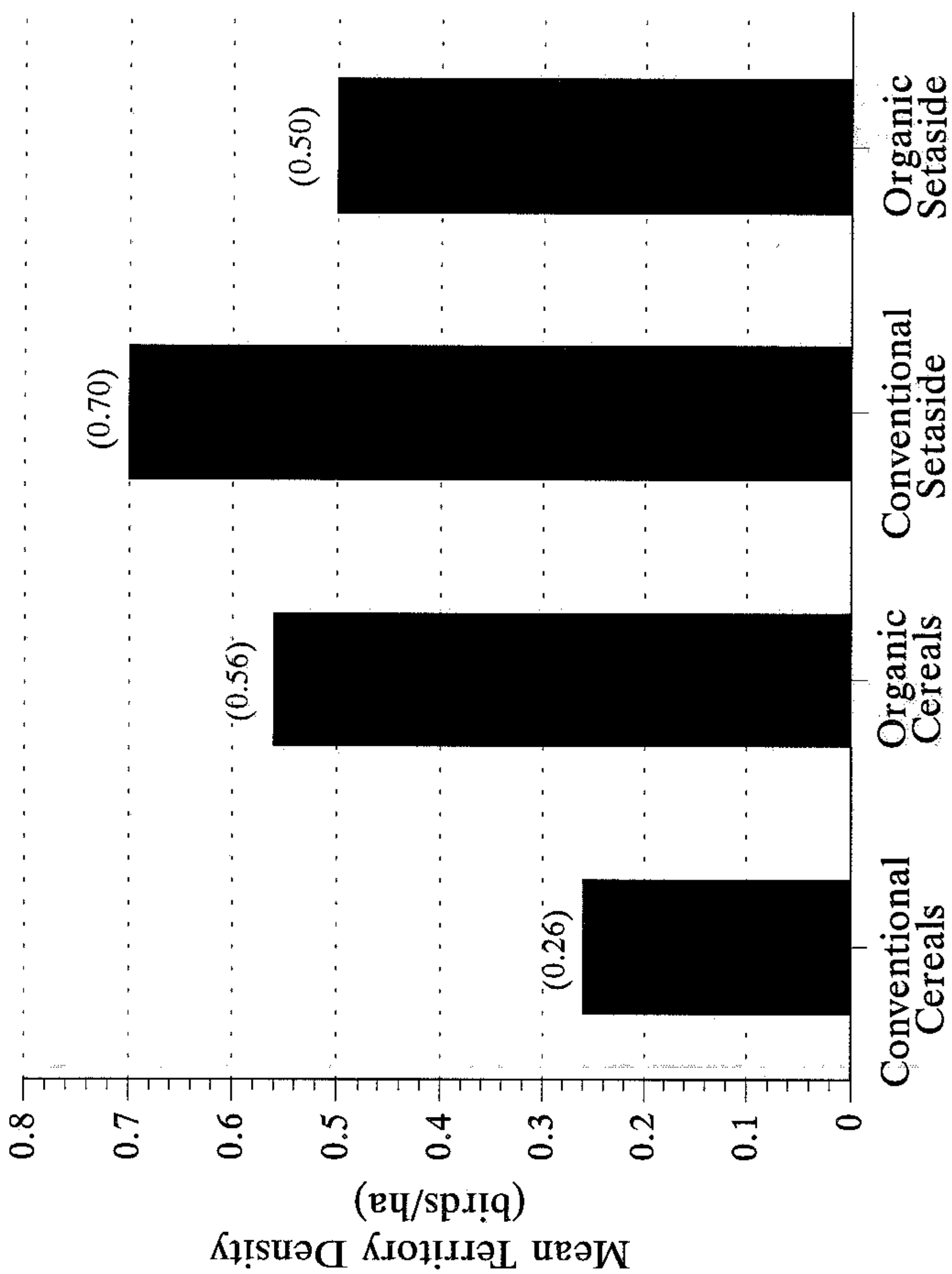


Figure 3 Skylark territory density (mean of two years) on different field types.

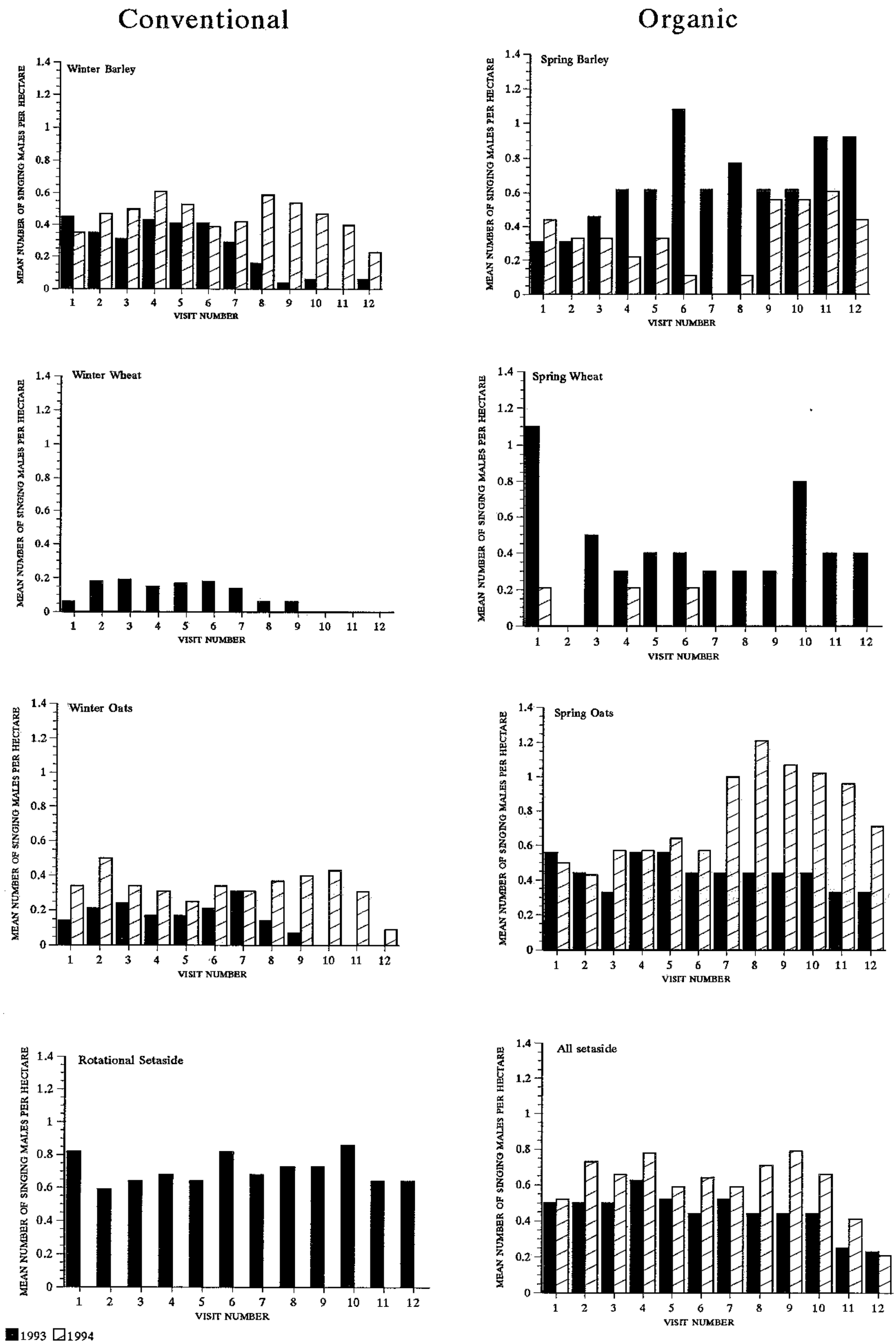


Figure 4 Seasonal change (mid March – mid June) in the densities of singing male skylarks on eight different field types (four organic, four conventional) during 1993 (solid bars) and 1994 (hatched bars). Note: there was no conventional rotational set-aside within the study area in 1994. Conventional winter wheat was present in 1994 but was unoccupied by skylarks.

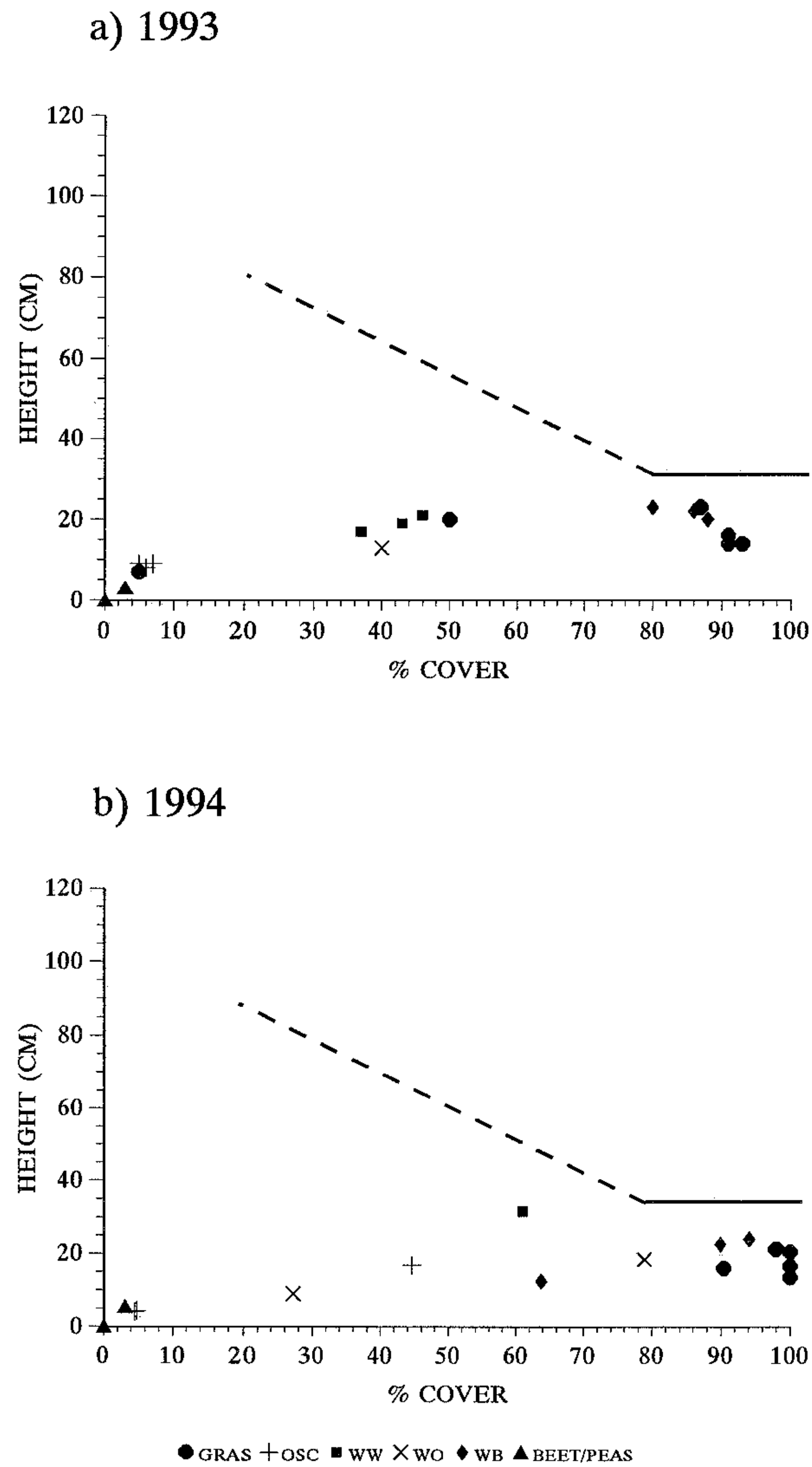
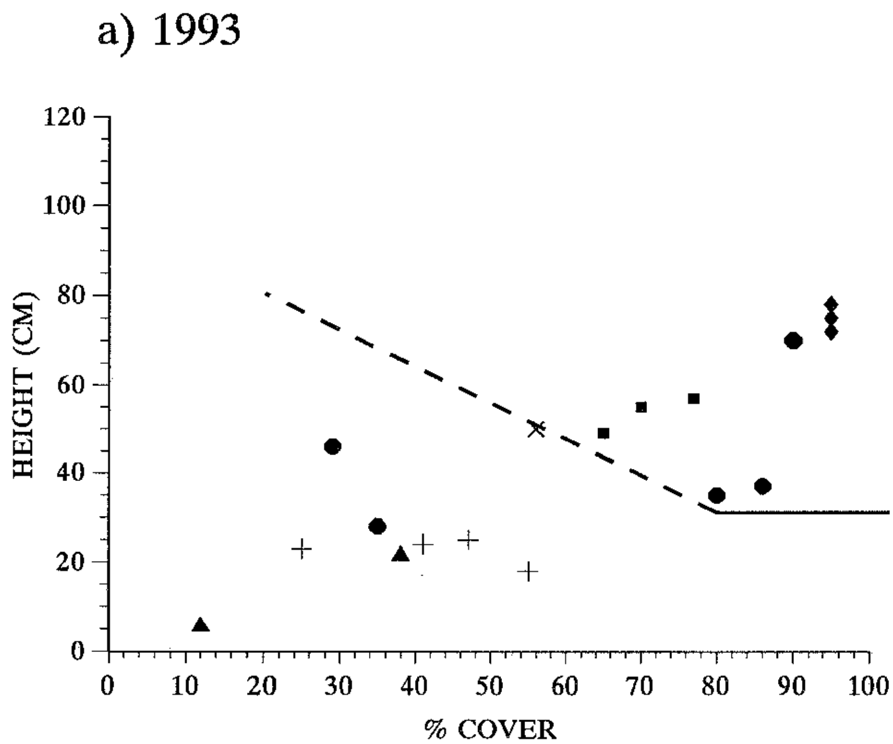


Figure 5 Height and ground cover on fields on Village (organic) and Hall (conventional) Farms, April 1993 and 1994. (GRAS = all ley and rotational set-aside; OSC = organic spring cereals; CWW = conventional winter wheat; CWO = conventional winter oats; CWB = conventional winter barley; BEET/PEAS = conventional sugarbeet/peas). The line shows the threshold above which crops are considered unsuitable for Skylarks (see text).



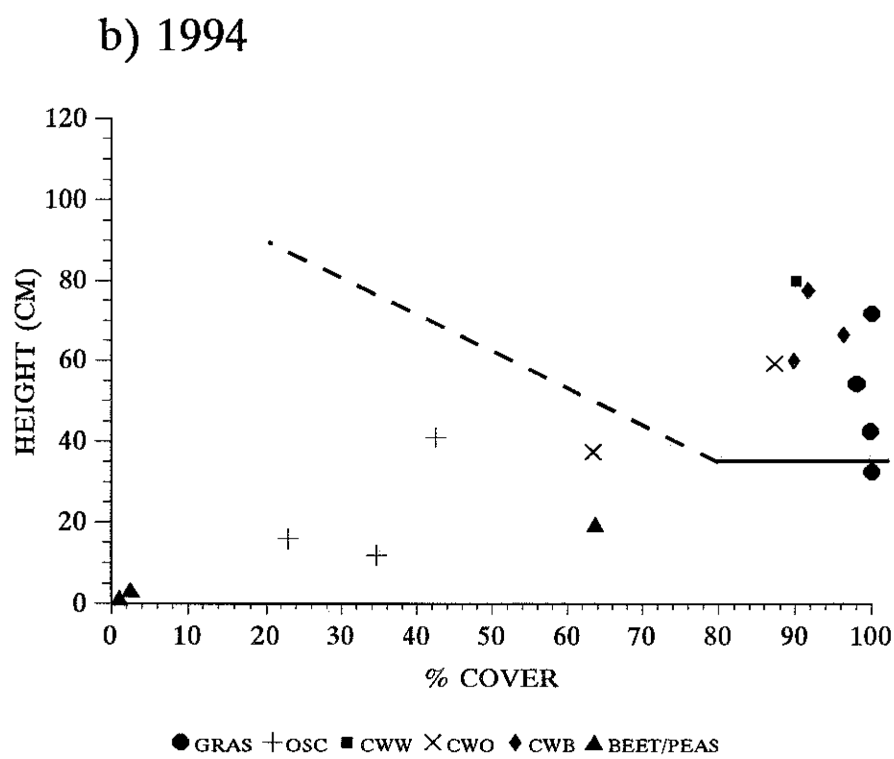


Figure 6 Height and ground cover on fields on Village (organic) and Hall (conventional) Farms, May 1993 and 1994 (GRAS = all ley and rotational set-aside; OSC = organic spring cereals; CWW = conventional winter wheat; CWO = conventional winter oats; CWB = conventional winter barley; BEET/PEAS = conventional sugarbeet/peas). The line shows the threshold above which crops are considered unsuitable for Skylarks (see text).

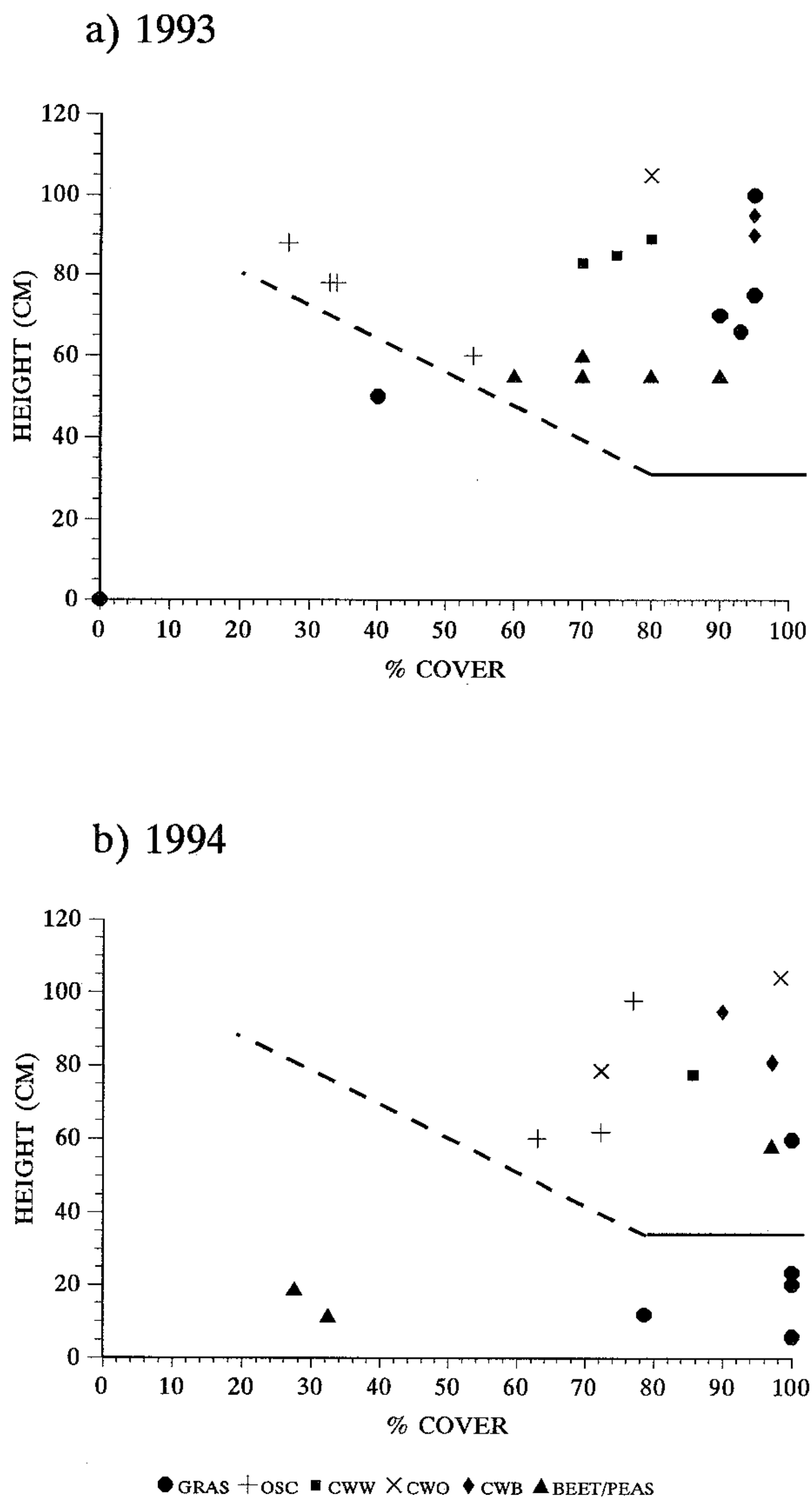


Figure 7 Height and ground cover on fields on Village (organic) and Hall (conventional) Farms, June 1993 and 1994 (GRAS = all ley and rotational set-aside; OSC = organic spring cereals; CWW = conventional winter wheat; CWO = conventional winter oats; CWB = conventional winter barley; BEET/PEAS = conventional sugarbeet/peas). The line shows the threshold above which crops are considered unsuitable for Skylarks (see text).

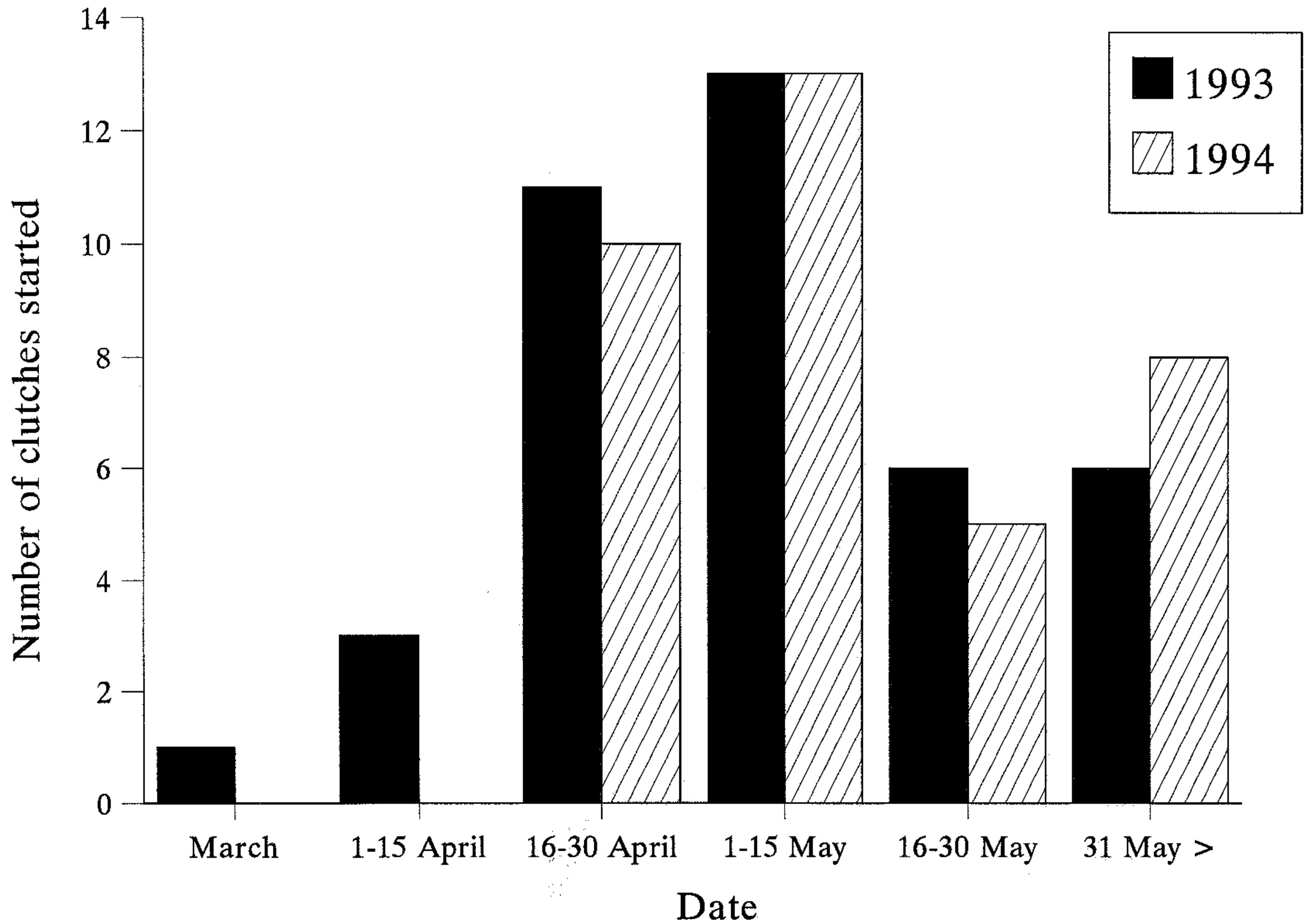


Figure 8 Seasonal distribution of clutch initiation of Skylarks on Village (organic) and Hall (conventional) Farms, 1993 (n=40) and 1994 (n = 36).

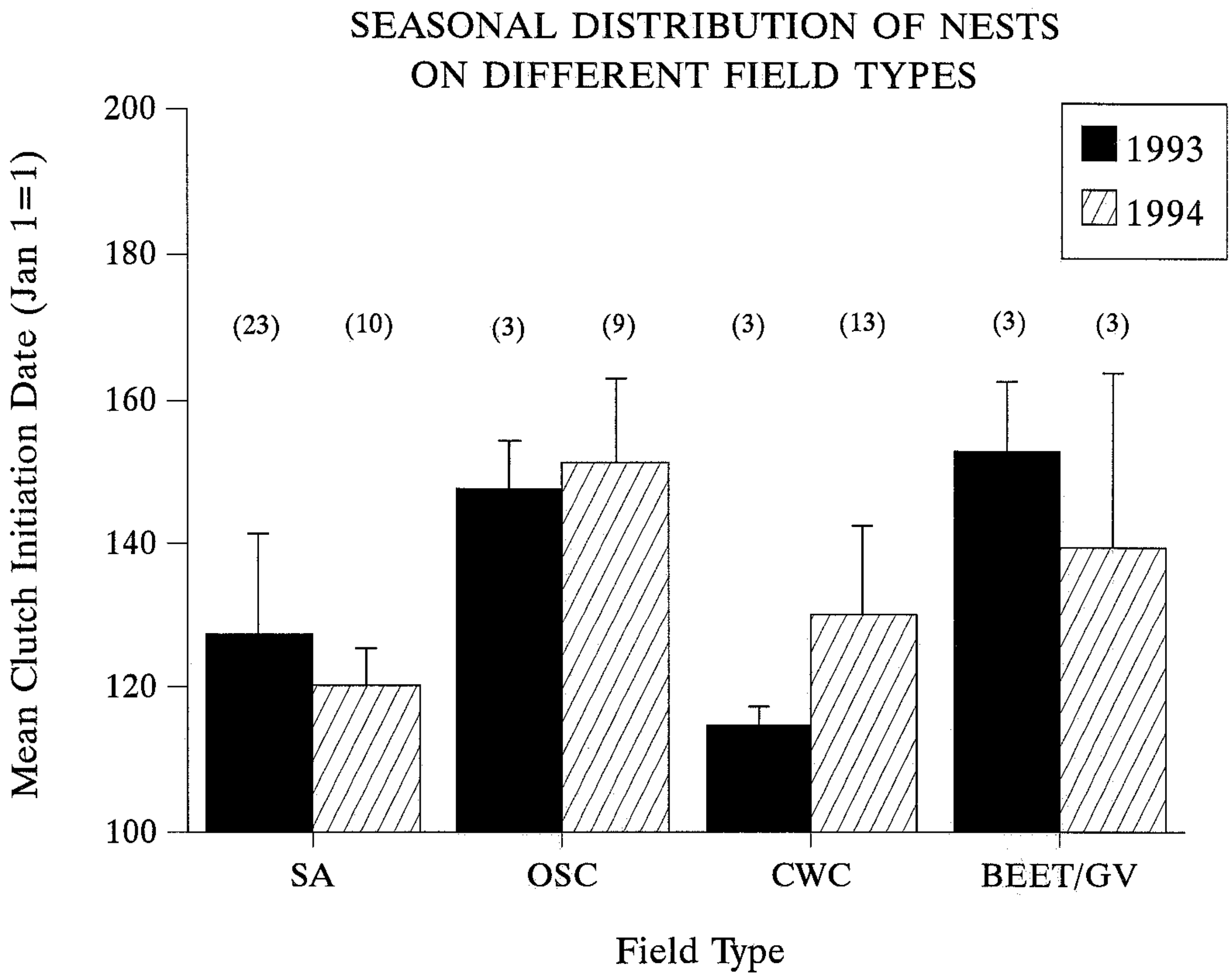


Figure 9 Mean clutch initiation date (±SE) by field type, Hall (organic) and Village (conventional) Farms, 1993 and 1994. (SA = all set-aside; OSC = organic spring cereals; CWC = conventional winter cereals; BEET/GV = conventional sugarbeet/grass verges).

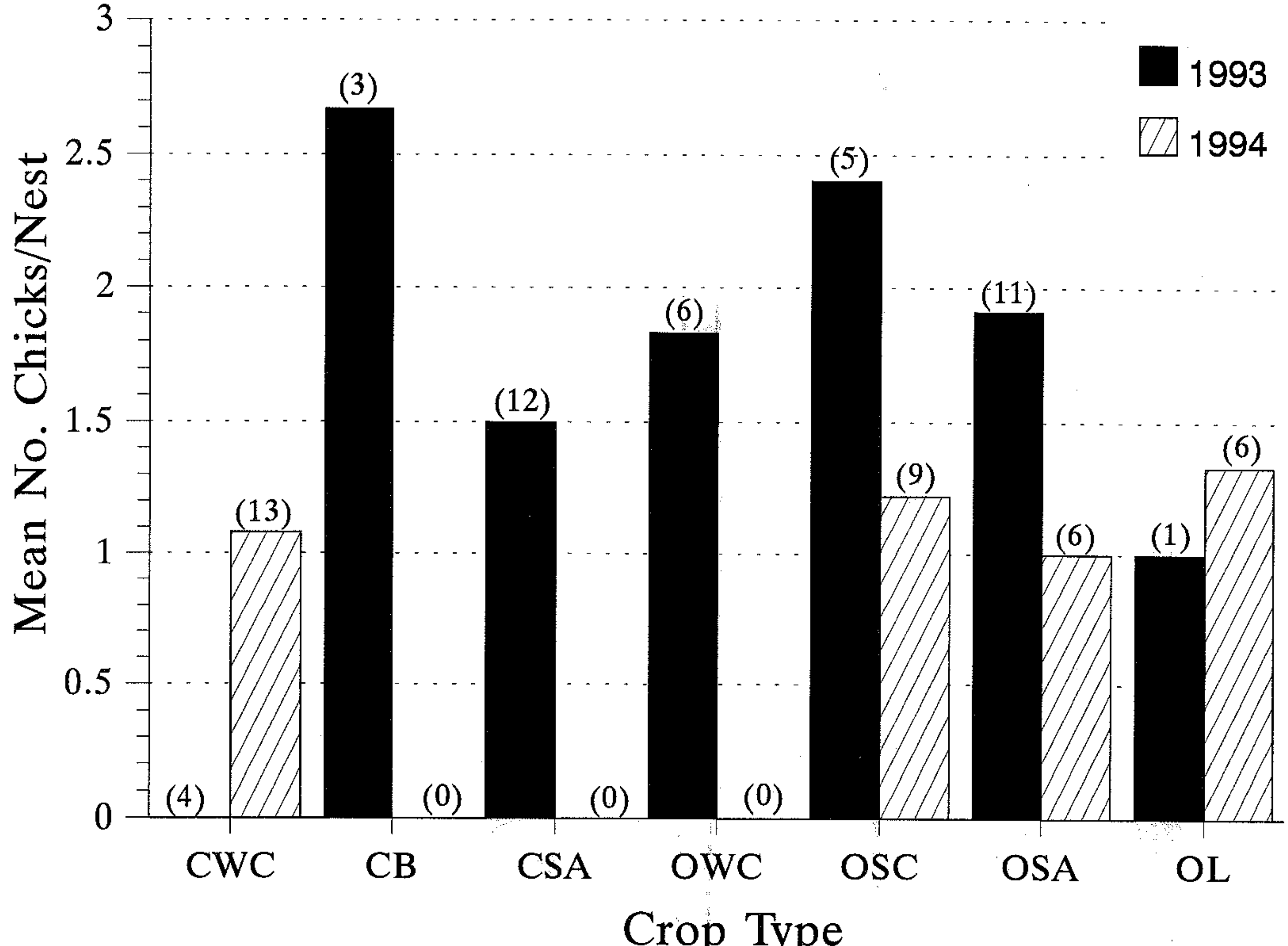


Figure 10 Mean number of chicks fledged per nest on seven different field types, Village (organic) and Hall (conventional) Farms, 1993 and 1994. (CWC = conventional winter cerreals; CB = conventional sugarbeet; CSA = conventional set-aside; OWC = organic winter cereals; OSC = organic spring cereals; OSA = organic set-aside; OL = organic grass ley). Number of nests in each habitat given in parentheses.

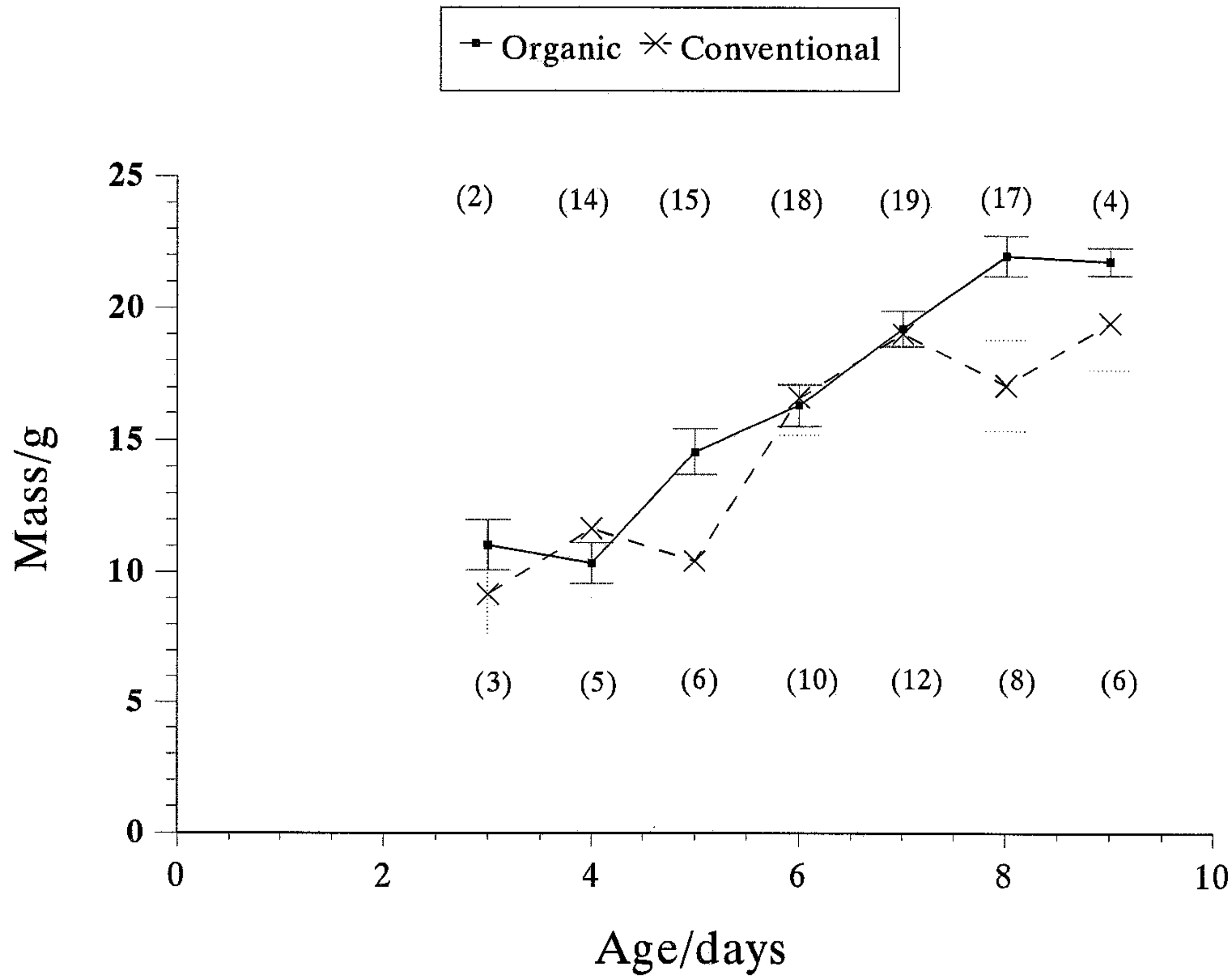


Figure 11 Relationship between mean chick mass per brood (±SE) and age on the organic (Village) and the conventional (Hall) farms. Sample sizes given in parentheses, Organic above, Conventional below.

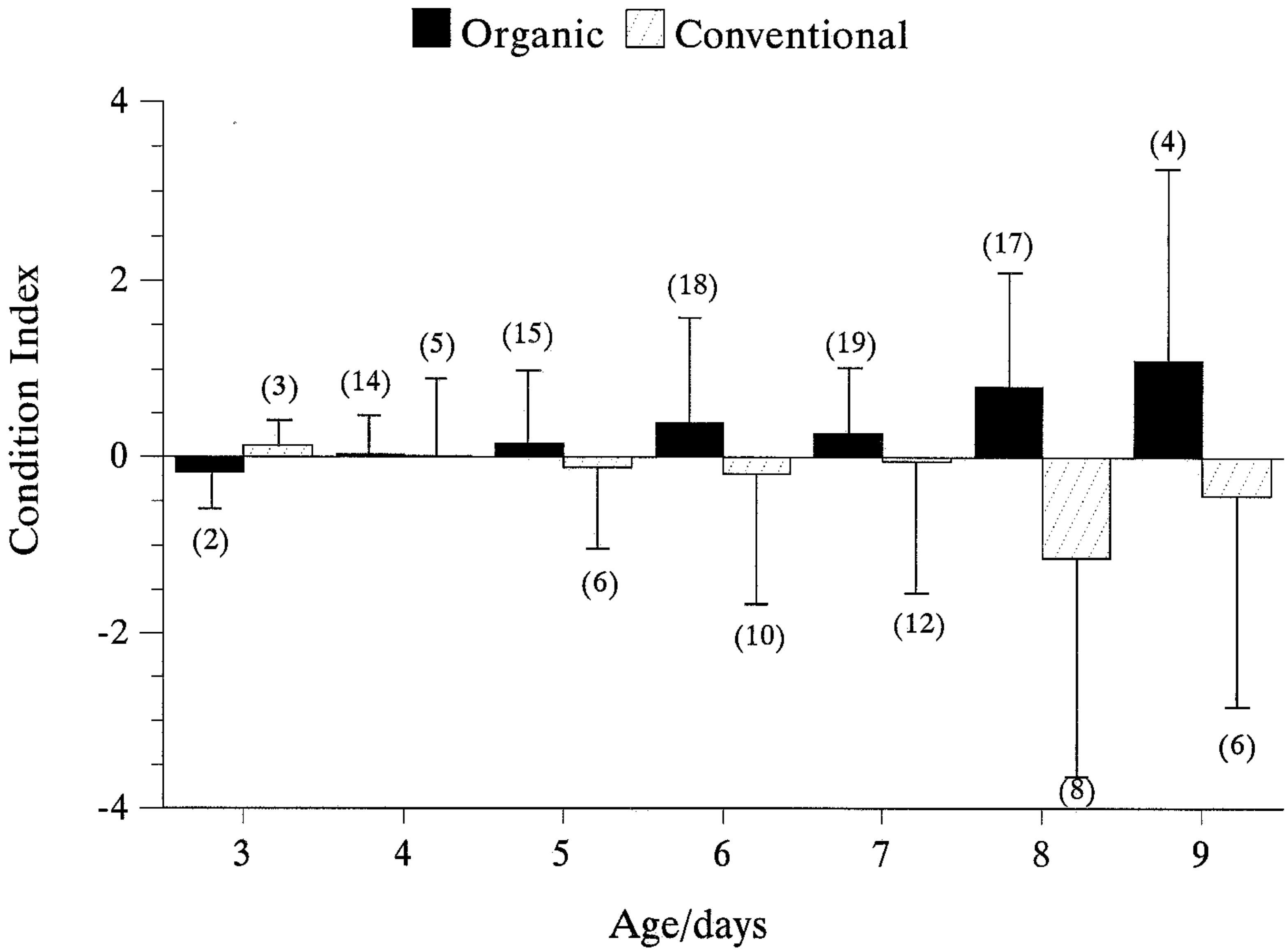


Figure 12 Effect of age and farm type on mean chick condition index (±SE) of Skylark brood on the organic (Village) and the conventional (Hall) farms, both years combined. Sample sizes given in parentheses.

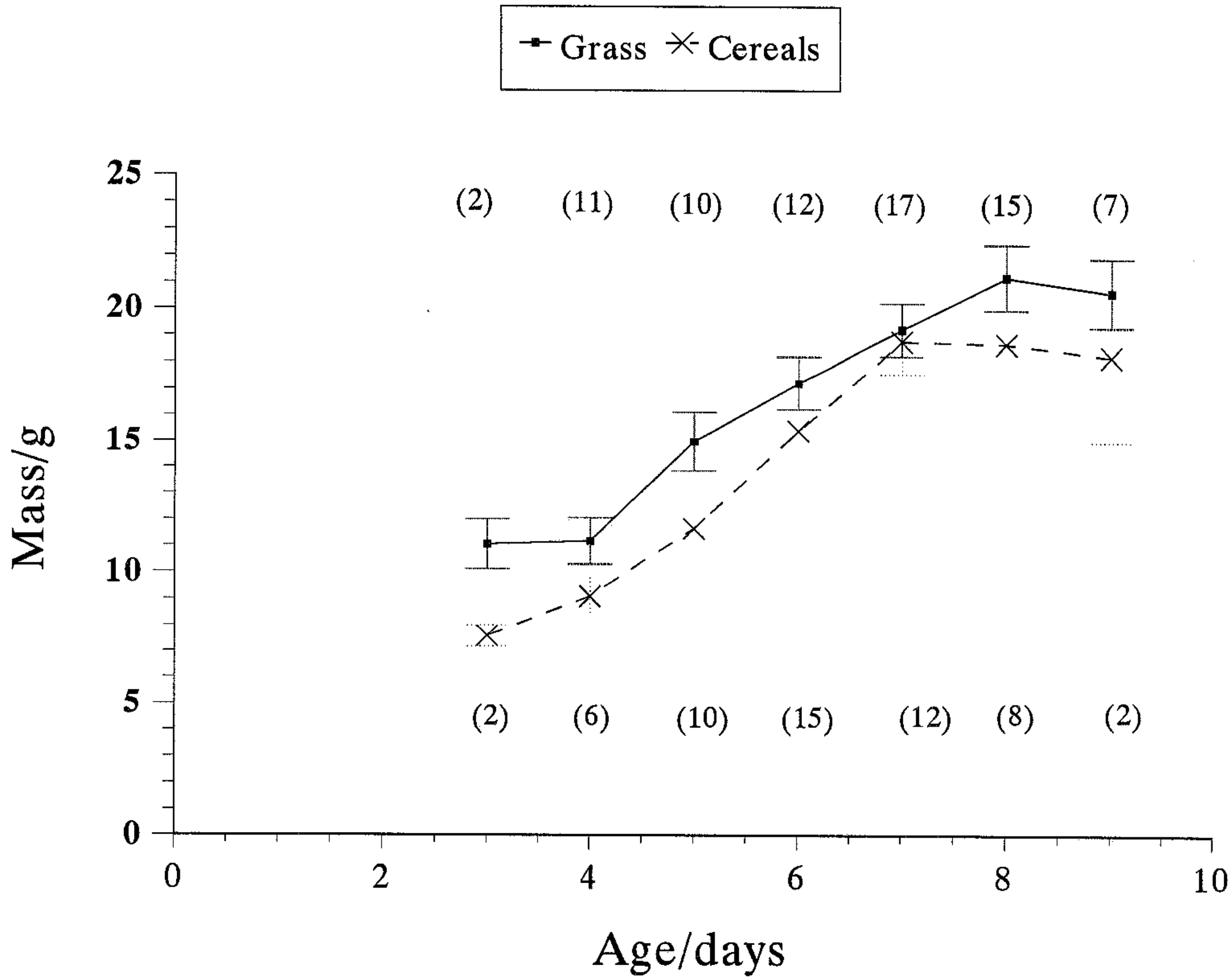


Figure 13 Relationship between mean chick mass per brood (±SE) and age on grass and cereall fields (Grass = organic grass ley and organic and conventional set-aside; Cereals = organic and conventional cereals). Sample sizes given in parentheses. Grass above, Cereal below.

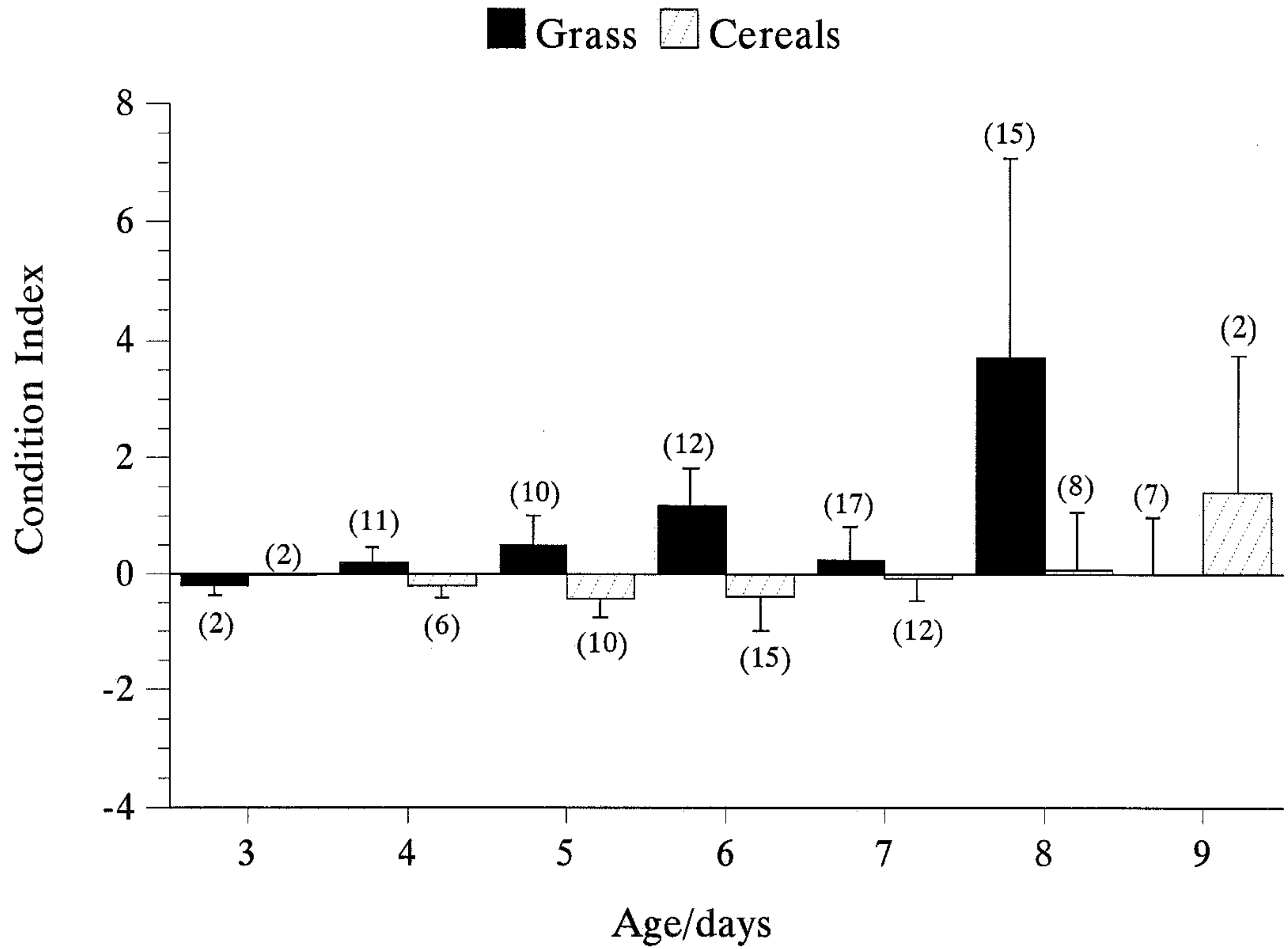


Figure 14 Effect of age and field type on mean chick condition index (±SE) of Skylark broods on grass and cereal fields. (Grass = organic grass ley and organic and conventional set-aside; Cereals = organic and conventional cereals). Sample sizes given in parentheses.

BTO Research Report No. 154

THE EFFECT OF ORGANIC FARMING REGIMES ON BREEDING AND WINTER BIRD POPULATIONS

PART IV

Invertebrate and Weed Seed Food-sources for Birds in Organic and Conventional Farming Systems

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&
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1. REPORT SUMMARY

1.1 Introduction

1.1.1 Aim of project To compare the abundance of invertebrate and weed seed food resources available to birds on organic and conventional farmland. The objective of the study was to assess accurately the likely benefit of these farming systems to birds feeding on farmland, by sampling invertebrates and weed seeds.

1.1.2 Factors implicit to achieving the project aims Variation between farms within one system could influence invertebrate or weed seed abundance and bias results. To minimise such effects and provide results representative of the farming systems as a whole, sampling was based on an extensive approach; farms were sampled in groups. The inference that either of the farming systems is beneficial to feeding birds is dependent on: (i) prior knowledge of the relevance of a particular invertebrate or seed as a food-source; evidence (ii) that this food-source is present in sufficient abundance and (iii) that the food-source is readily accessible. The methodology described below was refined to address these criteria.

1.1.3 Methodology Sampling concentrated on cereal crops, with an additional comparison of organic grass ley fields at a limited number of sites. Sampling initially consisted of sucking invertebrates from the crop using a vacuum insect net and extraction from soil cores. To aid the interpretation of results from this sampling, it was decided that more information was required on the diet of birds. This was achieved by analysing faecal sacs for undigested fragments of invertebrates that therefore represented a dietary component. Skylark chick faecal sacs were chosen for analysis as this was the key species for the intensive ornithological studies and samples could be taken during routine fieldwork. As a result of this study, the main invertebrate sampling technique was changed to pitfall traps, since this was a superior method for assessing those invertebrates found to be important food-sources. It was also anticipated that pitfall trapping would provide more accurate estimates of invertebrate availability, with greater numbers per sample, than the previous two techniques. Studies of weed seed food resources consisted of field surveys using a quadrat to assess the presence and abundance of species, and the use of a small hand held suction machine to suck seeds from post-harvest stubble. The interpretation of the results emphasised the aspects of the ecology of species known to be food-sources that might influence their availability to birds.

1.2 Soil core and vacuum samples

1.2.1 Significantly more dipteran immature stages and Coleoptera were found in soil cores on organic grass ley fields and significantly more earthworms on organic cereal fields than conventional cereal fields. Earthworms and dipteran larvae such as tipulids are known to be important food-sources for birds that specialize in soil invertebrates.

1.2.2 Total numbers of invertebrates trapped by both methods did not differ significantly between the two farming systems. Significantly more invertebrates were trapped, however, by both methods on organic grass ley fields than either conventional or organic cereals.

1.2.3 Significantly more Staphylinidae (Col.), especially the species *Tachyporus hypnorum*, were found on conventional fields. The relevance of this species as a food-source is, however, doubtful.

1.2.4 The weevil *Sitona lineatus* and the carabid *Demetrias atricapillus* were found in significantly greater numbers on organic fields. The former may constitute a food-source for skylarks, which have been shown to feed on this insect under laboratory conditions.

1.3 Faecal sac analysis

1.3.1 Carabid beetles were an important component of skylark chick diet, forming 47% of identifications. In some cases it was possible to identify the species present.

1.3.2 Coleoptera, other than carabids, from the families Elateridae, Curculionidae, Chrysomelidae and Staphylinidae were identified as food-sources.

1.3.3 Spiders and tipulids were also important components.

1.3.4 Reservations are expressed that the technique may under-represent soft-bodied invertebrates, which are susceptible to complete digestion by skylark chicks.

1.4 Pitfall trap samples

1.4.1 Twelve key species of carabid beetles were analysed, of which five common species were trapped in significantly greater numbers on organic farms. These were *Pterostichus melanarius* (the dominant species captured), *Pterostichus madidus, Harpalus affinis, Harpalus rufipes* and *Nebria brevicollis*. The other species analysed showed no significant variance between farming systems.

1.4.2 Williams' Index of Diversity was significantly greater for conventional fields, although caution is expressed over the reliability of this result due to the small sample size of species.

1.5 Botanical studies

1.5.1 The abundance of weed plants in quadrats was significantly greater on organic fields.

1.5.2 The abundance of weed seeds was not significantly different between farming systems. However, the relative proportions of monocotyledonous and dicotyledonous seeds in samples differed between farming systems. A larger proportion of the seeds from organic fields were dicotyledonous and from conventional fields were monocotyledonous.

1.5.3 Preliminary examination of the size of plants and the number of seeds produced suggested that those on organic fields may have been nitrogen deficient.

1.5.4 Weed species were significantly more diverse on organic fields, although diversity has less relevance to bird feeding than abundance.

1.6 Proposals for future work

1.6.1 Replication of the pitfall trapping exercise in subsequent years would substantiate the trends established from the data of one season. It would also be beneficial to extend the range of habitats sampled to take into account set-aside and other crops besides cereals.

1.6.2 More comprehensive information, on the diet of farmland birds in general, could be achieved by analysing the faecal sacs of a wider variety of species.

1.6.3 Greater integration of field studies on birds with invertebrate sampling would enhance the effectiveness of the latter as an indicator of diet. Areas of farmland frequently selected as feeding sites by birds could be sampled intensively for invertebrates and compared to other areas, selected at random. This would provide useful information on the invertebrates likely to be important as food-sources and the habitats that favour them.

1.6.4 Extending the range of farms sampled would provide more accurate results.

1.6.5 More work is required to investigate the possible link between nitrogen deficiency in plants and organic systems, and its implications for the provision of bird food-sources, particularly for weed abundance and phytophagous insects.

2. SOIL CORE AND VACUUM SAMPLES

2.1 Summary

2.1.1 A programme of invertebrate sampling between March and September 1992 assessed potential differences between organic and conventional farming systems. Studies focused on cereal fields at six sites with an additional comparison of organic grass ley fields at two of these, using two sampling techniques: vacuum sampling and soil coring.

2.1.2 Total numbers of invertebrates trapped by both methods did not differ significantly between the two farming systems. Significantly more invertebrates were trapped, however, by both methods on organic grass ley fields than cereal fields.

2.1.3 Soil core samples produced approximately equal proportions of earthworms, immature dipteran stages and Coleoptera. Of these invertebrate groups significantly more dipteran immature stages and Coleoptera were found on organic grass ley fields and significantly more earthworms were found on organic arable fields.

2.1.4 Over 50% of vacuum catches, comprised adult Diptera, but their abundance did not differ significantly between farming systems.

2.1.5 Other invertebrates were represented mainly by Coleoptera : significantly more Staphylinidae, especially the species *Tachyporus hypnorum,* were found on conventional fields and significantly greater numbers of the weevil *Sitona lineatus* were found on organic fields, as was the carabid *Demetrias atricapillus*.

2.1.6 Caution is expressed over aspects of the sampling methods.

2.1.7 The implication of these results in the assessment of bird food abundance is discussed, in relation to size and availability in space and time.

2.2 Aims

The sampling strategy endeavoured to provide a quantification of invertebrates available to birds that forage in the crop canopy and probe the upper layer of soil. Vacuum sampling was chosen as the best available method to assess the former, soil core sampling for the latter. For studies of the epigeal arthropods likely to be available to birds, see the section on pitfall trapping. Invertebrates below 5 mm in size were not considered either a nutritionally beneficial food-source or likely to be frequently selected by foraging birds, so were thus excluded from further analyses.

2.3 Methods and materials

2.3.1 **General sampling strategy** Sampling was carried out at six sites in the south of England, with the majority of these situated in East Anglia. Two pairs of organic and conventional fields were sampled at each site, except in the case of Boarded Barns Farm where one pair of fields was sampled. At three sites, organic and conventional arable fields were sampled on the same farm. At two of these sites (Boarded Barns Farm and Duchy Home Farm) grass ley fields, which were under organic management, were sampled as an additional comparison. At these sites sampling was carried out on four separate dates. At the remaining three sites a pair of farms was sampled, one organic and one conventional, close to each other. At these sites sampling was carried out on three dates. In each case the last sampling date constituted sampling on stubble, soon after harvest, before cultivation took place. For full details of sampling dates and fields sampled see Appendices 1-4. All of the organic farms sampled had gained Soil Association approval and thus comprised fields with a minimum of five years abstinence from pesticide application. In limited cases it was not possible to sample some fields on particular dates - this information is indicated in Appendices 1-4. This was due to either the crop being too wet, in the case of vacuum sampling, or the soil being too dry in the case of soil coring. A similar sampling programme was carried out during the 1993 season. After discussions concerning sampling methodology with the sponsors it was decided not to identify fully the 1993 samples. This report concentrates on the 1992 samples.

2.3.2 **Soil core sampling methodology** Soil samples were taken using a soil corer of 10 cm diameter to a depth of 5 cm - the estimated limit to which birds probe for invertebrates in the soil. Initially, 50 samples per field were taken on the first sampling dates at Boarded Barns Farm and Duchy Home Farm, but due to the length of time required for processing samples this was reduced to 25 thereafter. Samples were taken in a transect from the field headland at 5 m intervals. Each sample was stored in a polythene bag and frozen for preservation. Processing of samples initially consisted of a full extraction technique, involving sieving of soil and flotation of organic matter in a concentrated magnesium sulphate solution. However, this method was very labour intensive and yielded specimens comprising mainly of soil invertebrates below 5 mm length and not considered to be of practical value as bird food-sources. This method was therefore abandoned in favour of one that required less time and yielded larger invertebrates; this involved sieving the soil from each sample through a 5 mm grade mesh sieve with the aid of a high pressure water jet and subsequent careful inspection of the sieve for invertebrates. Invertebrates were identified to family level in most instances, but to species level for most Tipulidae or Coleoptera.

2.3.3 **Vacuum sampling methodology** A vacuum sampler (Dietrick, 1961; Thornhill, 1978), consisting of a portable machine driven by a small two-stroke motor, was used to extract arthropods from the crop canopy. Five samples were taken from each field on each sampling date. The samples were taken in a transect from the field headland at 10 m intervals. Each sample consisted of five 10 second sub-samples, each spaced 5 m apart along the transect, giving a sampling area of 0.5 m^2 for each sample and a combined sampling area of 2.5 m^2 for each field. Samples were placed in polythene bags, transported in a cool box to minimise predation, frozen later for preservation and identified with the aid of a binocular, zoom-type microscope. Invertebrates were counted and identified to either the level of sub-order, family or species.

2.4 Results

The invertebrates caught by both sampling methods covered a wide range of taxonomic groups. Often, particularly in the case of Coleoptera, many species were caught but the majority of species were represented only by a few specimens. We therefore combined many species, or families into wider taxonomic groups to provide sufficiently robust data for conclusive analyses. Coleoptera from both sampling methods were usually identified to species level. Most of the earthworms from soil cores were sexually immature and have thus been grouped to the family level. Immature dipteran stages from soil cores were identified to family level; important bird food-sources, such as the Tipulidae, were identified to species. A summary of the immature Diptera caught by soil coring is given in Appendix 5. For reasons of clarity only invertebrates caught in numbers greater than three are shown. This also applies to Appendix 6, which summarises the Coleoptera caught by soil coring. In most instances Coleoptera were identified to species level for both sampling methods (as were aphids). Otherwise, identification was restricted to important families such as Linyphiidae (Araneae), Braconidae (Hymenoptera), Tipulidae, Syrphidae, or Bibionidae (Diptera) or relevant sub-orders. Appendix 7 summarises the invertebrates caught in vacuum samples.

The variables chosen for data analyses are summarised in Table 2.1. Those selected have sufficiently large numbers to provide a basis for valid statistical analyses. As shown in Table 2.1, two separate analyses were carried out. Analyses One included the two sites where organic grass ley fields were sampled, in addition to organic and conventional arable fields, to provide an additional treatment comparison. Analyses Two concerned the remaining four sites and compared only organic and conventional arable fields. Table 2.1 also summarises the dates from which data were analysed. In some cases, where the subject was considered too small (<5 mm) to be considered of sufficient relevance as a food-source, extraction from samples was not continued after the first date for analyses two. Appendix 8 summarises the total number of each invertebrate constituting a variable in the statistical analyses for soil cores. Data were transformed to logarithms [log(n+1)] and subjected to a three-factor analyses of variance using the Genstat 5 program, where the factors were: sites, treatment, and time (sampling date). The results of these analyses are given in Table 2.2 for soil cores and Tables 2.3 and 2.4 for vacuum sampling. The sample means and standard errors for those variables for which a significant treatment difference was found are summarised in Tables 2.5 and 2.6. Results of these analyses are summarised below.

2.4.1 Soil Cores

Gross number of invertebrates >5 mm

For Analyses One the sample mean for organic grass ley was significantly larger than the means for organic or conventional arable fields. This was mainly due to the larger numbers of dipteran larvae and Coleoptera caught on these fields. See Figure 1, for a bar graph displaying the total number of invertebrates caught on either organic or conventional arable fields at each site.

Lumbricidae

For Analyses One the sample mean for date three was comparatively low. For Analyses Two the sample means show significantly more earthworms were caught on organic fields. The sample mean was also comparatively low for sample date two. See the Discussion for a possible explanation of these results and why caution should be exercised in forming conclusions from these data.

Immature dipteran stages

From Analyses One the sample means indicate significantly larger numbers of Diptera larvae and pupae were found on organic grass leys than on organic or conventional arable crops. This was mainly due to the large numbers of larvae from the Tipulidae and Calliphoridae families. The latter were mainly responsible for the comparatively large mean for organic grass ley at the Duchy Home Farm site (see the Discussion for possible reasons for this). For Analyses Two there was no significant difference between organic and conventional cereal fields.

Tipulid larvae

Tipulid larvae showed a nearly significant difference on organic grass ley (p=0.051), which may have been offset by the large number caught on one organic cereal field at Boarded Barns Farm (which followed grass ley in rotation). The sample means did, however, indicate that significantly more larvae were found on organic grass ley fields, compared to organic or conventional arable fields, at Duchy Home Farm. See the Discussion for possible reasons for this. The predominant species caught was *Tipula paludosa*.

Coleoptera

The sample means indicate significantly more Coleoptera were caught on organic grass ley fields than on organic cereal fields. The dominant species were *Clivina fossor, Amara* spp. (Carabidae) and *Sitona* spp. (Curculionidae). There was no significant difference between organic and conventional cereals.

2.4.2 Vacuum samples

Gross number of invertebrates

The sample mean for organic grass ley, compared to organic or conventional arable fields, was significantly higher (Tables 2.3 and 2.6), probably due to the higher numbers of *Sitona lineatus* caught on organic grass ley. See Figure 2, for a bar graph representing the total number of invertebrates caught on organic and conventional arable fields at each site. There was no significant difference on organic and conventional cereals.

Aphids

The three species predominantly caught were *Rhopalosiphum padi, Metopolophium dirhodum,* and *Sitobion avenae* on organic and conventional arable fields. The predominant species caught on organic grass ley fields was *Sitobion avenae.* There were no significant effects of treatment.

Linyphiidae (Araneae)

For Analyses One the sample mean for organic grass ley was significantly larger than the means for organic and conventional arable fields. For Analyses Two, the sample mean for the Bank and Fifty Farms site is comparatively small and there was no overall significant difference between organic and conventional cereals. See the Discussion for the possible reasons for this.

Braconidae (Hymenoptera)

Significantly more Braconidae were caught on organic grass ley fields, compared to organic or conventional arable fields. For Analyses Two, the sample mean for the Bank and Fifty Farms site is comparatively small and there was no overall significant difference between organic and conventional cereals. See the Discussion for possible reasons for this.

Sitona lineatus (Col.: Curculionidae)

For Analyses One, the sample mean for conventional fields was significantly smaller than that for organic arable and grass ley fields. As can be seen from Table 2.6 the standard error of the sample means infer that significantly larger numbers were found on the organic grass ley fields than the organic arable fields. The sample mean for date three was small and the mean for organic grass ley at the Boarded Barns Farm site on date four was comparatively large. For Analyses Two, the sample means show that there was a significantly greater number of the weevil found on organic arable fields. Also, the sample mean for date four was relatively large. For a possible explanation of the treatment difference and the significant variance in the numbers caught at different times, see the Discussion. See Figure 3, for a bar graph representing the total number of this beetle caught on organic and conventional arable fields at each site.

Staphylinidae >5 mm

For Analyses Two, the sample means show that significantly more staphylinids were caught on conventional fields than on organic fields (no significant difference between organic grass and organic and conventional cereals). As can be seen from Table 2.6, the numbers of larger staphylinids caught were relatively low, thus the results of this analysis should be treated with caution. The predominant species caught was *Philonthus cognatus*. See Figure 4, for a bar graph representing the total number of staphylinids caught on organic and conventional fields at each site.

Tachyporus hypnorum (Col.: Staphylinidae)

For Analyses Two, the sample means indicate that significantly greater numbers of this beetle were found on conventional fields (no significant effect in Analyses One). The sample means for Analyses One followed this trend with detransformed figures of 2.90 for conventional fields, and 2.15 for organic fields, although this was not shown to be significant. For a possible explanation of this treatment difference, see the Discussion. See Figure 5, for a bar graph representing the total number of this beetle caught on organic and conventional fields at each site.

Aleocharinae (Col.: Staphylinidae)

Although the total numbers were larger for conventional fields this was mainly due to a single conventional field, and there was no significant difference.

Carabidae >5 mm

The validity of the results of these analyses should be treated with caution due to the relatively small numbers of carabids caught. The predominant species caught were *Amara familiaris* and *Demetrias atricapillus* (of which only a proportion were 5 mm or over).

Demetrias atricapillus (Col.: Carabidae)

For Analyses Two, the sample means indicated that a significantly larger number of this beetle were caught on organic fields than on conventional fields. See the Discussion for possible reasons for these results.

Tipulid adults (Diptera)

The predominant species caught were *Nephrotoma maculata* from the early sample dates and *Tipula paludosa* from the later sample dates. There were no significant differences between treatments.

Diptera adults >5 mm

The majority of Diptera above 5 mm were from the sub-orders Cyclorrhapha and Brachycera. The majority of Diptera caught from the Nematocera sub-order were small midges, below 5 mm size, which were considered to be of limited value as a food-source.

Table 2.1 Summary of dates used for statistical analyses

(Refer to Appendices for details of dates and fields sampled)

Subject of Analyses	Dates Used in Analyses	
	Analyses One	Analyses Two
Vacuum Samples		
Total Invertebrates > 5 mm	1, 2, 3, 4	1, 2, 3
Aphididae (Hom)	1, 2, 3, 4	1,
Collembola	1, 2, 3, 4	1,
Linyphiidae (Araneae)	1, 2, 3, 4	1,
Braconidae (Hym)	1, 2, 3, 4	1,
Sitona lineatus (Col)	1, 2, 3, 4	1, 2, 3
Staphylinidae (Col)	1, 2, 3, 4	1, 2, 3
Tachyporus hypnorum (Col)	1, 2, 3, 4	1,
Aleocharinae spp. (Col)	1, 2, 3, 4	1, 2, 3
Carabidae > 5 mm (Col)	1, 2, 3, 4	1, 2, 3
Demetrias atricapillus (Col)	1, 2, 3, 4	1, 2, 3
Tipulidae adults (Dip)	1, 2, 3, 4	1, 2, 3
Diptera adults > 5 mm	1, 2, 3, 4	1, 2, 3
Soil Core Samples		
Total Invertebrates > 5 mm	1, 2, 3, 4	1, 2, 3
Lumbiricdae > 5 mm	1, 2, 3, 4	1, 2, 3
Diptera Larvae/Pupae	1, 2, 3, 4	1, 2, 3
Tipulid larvae	1, 2, 3, 4	1, 2, 3
Coleoptera > 5 mm	1, 2, 3, 4	1, 2, 3

Table 2.2 ANOVA results for soil core samples- summaries of F-ratios

Subject of analysis	Site	df	Tmt	df	Site* Tmt	df	Time	df	Site* Time	df	Tmt* Time	df	Site*Tmt *Time	df
Analyses One														
Invertebrates >5 mm	0.189	1	32.80**	2	521.13*	2	27.87**	3	3.30	3	1.62	6	4.86*	6
Lumbricidae >5 mm	0.114	1	1.55	2	0.90	2	6.46**	3	0.30	3	0.83	6	0.69	6
Diptera Immature Stages	4.35	1	51.12***	2	21.12**	2	5.67**	3	1.16	3	5.32**	6	2.57	6
Tipulid larvae (Diptera)	0.06	1	6.74	2	8.96*	2	2.23	3	1.47	3	4.36*	6	3.91*	6
Coleoptera >5 mm	2.09	1	7.55*	2	10.87*	2	25.89***	3	0.78	3	1.91	6	2.91	6
Analyses Two														
Invertebrates >5 mm	0.906	3	4.21	1	1.58	3	44.12***	2	0.53	5	0.38	2	1.62	5
Lumbricidae >5 mm	5.22	3	10.32*	1	1.26	3	13.16***	2	1.93	5	2.04	2	1.21	5
Diptera Immature Stages	0.71	3	0.60	1	1.57	3	3.93*	2	2.34	5	1.86	2	1.37	5
Tipulid larvae (Diptera)	0.51	3	0.64	1	0.92	3	4.66*	2	3.74*	5	4.28*	2	3.87*	5
Coleoptera >5 mm	0.63	3	1.23	1	0.57	3	153.48***	2	5.33**	5	4.90*	2	3.26*	5

Total df = 37 (Analyses One); 41 (Analyses Two) * p <0.05 ** p <0.01 ***p <0.001
Analyses One: Error df =14; Analyses Two: Error df =20

Table 2.3 ANOVA results for vacuum samples (Analyses One) - summaries of F-ratios

Subject of Analysis	Site	df	Tmt	df	Site* Tmt	df	Time	df	Site* Time	df	Tmt* Time	df	Site*Tmt *Time	df
Invertebrates >5 mm	4.59	1	7.37*	2	5.42	2	26.16***	3	2.39	3	2.10	6	0.51	6
Aphids	0.14	1	2.43	2	6.09	2	33.03***	3	10.38***	3	0.32	6	1.62	6
Collembola	1.22	1	1.08	2	3.52	2	14.54***	3	2.46	3	1.85	6	0.56	6
Linyphiidae (Araneae)	4.68	1	8.98*	2	1.27	2	5.50**	3	1.30	3	11.11***	6	0.46	6
Braconidae (Hymenoptera)	165.96***	1	112.02***	2	12.81*	2	50.13***	3	3.36	3	7.45**	6	1.54	6
Sitona lineatus (Col.: Curculionidae)	0.62	1	31.28*	2	0.17	2	19.66***	3	2.39	3	4.08*	6	4.06*	6
Staphylinidae >5 mm	0.17	1	2.36	2	1.53	2	19.10***	3	2.01	3	2.38	6	0.46	6
Tachyporus hypnorum (Col; Staphylinidae)	3.40	1	0.66	2	0.06	2	33.16***	3	25.89***	3	3.01*	6	1.98	6
Aleocharinae spp. (Col.: Staphylinidae)	10.32*	1	2.69	2	1.56	2	23.82***	3	7.92**	3	3.80*	6	3.45*	6
Carabids >5 mm	0.07	1	3.40	2	5.15	2	4.20*	3	7.40**	3	1.03	6	1.77	6
Demetrias atricapillus (Col.: Carabidae)	14.79*	1	4.72	2	1.42	2	13.48***	3	7.61**	3	1.52	6	1.28	6
Tipulid adults (Diptera)	2.11	1	0.52	2	0.80	2	31.15***	3	5.31*	3	2.52	6	0.58	6
Diptera >5 mm	4.36	1	0.24	2	0.31	2	40.84***	3	4.04*	3	3.02*	6	0.69	6

Total df =39 * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$
Total Error df =16

Table 2.4 ANOVA results for vacuum samples (Analyses Two) - summaries of F-ratios

Subject of Analysis	Site	df	Tmt	df	Site* Tmt	df	Time	df	Site* Time	df	Tmt* Time	df	Site*Tmt *Time	df
Invertebrates >5 mm	1.90	3	0.00	1	0.20	3	14.40***	2	0.67	6	5.95*	2	0.72	6
Aphids +	3.5 9	3	0.72	1	3.20	3								
Collembola +	10.57**	3	0.95	1	4.34	3								
Linyphiidae (Araneae) +	15.44**	3	0.35	1	7.48*	3								
Braconidae + (Hymenoptera)	10.21**	3	0.00	1	4.61	3								
Sitona lineatus (Col.: Curculionidae)	4.54	3	25.51***	1	0.56	3	19.00***	2	1.44	6	9.10**	2	0.47	6
Staphylinidae >5 mm	3.92	3	6.71*	1	1.54	3	8.78**	2	4.25*	6	5.02*	2	2.36	6
Tachyporus hypnorum + (Col.: Staphylinidae)	21.40**	3	11.06*	1	15.54**	3								
Aleocharinae spp. + (Col; Staphylinidae)	16.35**	3	0.79	1	1.59	3								
Carabids >5 mm	1.61	3	0.20	1	3.09	3	1.63	2	1.33	6	1.13	2	0.56	6
Demetrias atricapillus (Col.: Carabidae)	10.06**	3	9.00*	1	3.74	3	5.17*	2	5.70**	6	17.02***	2	4.00*	6
Tipulid adults (Diptera)	9.61	3	0.44	1	0.46	3	19.44***	2	9.09***	6	0.40	2	0.42	6
Diptera >5 mm	3.34	3	4.48	1	0.49	3	31.50***	2	0.74	6	3.37	2	0.61	6

Total df =43, except analysis marked +, = 13   * p <0.05   ** p <0.01   *** p <0.001
Error df =20, except analysis marked +, = Error df =16

Table 2.5 **Summary of detransformed means per sample for invertebrates for which there were significant treatment effects - soil core samples**

Subject of analysis	Mean per sample			Standard Error
	Organic	Conventional	Organic Grass Ley	
Invertebrates in Significantly Greater Number on Organic Grass Ley (Analyses One)				
Invertebrates >5 mm	0.2756	0.2511	0.4588	0.0209
Immature Diptera Stages	0.1138	0.0212	0.2474	0.0200
Coleoptera	0.0824	0.1046	0.1532	0.0168
Invertebrates in Significantly Greater Number on Organic fields (Analyses Two)				
Lumbricidae	0.1904	0.0812	-	0.0304

Table 2.6 **Summary of detransformed means per sample for invertebrates for which there were significant treatment effects - vacuum samples**

Subject of analysis	Mean per sample			Standard Error
	Organic	Conventional	Organic Grass Ley	
Invertebrates in Significantly Greater Number on Grass Ley (Analyses One)				
Invertebrates >5 mm	3.47	3.78	4.94	0.081
Linyphiidae (Araneae)	4.01	3.22	7.51	0.188
Braconidae (Hymenoptera)	3.32	2.64	8.27	0.069
Invertebrates in Significantly Greater Number on Organic Grass Ley and Organic fields (Analyses One and Two)				
Sitona lineatus (Col.: Curculionidae)	1.19	0.21	1.64	0.101
Invertebrates Significantly Greater on Conventional Fields (Analyses Two)				
Staphylindae >5 mm	0.01	0.25	-	0.046
Tachyporus hypnorum (Col.: Staphylinidae)	2.09	4.26	-	0.173
Invertebrates in Significantly Greater Number on Organic Fields (Analyses Two)				
Demetrias atricapillus (Col.: Carabidae)	0.35	0.19	-	0.042

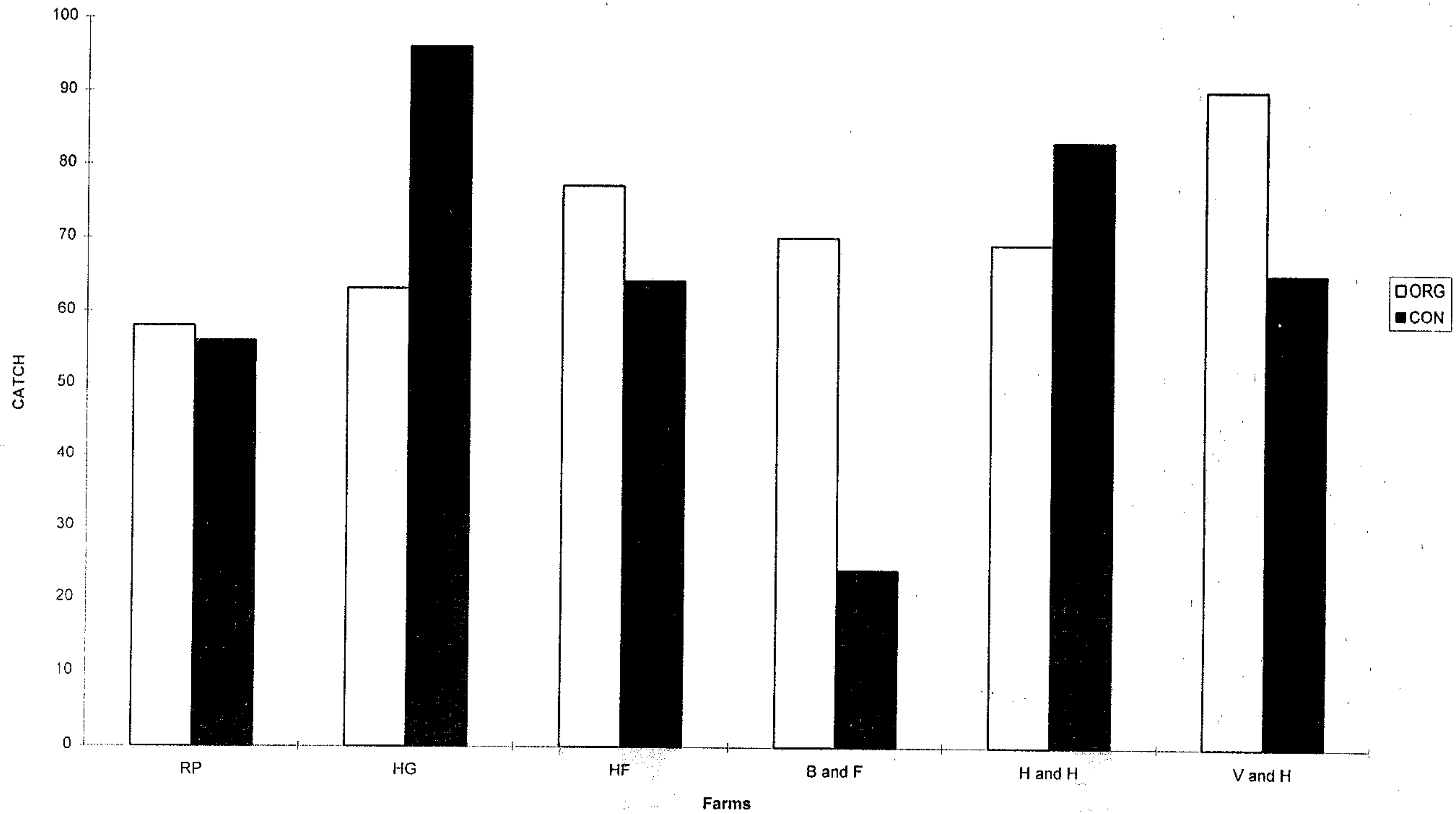

Figure 1 **Numbers of invertebrates >4 mm extracted from soil cores 1992**. (RP = Rhone-Poulenc; HG = Highgrove; HF = Home; B&F = Bank & Fifty, H&H = Hawstead & Horsecroft; V & H = Village & Hall.)

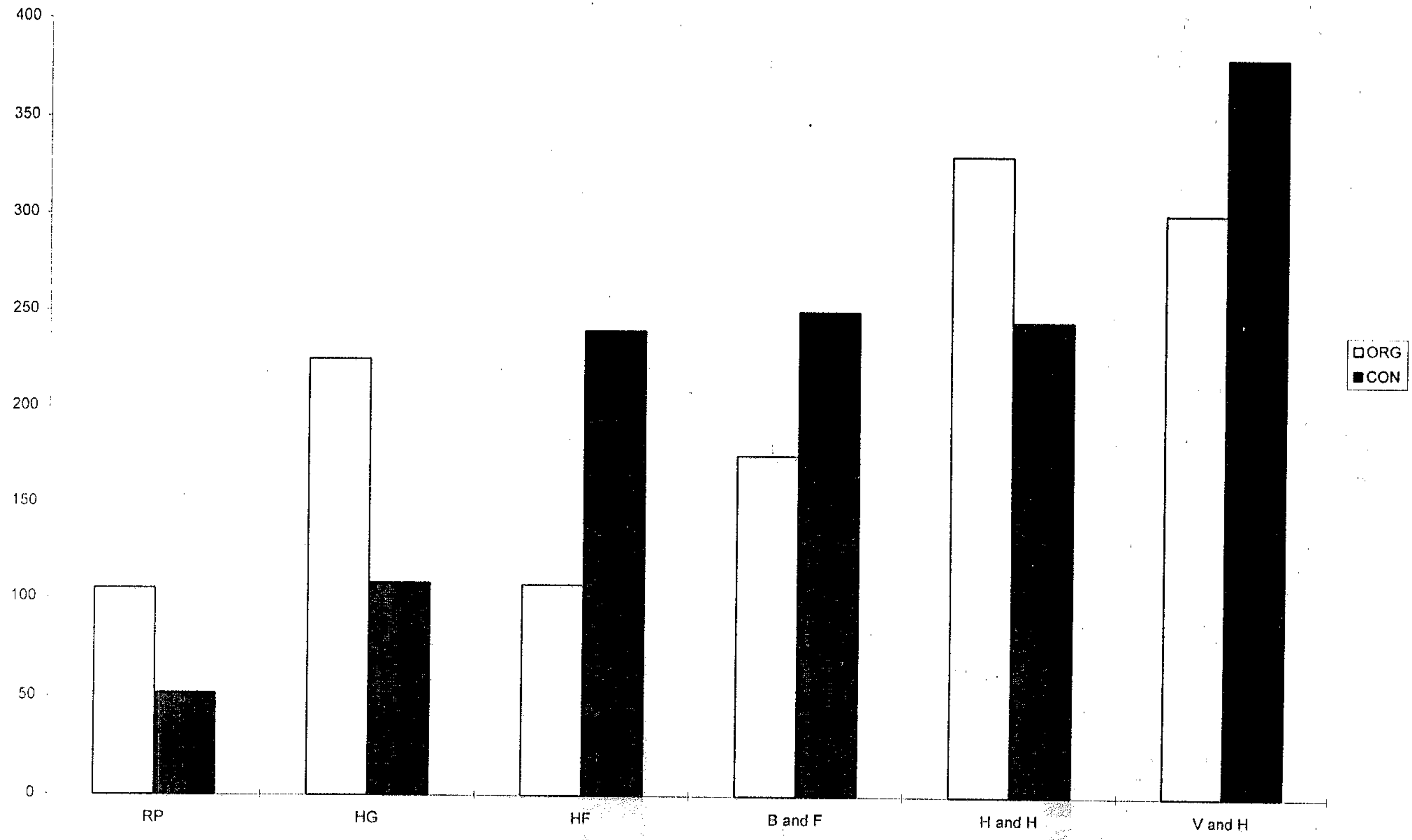

Figure 2 **Numbers of invertebrates > 5 mm caught in vacuum samples 1992.** (RP = Rhone-Poulenc; HG = Highgrove; HF = Home; B&F = Bank & Fifty, H&H = Hawstead & Horsecroft; V & H = Village & Hall.)

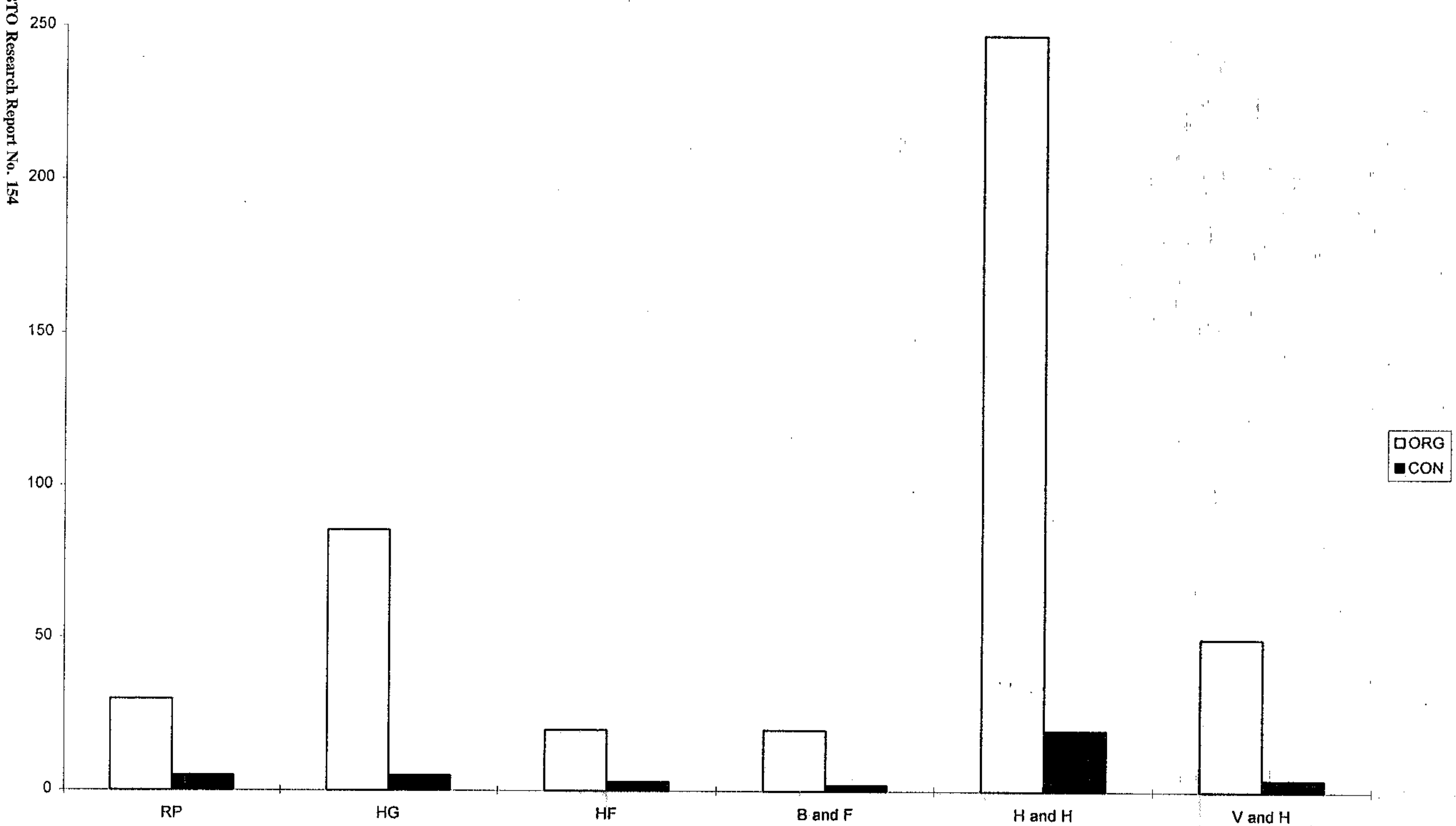

Figure 3 **Number of *Sitona lineatus* caught in vacuum samples 1992.** (RP = Rhone-Poulenc; HG = Highgrove; HF = Home; B&F = Bank & Fifty, H&H = Hawstead & Horsecroft; V & H = Village & Hall.)

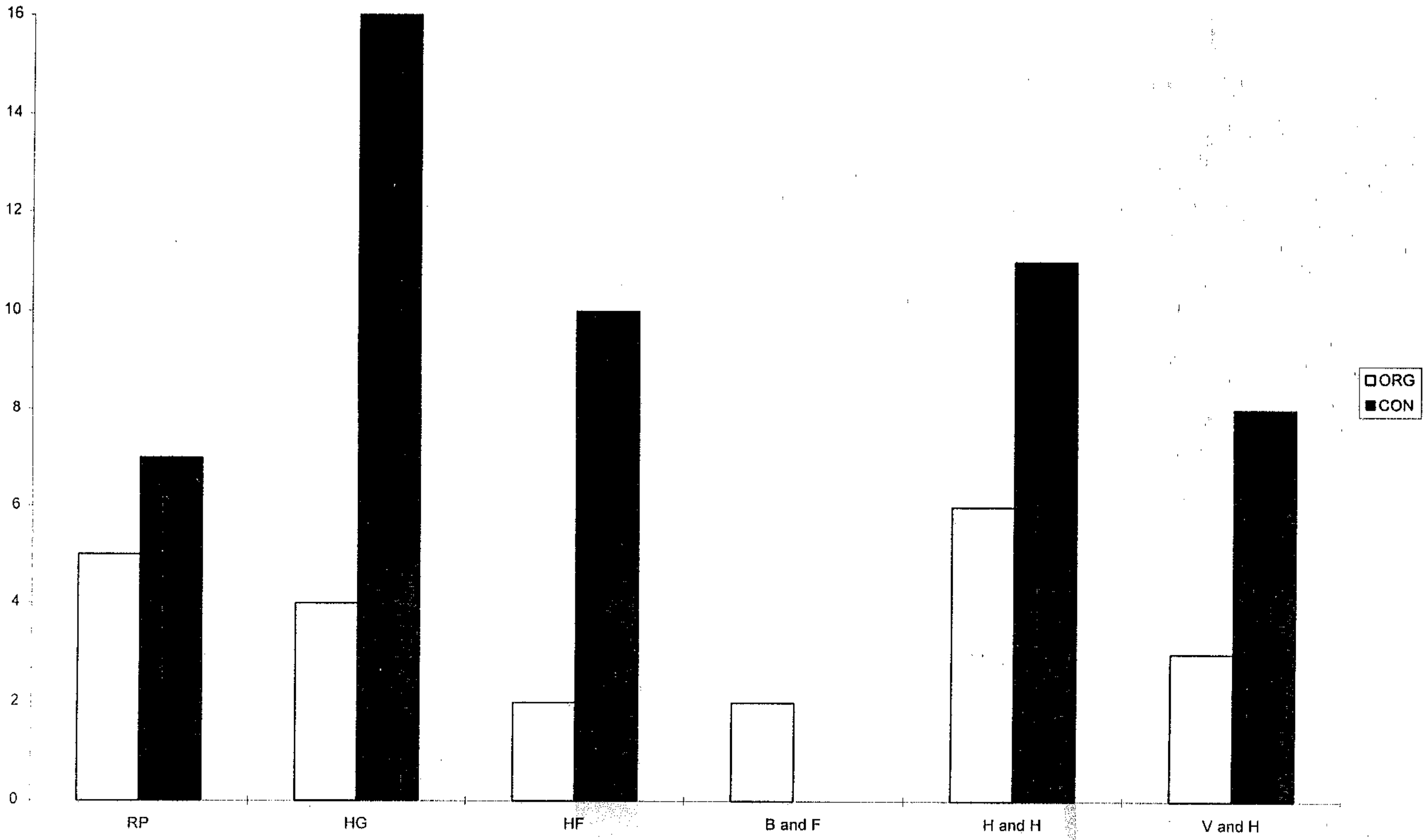

Figure 4 **Number of Staphylindae greater than 5 mm caught in vacuum samples 1992.** (RP = Rhone-Poulenc; HG = Highgrove; HF = Home; B&F = Bank & Fifty, H&H = Hawstead & Horsecroft; V & H = Village & Hall.)

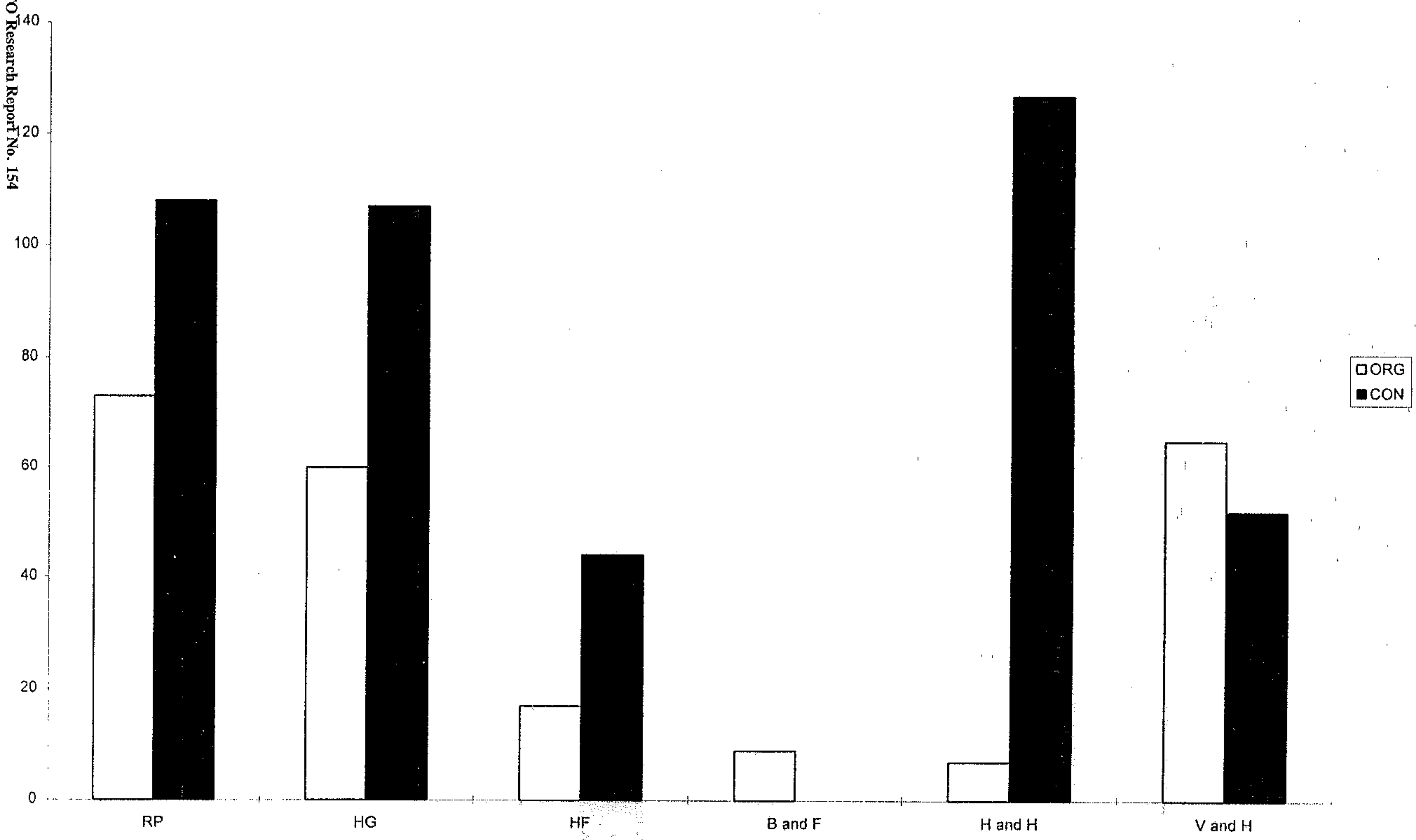

Figure 5 **Number of *Tachyporus hypnorum* caught in vacuum samples 1992.** (RP = Rhone-Poulenc; HG = Highgrove; HF = Home; B&F = Bank & Fifty, H&H = Hawstead & Horsecroft; V & H = Village & Hall.)

2.5 Discussion

2.5.1 Soil cores The soil sampling method yielded relatively small numbers of invertebrates of a size, 5 mm and above, likely to be of nutritional value to birds. Caution should be exercised in the interpretation of these results and when relating these data to likely field densities. Under-representation is likely to occur where invertebrate distribution is aggregated or invertebrate densities are too low to allow a high probability of capture in the limited amount of soil sampled. Practical limitations prevented more samples being taken in each field. Thus, although only one individual, per soil core, of a particular invertebrate may be caught from one field, this may be indicative of an actual density of several hundred-thousand per hectare. Such problems were recognised by Blackshaw (1988) when using a similar method to sample for tipulid larvae; he suggested modifications to raw data to yield more accurate estimates of field populations. The method of soil sampling described will also grossly underestimate population density if the soil is fairly dry, due to the migration of insects from the upper surface of the soil, from which sampling was restricted although this should reflect unavailability for birds. A chemical extraction technique, such as formaldehyde for earthworms or orthodichlorobenzene for tipulid larvae (Dawson, 1932), could be used to yield more precise results, but the labour involved was considered outside the scope of this study and would sample invertebrates unavailable to birds.

Those soil invertebrates identified by previous studies as being particularly relevant as bird food-sources are earthworms, tipulid larvae, beetles and molluscs (Murton, 1971). Availability, rather than abundance, is likely to be the over-riding factor for the success of bird species specialising in soil invertebrate feeding. Availability is affected greatly by farming practice and prevailing soil condition. For example, direct drilling techniques increase soil invertebrate density (Edwards, 1984), but normal ploughing and tilling provides birds with the best opportunity to access such invertebrates. The decline in spring-sown crops has possibly caused a decline in soil invertebrate feeders, such as the song thrush, that rely on spring cultivation to provide a high number of soil invertebrates. Also, results showed that the number of invertebrates declined during mid to late summer, probably as a result of drier soil conditions. This may prompt the observed switching of birds such as rook and starling from soil invertebrates to surface active invertebrates in late summer (MacDonald, 1983). The removal of the crop at harvest may considerably improve access for birds to probe the soil as only stubble is present, but if the soil is dry there will be few invertebrates available in the upper surface of the soil.

Earthworms are an important constituent of the diet of various birds such as carrion crows, rooks and thrushes (Holyoak, 1968). The Lumbricidae caught were largely sexually immature and therefore probably aggregated, because of the localised abundance of eggs in cocoons. Some large earthworms can avoid capture in soil cores by moving quickly, so soil coring is a questionable method for estimating earthworm populations reliably. Further extensive investigation, preferably using a full chemical extraction technique, would be required to substantiate the significantly greater number of Lumbricidae caught on organic cereal fields compared with conventional cereals. This result is however, concurrent with the observation of Edwards and Lofty (1982) that earthworm populations increase substantially with the application of farmyard manure. The organic content of soil is significantly larger when farmyard manure, instead of inorganic fertiliser, is used to improve soil fertility (Mattingly, 1974) as on organic farms. This increase in soil organic matter, which constitutes the diet of heterotrophic soil organisms such as earthworms (Edwards, 1984), is therefore the probable cause of the larger population size on organic fields. The removal of the harmful effects of nematicides and molluscicides (Edwards, 1984) on organic fields is also likely to be an influential factor. It is interesting to note that Scullion and Ramshaw (1987) observed that inorganic fertiliser deterred the tendency of species such as *Lumbricus terrestris* and

Allobophora ealiginosa to be active at the surface of the soil. The use of inorganic fertiliser on conventional fields may therefore impair the availability of this food-source to birds. Availability may also be impaired during mid summer when the soil is comparatively dry. The analyses showed that significantly fewer earthworms were caught at this time. This is probably due to the aestivation of earthworms in deep burrows in order to avoid desiccation in the upper level of the soil. The results of the extensive bird survey indicated that lapwing and fieldfare, which are both earthworm feeders, were significantly more common during winter on conventional fields. This would appear to be contradictory to the invertebrate analyses - although it is suggested that the size of fields may be of primary influence (see Chamberlain *et al.*, 1995).

The sample mean for tipulid larvae was comparatively large for organic grass ley fields, although this was not significantly different from the cereal fields in the analyses. This conformed with previous observations of habitat affinity (Brindle, 1960; Coulson, 1962). Tipulid larvae are an important bird food-source, particularly for the starling, the breeding season of which coincides with peak biomass of this invertebrate for chick feeding (Dunnet, 1955). It is therefore possible that organic farms, which are likely to have a preponderance of grass/clover leys used in rotation to improve soil nitrogen levels, may harbour larger populations of this food-source. However, the results of the extensive bird survey did not indicate that the starling was significantly more common on organic farms during the winter (see Chamberlain *et al.*, 1995). It is, however, possible that the survey was conducted too early for tipulid abundance to an influential factor in this result. In arable fields tipulid larvae are likely to be found in the spring of the year following conversion from grass ley, especially if the soil is comparatively wet. High densities of the larvae can then cause significant yield losses by feeding on the crop roots. This is more likely to occur on organic farms due to the greater use of grass ley in rotation. However, this occurred only twice during this study and was not confined to organic fields. The estimated economic threshold value for tipulid damage, is 1.75×10^6/ha (Blackshaw, 1988) which is relatively large and it is possible that with correct management densities can be kept below this such that there may be no deleterious effects on plants. For example, dense planting can negate the effect of even large tipulid densities (French, 1984). Tipulid larvae might, in these circumstances, benefit birds without adverse direct effects on crops. Chlorpyrifos controls tipulids well with no adverse effect on birds (Dowsett *et al.*, 1987). Rolling of grassland in July, to impede adult emergence, is also an effective control measure (Kell and Blackshaw, 1988). This may provide an alternative to chemical control on organic farms.

The total number of dipteran immature stages was significantly larger on organic grass ley fields. This was due to the dominance of larvae of Calliphoridae, found primarily at the Duchy Home Farm site. Grass ley fields at this site were regularly grazed by cattle and sheep which would probably have provided dung favouring the saprophagous Calliphoridae larvae, especially of the genus *Lucilia* (Smith, 1989). There may also be secondary advantages for birds probing grass leys such as greater access due to shorter vegetation, and where animals are grazed, the provision of water all the year round. Grass ley is also an important hunting habitat for raptors such as kestrel and barn owl (Shrubb, 1980; Pettifor, 1983). Other species of dipteran larvae which would favour manure application such as Muscidae and Scathophagidae species were found exclusively on organic fields, although only in low numbers. Larvae such as the Calliphoridae, Muscidae and Scathophagidae are of sufficient size in the late instars to be of nutritional value to probing birds. The same is true of bibionid larvae, small numbers of which were found on organic fields. These larvae may be carried in manure when it is applied to fields (Morris, 1922). The larvae have been known to reach a sufficient density to cause damage to cereal and root crops (Freeman and Lane, 1985), in which case they could represent a beneficial food-source to birds - especially as they are similar in size and appearance to tipulid larvae.

The similarity in the number of Coleoptera from both farming systems is inconclusive as the numbers represent many different species, none of which were found in quantities sufficient to establish reliable trends. Many of the trapped beetles, such as adult Carabidae, are likely to have been present on the soil surface when the soil cores were taken rather than actually present within the soil. Although found only in relatively small numbers *Sitona* spp. pupae and larvae were confined to organic fields, possibly as a result of feeding on volunteer clover root nodules from rotational grass/clover leys. It is possible that some soil dwelling larvae, such as *Harpalus rufipes* (Col.: Carabidae), may be able to utilise a greater resource of weed seeds, on which they feed, on organic fields due to the lack of herbicides. This, however, has not been substantiated by this study.

2.5.2 **Vacuum samples** Some important considerations regarding the efficiency of the vacuum sampling method should be noted when interpreting the data presented. The ability of the machine to capture invertebrates may be impaired by high densities of vegetation (Hand, 1982). This could lead to the introduction of a possible bias against capture on organic fields, where weed density may be increased due to the lack of herbicide applications. It is interesting to note that the results of the analyses show that Braconidae (Hymenoptera) and two species of beetle were caught in significantly lower numbers at the Bank and Fifty Farm sites, where the density of weeds on the organic fields was extremely large. The capture efficiency of the vacuum sampler also varies between species (Hand, 1986). The capture rate is likely to vary considerably with climatic conditions, particularly in relation to temperature. This is likely to have been a major contributory factor in the significant variation between different sample dates as well as the programmed biological temporal variation. Hand (1986) recommended employing correction factors to the results achieved to take into account the species sampled and the density of vegetation. However, this would rely on a previous quantification of capture efficiency for a particular species under laboratory conditions, so was considered impractical within the context of this study. Thus caution should be exercised with regard to the significantly greater number of invertebrates (>5 mm), Braconidae and linyphiid spiders found on organic grass ley. The efficiency of the vacuum sampler will be greater because of the vegetative structure of the shorter grass relative to the taller and more dense crop. The aphidaphagous nature of the linyphiid spiders and many species of braconid wasps may lead to larger densities on grass ley if the number of aphids is proportionably larger, due to the absence of insecticide spraying. However, no significant treatment difference was found in the number of aphids caught. The results achieved for linyphiid spiders concur with the observations of Vickerman (1974), that a greater number were recorded from a winter barley crop containing a dense growth of grass weeds.

The results achieved for the weevil *Sitona lineatus* (Col.: Curculionidae) are particularly relevant to the assessment of the potential benefits to birds from organic farming. The skylark feeds on *lineatus* under laboratory conditions (Green, 1978) and is also known to utilise Curculionidae generally. The weevil is sufficiently large and prodigious to be of nutritional benefit to birds. It is also likely to be accessible to birds, as it is active during the day, with peak activity occurring on warm days at about noon (Hamon *et al.*, 1987). *Lineatus* feeds on a number of legumes including white clover (*Trifolium ripens* L.), on which it also overwinters (Jackson, 1920; Markula & Koppa, 1960; Wiech, 1984; Schotzko & O'Keefe, 1988). The significantly larger number of *Sitona lineatus* found on organic fields, could be a result of a population persisting from a previous grass/clover ley, possibly due to the presence of volunteer plants. This is more likely on organic farms where grass/clover leys are used in rotation to improve the nitrogen content of the soil. A comparatively larger number of *Sitona lineatus* were recorded directly from grass/clover ley. A larger number of *Sitona lineatus* were caught on one field at Hawstead Farm, an organic farm, adjacent to a field with a bean crop. This is consistent with the large number of the weevil caught, in the absence of insecticides, on an organic leguminous crop (Wijnands & Kroonen-Backbier, 1986), and the preference for beans as a food-source (Murray & Clements, 1994). The large capture rate in a neighbouring field was probably due, on a post-harvest sample date, to the activity associated with post teneral weevils flying from crops to overwintering sites in late summer (Hamon *et al.*, 1987). *Lineatus,* also displays post-diapausal flight activity in the spring in order to disperse to leguminous crops. Organic farms with leguminous crops may thus harbour large densities of *lineatus* with sufficient daytime activity to be advantageous to birds needing to feed on invertebrates in the spring, such as skylark, or to birds such as starling which need to switch from soil invertebrates (due to their comparative scarcity) in late summer (MacDonald, 1983). It is interesting to note that grass/clover leys and triticale stubble under sown with clover had high territory and fledging success for skylarks at Village Farm (see the results of the intensive bird survey, Evans *et al.*, 1995). This, however, presents a conflict of interests for the organic farmer as large densities of this weevil could exceed the economic threshold for crop damage. This problem will be compounded by the likelihood of the provision of an overwintering refuge on grass/clover leys on organic farms. However, it is possible that in the absence of leguminous crops on organic farms, grass leys may provide a population of sufficient size to be of benefit to birds. If a known resistant variety of clover such as Donna (Murray & Clements, 1994) is used, biological fixation of nitrogen may not be adversely affected. It is interesting to note that lapwings have been observed to show a preference for winter wheat following a clover ley during the winter (O'Connor & Shrubb, 1986). Lapwings were, however, found to be significantly more abundant on conventional fields in the extensive bird survey, although this may simply be due to the effect of field size (see Chamberlain *et al.*, 1995).

As previously stated, the significantly greater number of larger staphylinid beetles found on conventional fields should be regarded with caution due to the comparatively small sample mean. However, this result may be suggestive of a trend favouring staphylinids on conventional fields. This may be due to the fact that such beetles are able to utilise the higher densities of aphids on conventional crops for predation (although there were no significant differences in this study), prior to insecticide application and then avoid contact with the latter due to their relatively good dispersal power. The predominant species caught, *Philonthus cognatus,* is aphidaphagous and is a good flier. This may also have been the case with the smaller staphylinid *Tachyporus hypnorum,* for which a more reliable trend towards higher densities in conventional fields was established. This may appear contrary to a previous correlation of the species with high weed density in crops (Kowalski, 1986; Powell *et al.*, 1985), a factor that should have favoured organic fields. *Tachyporus hypnorum* has, however, been shown to be unaffected by insecticide-contaminated soil in relation to the predation rate of aphids (Forster, 1990), although this species is directly susceptible to deltamethrin (Forster, 1991). This beetle is active during the night (Kennedy *et al.*, 1986) which, together with its relatively small size, makes this insect of questionable importance as a food-source.

The vacuum sampler is of limited value in the assessment of the populations of larger carabid species because of the low efficiency of capture. The technique can, however, capture a reasonable number of the smaller species of carabid. This was observed in the case of *Demetrias atricapillus.* This may have been more vulnerable to capture by the vacuum, because it climbs plants in order to search for prey, especially aphids. The significantly larger numbers of this beetle caught on organic fields, shown by Analyses Two, could possibly be due to habitat degradation of hedgerows, by herbicide drift on conventional fields reducing overwintering sites. The beetle prefers hedgerows for overwintering that are rich in vegetation, especially cocksfoot (Thomas *et al.*, 1992). However, this suggestion must remain highly speculative in the absence of supportive evidence. Together with the ability to climb plants, this beetle has relatively bright coloration and a diurnal activity pattern.

These facts may make the beetle more conspicuous to birds and therefore vulnerable to predation.

The analyses of the adult Diptera would require further taxonomic work to elucidate potential differences between the farming systems. At the sub-order level, specific species' preference is likely to negate the establishment of an overall trend. For example, species such as *Scathophaga stercoraria* (Scathophagidae) may be more common on organic fields due to their preference for manure application. Such studies would constitute interesting future work.

It can be concluded that vacuum sampling is suggestive of a trend towards larger numbers of *Sitona lineatus* and *Demetrias atricapillus* on organic fields, which may be of benefit to birds as a food-source. However, staphylinid beetles, especially the species *Tachyporus hypnorum* may be more prodigious on conventional fields. Where significant differences between the farming systems exist, they appear to be at the species level. The reason for such differences may be due to the provision of a specific requirement that favours a species. The opportunity for discrepancy between species in wider taxonomic groups therefore exists. This may explain the lack of significant variance between the gross number of invertebrates in large taxonomic groups. Correct assessment of the abundance of invertebrates should, therefore, focus on species or taxa for which favoured environmental parameters are known to be consistent. The ecology of such invertebrates must be considered when assessing the benefit, to birds, as a food-source. For example, availability at certain times of the year may be adversely affected by the life cycle of a species. Also, if the species is mainly active at night it will be of little benefit to feeding birds.

3. FAECAL SAC ANALYSES

3.1 Summary

3.1.1 Carabid beetles were an important component of skylark chick diet. Insect fragments from this family were the most common encountered in faecal sacs, forming 47% of identifications. In some cases it was possible to identify the species that had been consumed.

3.1.2 Other Coleoptera also identified as food-sources were Elateridae, Curculionidae, Chrysomelidae and Staphylinidae.

3.1.3 Fragments of spiders and tipulids were also found in a number of faecal samples.

3.1.4 Reservations are expressed that the technique may under-represent soft-bodied invertebrates, which are susceptible to complete digestion by the skylark chicks.

3.2 Introduction

In 1992 and 1993 sampling for invertebrates was carried out using a vacuum suction sampler and 10 cm diameter by 10 cm deep soil cores taken using a soil auger. Although these two techniques gave a good general comparison of the diversity and abundance of invertebrates the actual numbers of many taxa which might be important in the diet of skylark chicks were very low (see results on sampling). In particular, few large macroarthropods were caught by either sampling method and it was decided to ascertain what young chicks were being fed so that the sampling programme could concentrate on these groups.

In a personal communication with Dr Jeremy Wilson of the BTO it was decided to use chick faecal sac analysis to determine the main food items of skylark chicks. The initial test sampling of chick faecal sacs was carried out at Hall Farm (conventionally managed) and Village Farm (organically managed), both farms were already involved in the project. A sampling regime for 1994 would be developed dependent on the results from the faecal sac analysis.

3.3 Materials and methods

Skylark nests were located and marked with canes in seven cropping systems both conventionally and organically managed. Chick age, in days, was assessed and faecal samples obtained. Twenty-nine nests were located and sampled giving a total of 219 faecal sacs for analysis. The mean chick age was six days with a range of three to 12 days old. Faecal sacs from individual nests were preserved in 70% alcohol. Sampling was carried out during the months of May and June 1993, each sample was individually dated. See Appendix 9 for a detailed list of invertebrates identified in these samples. Preserved faecal sacs were analysed over a two-week period and invertebrate remains identified as far as possible. A second, smaller set of faecal sac samples was obtained in May 1994 from Hall and Village Farms (Appendix 10).

3.3.1 **Examination of faecal samples and analysis of their arthropod content** Individual faecal sacs were examined by rinsing the sac into an 8 cm × 12 cm clear plastic dish which had a 1 cm x 1 cm grid etched onto the bottom. A small spatula made from copper wire beaten flat and fitted into a microbiological wire-loop holder was used together with two pairs of very fine watchmakers' forceps to break open the sac and tease out the contents. This operation was carried out using an Olympus SZH research stereo microscope at a magnification of ×7. Previous workers had experienced problems with faecal sacs breaking down and clouding the sample, making observations difficult (Pearson-Ralph, *et al.*, 1985; Moreby, 1988). By preserving the sacs in 70% alcohol the problem lessened considerably as the sac either became very rubbery or very brittle and readily cracked apart to give a good clear sample.

As the arthropod remains were teased out they were identified where possible and in many instances could be identified to species by matching up structures on intact, set specimens. This worked particularly well for Coleoptera especially the Carabidae and a number of species could be identified (Appendix 11). Other arthropods were identified to Order or Family where possible (Appendix 12).

3.4 Results

From a total of 29 skylark nests, 219 faecal sacs were obtained during the months of May and June 1993. Table 3.1 lists the invertebrates identified and the life stages. This is followed by a brief description of the fragments found that enabled positive identifications to be obtained.

3.4.1 Arachnida Spiders were found to be a common component in the diet of skylark chicks, occurring in nearly every faecal sac and covering all ages of chicks. The fragments recognised as belonging to spiders included leg fragments, male pedipalps, fangs (these usually remained as a pair) and in one instance a complete head carapace with eyes was identified. One interesting observation was a faecal sac containing completely intact spiderlings, indicating a female spider carrying its own egg sac had been taken and yet the spider egg sac was strong enough to preserve the young spiders intact during passage through the chick's digestive system.

3.4.2 Coleoptera At least five major families were identified from various remnants which included elytra, legs, thoracic shields, heads and pieces of genitalia. Of those beetles identified the Carabidae were the most common. Thoracic shields, especially the hind angles, allowed positive identification to species to be obtained. Ten species of Carabidae were identified (Appendix 11) and appeared to be the most common dietary intake of the chicks. Other Coleoptera were identified to family by particular fragments e.g. the 'peg' in Elateridae, heads of Curculionidae, legs and elytra from Chrysomelidae and Staphylinidae from heads and elytra. Coleopterous larvae were identified from heads and mandibles. The larvae of *L. pilicornis* were easily identified by the three-toothed retinaculam of the mandibles and intact heads with distinctive nasale.

3.4.3 Hymenoptera Very few specimens found but those identified were usually intact adults e.g. Formicidae (ants).

3.4.4 Lepidoptera The soft bodied larvae yielded very few identifiable remnants however, the distinctive mandibles did show up and the occasional spiracle. One sample yielded an intact head capsule with mandibles.

3.4.5 Diptera Remains of tipulid pupae and larvae were fairly easy to recognise but remnants of adults were very scarce, the occasional wing was found. However, in a large number of samples very small, black, seed-like structures were observed usually in very high numbers. These turned out to be tipulid eggs, indicating that gravid, adult females were being taken as a food-source. As seen previously with spiderlings, the eggs appeared to have survived passage through the chick's digestive system without any obvious damage. If it could be shown that the eggs were still viable then the skylark could be providing an important method of dispersal of tipulid eggs.

Other invertebrates also identified were Thysanoptera (a single intact adult) and an oribatid mite (also intact). However, it is more likely that these individuals came in on some other food-source or had been picked up by the chicks whilst in the nest. It is unlikely that these invertebrates were actively taken by adults as food for the young.

Using the results in a semi-quantitative manner, by considering each identification as indicating the presence of a particular arthropod taxon, Table 3.1 shows the % presence in faecal sacs of the different arthropods extracted.

Table 3.1 % presence of arthropod taxa in faecal sacs

Taxon	% Presence in sacs
Carabids	46.6
Staphylinids	6.2
Other Coleoptera	11.4
Tipulids	14.5
Spiders	15.5
Lepidopteran larvae	4.2
Ants	0.5
Mites	0.5
Heteroptera	0.5

3.5 Discussion

Coleoptera make up 64.2% of the identifications for the 1993 samples (Table 3.1). This compares with 83% found in faecal remains of skylark adults by Green (1978). Caution is expressed that this technique may under-represent softer-bodied invertebrates, such as Diptera larvae or earthworms. The parts of these invertebrates that are sufficiently hardened by chitin, such as the mouthparts of Diptera larvae or the chaetae of earthworms, are likely to be over-looked in the analyses due to their small size.

As can be seen from Appendix 9, a wide range of invertebrate fragments were extracted from both conventional and organic set-aside. This correlates well with the observations of chick condition on these fields during intensive field studies for the 1993 season. The condition and productivity of skylark chicks were considered to be successful on both of these field types (see Evans *et al.*, 1995). The faecal sac analysis from these fields strongly suggests that such success might be linked to invertebrate abundance. It is interesting to note that the set-aside on the conventional farm was free from pesticide or synthetic fertiliser application during the breeding season. This may have had implications for invertebrate abundance on these fields. Appendix 10 shows that a similar range and number of invertebrates were identified from faecal sacs from both organic and conventional cereal fields during the 1994 season. This suggests that a similar provision of invertebrate food resources on these fields may have influenced the lack of difference observed in chick productivity. The results of the pitfall trapping programme on these fields also indicated that the abundance of carabids on these fields may have been similar.

As a result of the faecal sac analysis, and the results of a preliminary survey at Eastbrook Farm, Wiltshire (see Appendix 13) in the autumn of 1993, it was decided to adopt a pitfall trapping programme on all farms involved in the project to replace vacuum sampling and soil coring for the 1994 season as this is the only practical way to sample the larger Coleoptera in sufficient numbers for analysis (see section on pitfall trapping).

4. PITFALL TRAP STUDIES

4.1 Summary

4.1.1 Studies of the epigeal arthropod fauna on organic and conventional farms were carried out between May and August 1994. Quantitative analyses concentrated on ground beetles (Col.: Carabidae) because they formed the largest component of pitfall trap catches.

4.1.2 Over 33,000 individuals from 50 carabid species were recorded, with total numbers from 13 organic fields being 1.7-times greater than 15 conventional fields. Approximately 77% of species were categorised as eurytopic, preferring open country. *Pterostichus melanarius* was the dominant species captured, comprising 60.0% and 60.5% of carabids from organic and conventional fields respectively.

4.1.3 The abundance of 12 key carabid species in pitfall traps at five sites indicated that the number of *P. melanarius* and four other species caught were significantly higher on organic farms.

4.1.4 Williams' Index of Diversity was significantly greater for conventional fields, although caution is expressed over the reliability of this result due to the small sample size of species.

4.1.5 The implications for carabids as food for skylark chicks are briefly discussed.

4.2 Aims

The primary objective was to investigate the surface-dwelling or epigeal arthropod fauna at several sites in southern England to determine if any differences exist between organic or conventional farms. Studies were focused on ground beetles (Col.: Carabidae) since preliminary examinations of faecal sacs from skylark chicks suggested that carabids were an important food-source.

4.3 Methods and materials

Sampling was carried out largely in southern England in the counties of Oxfordshire, Suffolk and Wiltshire. Samples were obtained either directly by personnel from IACR-Rothamsted or from volunteers already recording data for the British Trust for Ornithology who posted samples to Rothamsted.

At each site two pairs of fields were sampled, except in the case of the Institute of Grassland and Environmental Research (IGER) site where only one pair of fields was available. Each pair of fields consisted of a conventional and an organic field. At the Eastbrook, IGER and Hall (Lincs.) sites both field types were sampled at the same farm. At the other sites sampling was carried out on a pair of organic and conventional farms that were close together. Winter cereal crops were sampled, except in the case of one spring oats field at Hall Farm. This crop was, however, sown early and was at a similar growth stage to the winter cereals at the time of sampling. Where possible consistency was maintained between crop types on comparable fields. Twelve pairs of winter wheat fields were sampled. This was the crop sampled exclusively at the Coldharbour/Leadenporch, Step/Colleymore and IGER sites. Single pairs of winter wheat fields were sampled at the Eastbrook and Village/Hall sites. Single pairs of winter barley fields were sampled at the Eastbrook, Batchley/Grendon Manor and Village/Hall sites. One pair of winter oats fields was sampled at the Batchley/Grendon Manor site. The other fields consisted of different crops within each pair. At the Village/Hall site one pair of fields consisted of winter barley and a winter oats field paired with a winter wheat field. At the Overtons site only conventional crops were sampled, which consisted of a sugar beet field and a winter wheat field. The intention of sampling at this site was to investigate a possible correlation between the large number of skylarks, that had frequently been observed in the vicinity, and the abundance of epigeal arthropods. These details of the crops sampled and sites are summarised in Appendix 15.

Each field was sampled using five pitfall traps placed in a transect from hedgerow to field centre at 20 m intervals. Each trap consisted of an outer plastic ring (102 mm length, 65 mm internal diameter) sunk into the soil and contained a white plastic cup (77 × 60 mm) with approximately 65 ml of 50% ethylene glycol solution. Traps were protected from rainfall by plastic dishes (132 mm diameter) suspended 50-80 mm above the traps with wire loops.

Sampling was normally carried out for 14 continuous days, during May to July, after which the traps were replaced.

Captured material was sorted and identified under ×20 magnification with a stereo microscope. Carabid nomenclature and taxonomy was based on Kloet and Hincks (1977).

4.4 Data analysis

4.4.1 Diversity statistics Species lists, abundances and species richness were compiled for organic and conventional farms.

Catch data from the dates shown in Appendix 15, for organic and conventional farms, was tested to determine if they were adequately fitted by Fisher's log-series distribution which gives a good description of species frequency distributions for a wide range of taxonomic groups. The expected number of species, E_r, with r individuals recorded from sample size X is given by:

$$E_r = \propto X^r / r$$

where $\propto > 0$ and $0 < X < 1$ and where $\propto$ is Williams' Index of Diversity. The expected number of species in a sample is given by $E(S) = -\propto \log(1-X)$, and the expected number of individuals by $E(N) = \propto X / (1-X)$.

The $\propto$ index was originally produced for site comparisons of moth light trap catches collected over several years because theoretical derivation of $\propto$ indicated that it was independent of sample size (Fisher *et al.*, 1943). The superiority of this parameter over others was confirmed by Taylor *et al.* (1976). Its advantages include independence of sample size, relative insensitivity to the most abundant and rarest species and its power as a discriminant between sites.

The maximum likelihood estimate, $\propto'$, of $\propto$ is given by:

$$S = \propto' \log(1 + N / \propto')$$

where S is the number of species and N is the number of individuals caught.

Values of $\propto$ were calculated using the Maximum Likelihood Programme v. 3.08 (Ross, 1987) and Analysis of Variance (ANOVA) was used to determine if there were differences in $\propto$ between farming systems or sites.

4.4.2 Analysis of variance for selected carabid species

Three factor ANOVAs were performed using Genstat 5 for 12 carabid species at five sites for five collection dates (Table 4.1). Major factors were farming system, site and collection date. The effects of two factor and three factor interactions were estimated. Data were transformed using a $\log_{10}(x+1)$ transformation where x = number of individuals $trap^{-1}$.

Table 4.1 Sites and dates for 3-factor ANOVAs

Site	Dates for ANOVA
Coldharbour/Leadenporch	(M), (M), 27/6, 7/7, 22/7
Eastbrook	27/5, 10/6, 27/6, 7/7, 22/7
Step/Colleymore	27/5, 10/6, 27/6, 7/7, 22/7
Village/Hall	29/5, 14/6, 28/6, 12/7, 27/7
Hall (Lincs.)	31/5, 13/6, 28/6, 12/7, (M)

(M): missing value

4.5 Results

4.5.1 All sites Over 33,000 individuals from 50 species were recorded. Considerably more individuals were trapped in the organic fields compared with the conventional (Appendix 16). The numbers of species recorded from organic and conventional farms was 41 and 44 respectively. The dominant Tribe was Pterostichini which made up 74% of the species and 99.6% of individuals. Species lists for organic and conventional farming systems are given in Appendix 16. Appendix 17 provides brief notes on habitat affinities, adult diel activities and oviposition periods for all carabids largely based on Lindroth (1985, 1986), Luff (1978, 1993) and Thiele (1977).

Figure 6 summarises biological information from Appendix 17 for species where relevant information was available. Species were largely eurytopic, defined as not showing much preference for any particular habitat group (den Boer, 1977). Most species were spring breeders and more were active at night (Figure 6).

The dominant carabid in pitfall trap catches was *melanarius*, a cosmopolitan species commonly recorded from farmland. *P. melanarius* formed 60.0% and 60.5% of carabids caught from organic and conventional farms respectively. *P. madidus* dominated catches at Village Farm rather than *P. melanarius* possibly because of woodland adjacent to study fields which may have served as a refuge or overwintering habitat.

Rank-abundance curves indicated carabid assemblages were similar from organic and conventional systems (Appendix 18) and 11 species occupied ranks 1 to 12 in both farming systems. Very common species in catches (species ranks 2-8) were three to four times more numerous from organic fields compared to conventional fields, but this was countered by less common species in catches (species ranks 20-30) being two to four times greater from conventional fields.

Combining results from both systems showed that 22% of species were recorded at just one farm while 12% of species were found at all 15 farms.

A comparison of the pitifall trapping with soil coring and vacuum sampling is shown in Appendix 14. From this comparison it is clear that pitfall trapping yielded many more invertebrates of the kind found in skylark chick faecal sacs and so provided a much more accurate assessment of the dietary intake. Numbers of arthropods, especially the macroarthropods, were greatly increased so allowing a much improved statistical analysis to be carried out (see analysis of results).

Pitfall trapping also provided a better return in terms of number of arthropods caught for a given effort in the field when compared to vacuum sampling and soil coring. Processing of samples was also greatly speeded up.

4.5.2 $\propto$ **Index** Agreement with Fisher's log-series was accepted for catch data from organic and conventional farms ($\chi^2 = 5.30$, 4 df, $p>0.05$ and $\chi^2 = 6.24$, 4 df, $p>0.05$ respectively) after data had been combined for all collection dates and fields within each of the two farming systems.

A two-way ANOVA with individual field results as replicates indicated significant differences in carabid diversity between farming systems ($F_{1, 27} = 4.86$, $p < 0.05$) but not between sites, with greater diversity being found from conventional farms (mean = 3.63 $\pm$0.41 c.f. 2.72 $\pm$0.41). These results are summarised in Appendices 19 and 20. However, caution is expressed over the reliability of these data as the number of species sampled is fairly small. The number of individuals captured at sites such as Leadenporch farm is also small which will introduce a degree of bias. Such constraints are probably due to restricting sampling to one family: representation of wider taxonomic groups, such as all Coleoptera, would produce more reliable results.

4.5.3 **ANOVA** Summaries of F-ratios for selected carabid species are presented (Table 4.2) and there were five species where significantly higher means were recorded from organic farms (Table 4.3). Significant effects of the Time on numbers of carabids probably reflected the reproductive activities and intrinsive phenologies of the species involved. Autumn breeders (e.g. *P. melanarius, P. madidus, C. fuscipes, H. rufipes*), which exist as adults during the summer, were generally more numerous in collections made after end-June. Spring breeders (e.g. *A. dorsale, B. lampros, N. brevicollis, P. cupreus, H. affinis*), which are present as larvae during the summer, were more numerous in collections from end-May to mid-June.

Step and Colleymore Farms had comparatively higher means of *P. melanarius, P. cupreus* and *N. brevicollis*, while Village and Hall Farms had higher means of *P. madidus* and *H. affinis*. The lowest means of *T. quadristriatus* were at Coldharbour and Leadenporch Farms compared to other sites, and numbers of *H. rufipes* were lowest at Eastbrook.

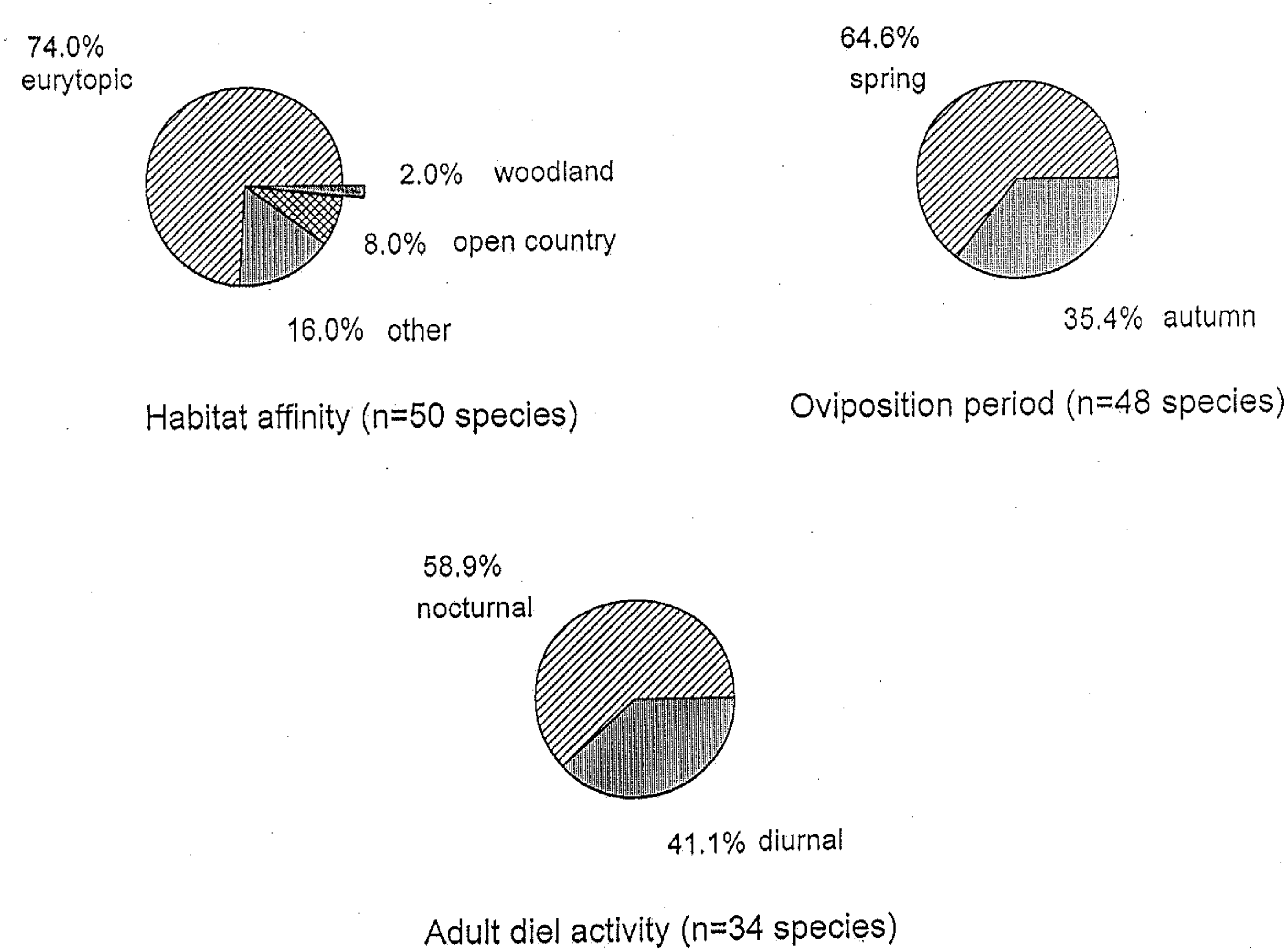

Figure 6 Classification of carabid species.

Table 4.2 ANOVA results for selected carabid species - summaries of F-ratios

Carabid species	Site	df	Tmt	df	Site* Tmt	df	Time	df	Site* Time	df	Tmt* Time	df	Site*Tmt *Time	df
Pterostichus melenarius	8.13 ***	4	18.91 **	1	13.77 ***	4	39.21 ***	4	1.39	13	1.44	4	2.02	13
Pterostichus madidus	7.40 **		5.39 *		4.01 *		8.86 ***		3.63 **		2.02		2.69 *	
Pterostichus cupreus	3.53 *		3.45		1.12		17.78 ***		2.18 *		5.73 **		1.37	
Pterostichus niger	1.72		2.28		1.63		1.91		1.13		1.20		1.51	
Bembidion lampros	0.67		0.01		0.94		14.20 ***		1.67		0.24		0.78	
Loricera pilicornis	1.74		1.71		0.46		0.79		0.90		1.28		0.50	
Agonum dorsale	3.01		0.11		1.70		25.41 ***		1.31		0.97		0.92	
Nebria brevicollis	7.69 **		34.82 ***		4.39 *		47.67 ***		2.82 **		9.48 ***		1.23	
Harpalus rufipes	5.23 *		29.10 ***		9.13 **		11.75 ***		1.96		4.67 **		3.11 **	
Harpalus affinis	24.00 ***		70.11 ***		15.74 ***		4.71 **		2.24 *		4.59 **		1.53	
Calathus fuscipes	2.00		2.05		1.83		2.73 *		2.27 *		0.87		0.92	
Trechus quadristriatus	4.44 *		0.39		0.72		2.41		2.03		1.18		0.70	

Total df = 85
Error df = 42

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

One or more significant two-factor interactions were estimated for seven of the species and these interactions are illustrated in Figures 7 and 8.

For individual species, it must be emphasised that ANOVA results will differ from data used for diversity analyses, since the former are based on catches from three to five dates at five sites and the latter are based on two to seven collections at seven or eight sites. This difference is illustrated by data for *P. niger*. A total of 960 individuals was recorded from organic and conventional systems (Appendix 16) but 640 individuals (66.7%) were from Batchley and Grendon Manor which were not included in the three-factor ANOVA.

Table 4.3 Detransformed means for five species from organic and conventional systems

Carabid species	$\bar{X}$, Organic	$\bar{X}$, Conventional	Std. Error
Organic > Conventional, $p < 0.05$			
Pterostichus melanarius	18.59	7.95	0.27
Pterostichus madidus	1.39	0.36	0.28
Harpalus rufipes	1.07	0.16	0.11
Harpalus affinis	0.29	0.03	0.03
Nebria brevicollis	1.54	0.40	0.26

where $\bar{X}$ = mean nos. $trap^{-1}$

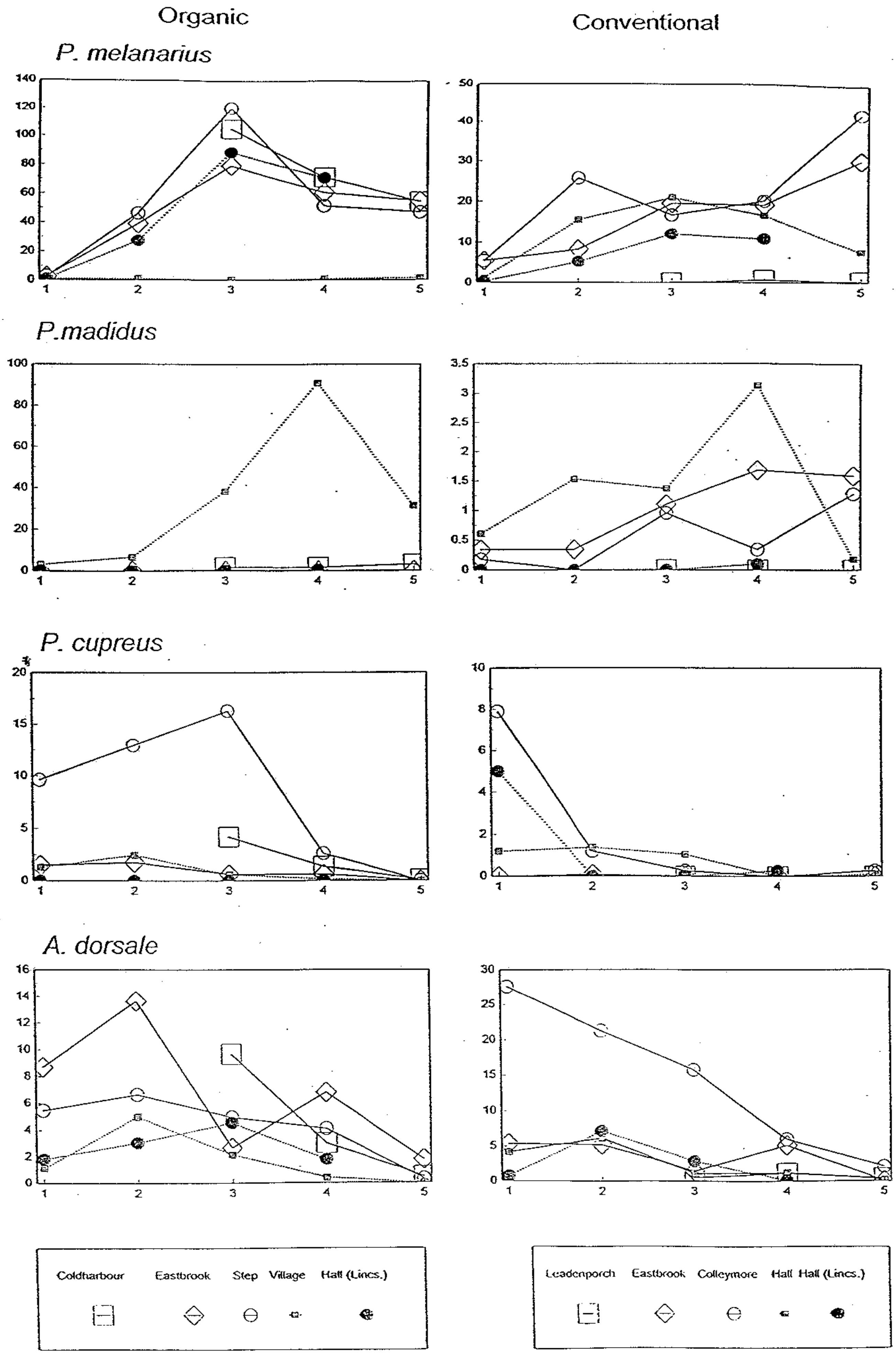

Figure 7 ANOVA results - mean numbers per trap for five collection dates.

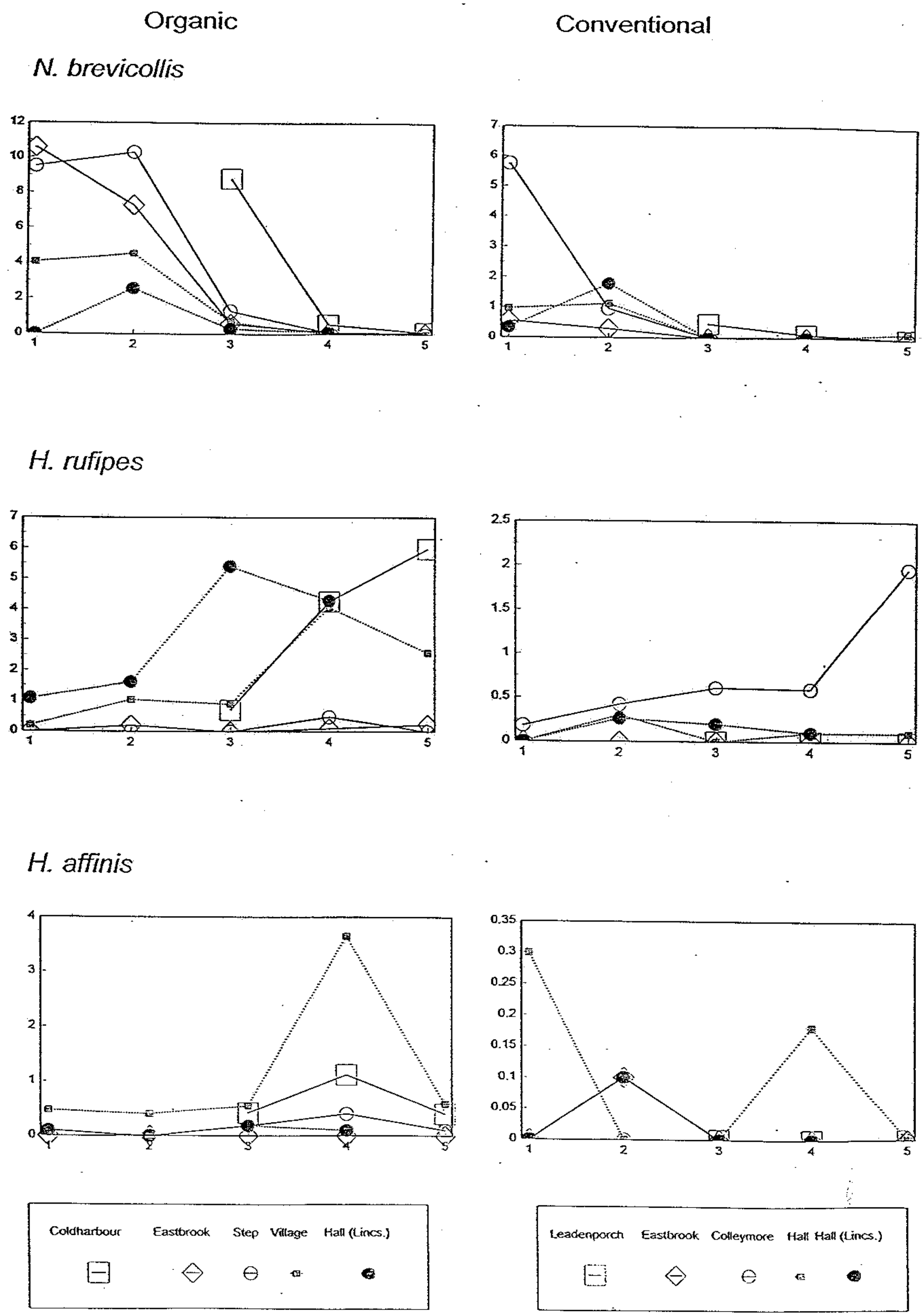

Figure 8 ANOVA results - mean numbers per trap for five collection dates.

4.6 Discussion

4.6.1 Pitfall trapping Caution must be used in the interpretation of data from pitfall trap captures. The rate of capture in a pitfall trap is influenced by both the abundance and activity of a particular species. The relative importance of either of these factors will vary with a specific environmental condition. For example, a comparative scarcity in the food for a species will produce a compensatory increase in its searching behaviour. The movement of the species is therefore increased, and it will be more susceptible to capture. The rate of capture of species such as *P. melanarius* on organic fields is suggestive of a large population. This implies that a good resource of food is available either to prompt movement to this habitat or to support the number of individuals found. If this is the case there will be a corresponding depression in activity due to the decreased need to search for food. It is thus possible that a prediction of population size, from pitfall trap catches, on such fields will be an underestimation compared to fields with a lower capture rate but higher activity. At certain times, such as during insecticide application or when dispersal to an overwintering habitat is required, the presumption that food is the principal factor influencing activity may be unjustified. For example, *P. melanarius* and *P. madidus* were caught in significantly higher numbers from herbicide-treated plots compared to untreated plots, where collections were reduced because of vegetation density (Powell *et al.*, 1985). The high weed densities in some organic fields may have led to a depression in the capture rate. Pitfall traps are, however, a very useful sampling method because they can be operated 24 hours a day and in all weather conditions (Lindroth, 1985).

4.6.2 Species richness and diversity In a review of studies concerning carabid beetles on mainland Europe, Thiele (1977) proposed that there were eight characteristic species associated with arable habitats, namely *P. melanarius, P. cupreus, A. dorsale, A. muelleri, B. lampros, H. rufipes, H. affinis* and *T. quadristriatus*, with *P. melanarius* being the most frequently encountered species. Many factors, such as pesticide use, fertiliser use and cultivation techniques, obviously influence species diversity (e.g. Thiele, 1977). Significant correlations have also been detected between hedgerow length and the numbers of species recorded in arable fields in Germany, since hedgerows provide temporary shelter during periods of intensive field cultivations (Mader & Muller, 1984).

Knauer and Stachow (1987) recorded 77 species from winter wheat, winter barley and oilseed rape fields, on a conventional farm over three cropping seasons. *A. dorsale* accounted for 56.2% of 117,231 individuals caught while *P. melanarius* comprised 10.6% of the total, and the greatest diversity was observed in winter barley fields compared to winter wheat or winter rape. Hokkanen and Holopainen (1986) registered 4,541 individuals from 54 species and found no difference in the diversity indices between organic or conventional cabbage fields in Finland, although more species were recorded from organic fields. This concurs with the observation of Dritschillo and Wanner (1980), that more carabid species were caught on organic than conventional arable fields, although diversity was not significantly different between farming systems, in Illinois, USA. The use of farmyard manures caused a temporary increase in species richness and diversity of carabid beetles on sugar beet fields in Ireland (Purvis & Curry, 1984). In the present study this trend was reversed and more carabid species and a higher diversity were found on conventional arable fields.

4.6.3 ANOVA results The results of this study are similar to those of Dritschilo and Wanner (1980) who captured significantly more carabids on organic than conventional arable fields. Hokkanen and Holopainen (1986) determined that *P. melanarius, P. cupreus, L. pilicornis* and *A. dorsale* were significantly more numerous in biologically (= organically) managed cabbage fields, while *T. quadristriatus, B. quadrimaculatum* and *B. lampros* were more numerous in conventionally managed fields. The authors suggested that higher carabid abundance in biologically managed fields was probably due to a greater resource of food provided by the organic manures. In a study on bean fields in Maine, USA. *P. melanarius* and *L. pilicornis* were significantly more abundant in low-input plots, while *A. muelleri* and *C. fossor* were significantly more abundant in conventional plots during the first season of the study. In the second season, only *A. muelleri* populations were significantly different between cropping systems and a significantly greater number was trapped in the low-input plots (Fan *et al.*, 1993).

In the present study, numbers of *P. melanarius* and four other species were significantly higher in captures on organic fields but no significant differences were detected for seven species including *P. cupreus*, *L. pilicornis,* and *A. dorsale*. Moreby *et al.* (1994), in a study on winter wheat fields on southern England, found few differences in arthropod numbers between organic and conventional systems and suggested that analyses should be directed at a farm rather than field level. They used a Dietrick vacuum insect suction sampler (Dietrick, 1961) which would not have sampled carabids efficiently and significant differences were reported. A study of field boundaries, conducted as part of the extensive bird survey, found that organic fields possessed larger hedges that were trimmed less regularly (see Chamberlain *et al.* 1995). This may have decreased the mortality rate of species such as *Pterostichus madidus*, which overwinter in hedgerows and woods, by the provision of a more suitable habitat. Ditches were found to be more common at field boundaries on conventional fields. This may have impeded carabid movement from overwintering sites to fields. Organic farms have a greater diversification of land-use (Lampkin, 1990). This might increase carabid abundance by the provision of suitable overwintering habitats. These factors may be influential to the results of this study.

4.6.4 Carabids as food-sources for skylark chicks The results of the faecal sac analysis indicate that carabids are an important component of the diet of skylark chicks (see Evans *et al.*, 1995). Skylark chicks appeared to be better nourished on organic farms, during an intensive study of the species at Hall and Village Farms (see Evans *et al.*, 1995). The results of this study therefore suggest that a reason for this may be greater abundance of carabids on organic fields. However, similar numbers of carabids were trapped on organic and conventional arable fields at this site. It is emphasised that this did not take into account possible differences in abundance in alternative fields growing set-aside or grass leys.

Carabid species can be simply classified as either spring or autumn breeders (Appendix 11) although species have been divided into six reproductive groups (see Thiele, 1977), while den Boer and den Boer-Daanje (1990) preferred to distinguish species by the presence of summer or winter larvae. During the skylark breeding season, chick broods are found between mid-April and mid-July. This period approximately coincides with the presence of early instar larvae (L1/L2) of spring breeding carabid species and adults of autumn breeding species. A typical example of an autumn breeding species is *P. melanarius* while *L. pilicornis* is a typical spring breeder and both species have been detected in faecal sacs. *P. melanarius* is the most common carabid in pitfall trap catches on both organic and conventional systems and is a relatively large sized species (adult length 12-18 mm). It is speculated that newly emerged chicks require softer-bodied invertebrates (e.g. small spiders, larval stages of Lepidoptera, Hymenoptera, Diptera and Coleoptera), while older chicks can feed on harder-bodied insects (adult stages), although this may not hold true if there is some pre-mastication by adults of prey before it is offered to chicks.

One important consideration which may affect the predation of carabids by farmland birds are the diel activities of adults and larvae, since birds feed during daylight and 20 of 34 carabid species recorded in the present study have been categorised as nocturnal. However, nocturnal species (e.g. *P. melanarius*) also exhibit some mobility during the day but to a much reduced extent, and vice versa (Luff, 1978). Most carabid larvae are considered to be nocturnal (see Thiele, 1977) but Kegel (1990) found that adults of *L. pilicornis* were nocturnal, whereas the larvae were active during the day. Kegel (1990) also concluded that diurnal species were generally metallic coloured (e.g. *P. cupreus, A. dorsale, H. affinis*) as were spring breeders whereas autumn breeders were mostly darkly coloured and nocturnal.

Diel activity may not be important if birds locate daytime refuges occupied by resting carabids, e.g. under stones, bases of plants, cracks of soil. However, adults of *H. affinis* have been shown to occur at depths of 25 cm while *Amara* and *Notiophilus* spp. were found in the upper 5 cm of soil (Luff, 1978). Skylarks are surface feeders and will generally only locate invertebrates present in the soil litter. Further work is required to monitor the foraging behaviour of individual birds and to carry out invertebrate sampling of any areas preferred as feeding sites.

5. BOTANICAL STUDIES

5.1 Summary

Paired organic and conventionally managed fields were surveyed to establish whether there were differences in bird populations between the two systems. This botanical survey was carried out during the summers of 1992 and 1993 in order to assess the effect of the management of cereal fields on the flora, and subsequent food supply of farmland birds.

5.1.1 The abundance of flora on the organic fields was significantly greater than on the conventionally managed fields.

5.1.2 There were more species present on the organic fields. Birds such as the skylark (*Alauda arvensis*) which are seasonally omnivorous are believed to survive the winter by feeding on seeds. To assess the extent of this food-source, post harvest soil surface samples were taken using a Vortis vacuum sampler.

5.1.3 There was no significant overall difference in seed abundance between the two systems.

5.1.4 Grass seeds were relatively more abundant on conventionally managed farms and broadleaved weed seeds on organic farms.

5.1.5 The flora on the organic fields were significantly more diverse than conventional fields for both plants and seeds, measured using either the Williams alpha or Shannon Wiener diversity indices.

5.1.6 Organic crops were shorter, had smaller plant populations, and more bare ground then conventional crops.

5.1.7 Fewer seeds per plant were recovered from organic fields than from conventional fields.

5.2 Aims

To assess the extent to which different management systems influence non-crop plants and how this affects the food supply of farmland birds.

5.3 Materials and methods

At the time of the first botanical involvement a sampling grid had already been established by the entomological team and it was thought to be sensible for the botanical survey to follow the same pattern. The grid (which did not involve permanent sample points) consisted of five transects of five sampling points (SP) at 20 m intervals. In the conventional fields the transects usually followed tramlines and in most of the organic fields there were 'weeding paths' spaced at similar intervals which could be used for access. (In one or two organic fields where there were heavy infestations of climbing weeds, and it was impossible to walk through the crop without causing damage, the SPs were placed on a diagonal.) Normally the first SP was 20 m along the first non-headland tramline from the point where it crossed the last headland tramline running in the other direction. (So that SPs were at least 20 m from the headland in either direction.) Surveys were carried out in the summers of 1992 and 1993 and covered about a dozen pairs of fields in each year. Data shown here refer to those farms which were surveyed on each occasion. All tables are based on data from the same fields.

For the vegetation surveys, which were carried out in the standing crop in July of 1992 and 1993, a quadrat with a side of 0.5 m was placed at each SP and all non-crop plants were identified (using Clapham *et al.*, 1968; Keble-Martin 1965; Ross-Craig, 1974). Assessments were made of the percent cover of crop, weed and bare ground, and crop height was measured. The number of crop stems was counted in two quadrats in each transect.

The seed survey was carried out after harvest in September of 1993 using a Vortis vacuum sampler. (Arnold, 1994). Again samples were taken from the SPs of the standard grid. The sample area of the Vortis sampler is 0.2 m^2. Each sample consisted of 5 × 10 second sucks spanning the width between the centres of two combine harvester swaths. This gave a total sampling area of 1 m^2. Seed identification was carried out with the aid of a reference seed collection, the NIAB Seed Identification Handbook (Flood & Gates, 1986) and the drawings of Ross-Craig (1974).

5.4 Results

The results are summarized below, and in the attached Appendices. Tables 5.1 to 5.3 and Appendices 21 to 23 refer to the seed survey, and Tables 5.4 to 5.6 and Appendices 24 to 27 refer to the vegetation survey. Table 5.6 and Appendix 28 combine data from both surveys. All numerical results are from cereal fields.

5.4.1 Seeds The Shannon Wiener diversity index (*H*) for seeds for the conventional fields was significantly lower than for the organic fields (Table 5.1 and Appendix 21a). Similarly, Williams' Log Series Alpha Index was lower for conventional fields than for organic fields (Table 5.1 and Appendix 21b). The use of particular Diversity Indices has been controversial and so the values of two of the most popular ones are given here. Magurran (1988) gives detailed descriptions of these and other indices. Seed species diversity of conventional fields was consistently lower than in organic fields in this survey whichever index was used (see Table 5.1 and Appendix 21). Details of the Statistical Tests used are given in Section 2, Soil Cores and Vacuum Samples).

Table 5.1 Species diversity of seeds (indices)

	Organic	Conventional	S.E.D.	Significance
Shannon Wiener (*H*)	3.45	2.45	0.19	***
Williams alpha	3.13	2.07	0.49	*

Significance : * $P = < 0.1$ ** $P = < 0.01$ *** $P = < 0.001$

Except when dicotyledonous plants were considered alone, there was no significant difference between the seed species abundance lists for the two systems (Table 5.2, Appendix 22). However, half the seeds taken from the conventional fields were *Poa annua*. Its seed weight at 0.26 mg is probably too light for skylarks which prefer seeds larger then those of *Stellaria media* which weigh 0.35 mg (Green, 1978). Birds probably search for seed visually and so larger seeds would be easier to find. However seed weight usually increases with seed length for the particular species found in this survey as shown in Figures 9 and 10 which are based on relevant data taken from Grime *et al.* (1988). In addition, weight is usually considered to give a better indication of nutritive value. Additional information on seed characteristics is taken from Salisbury (1964).

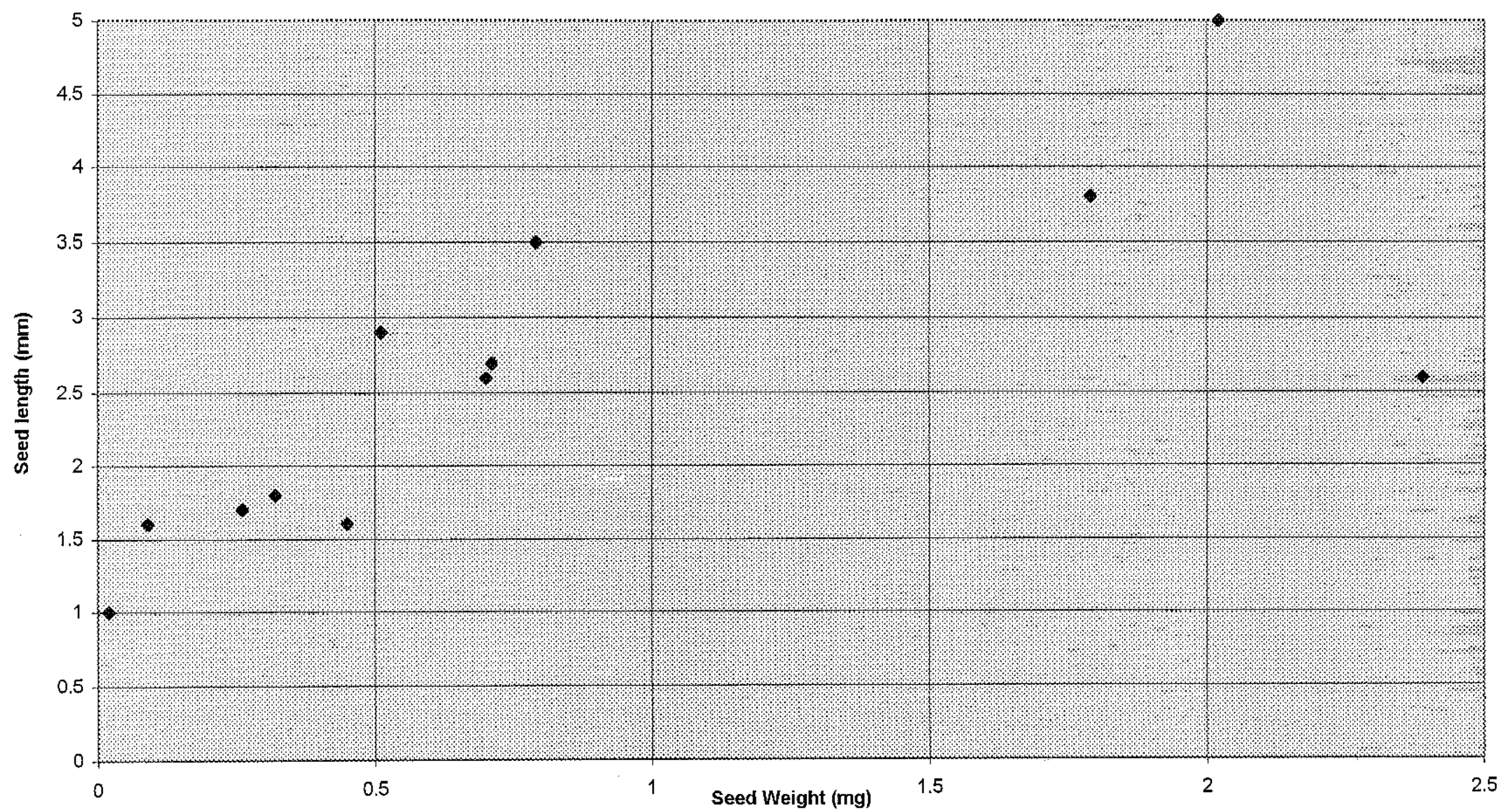

Figure 9 Relationship between seed weight and length: main monocotyledonous arable weeds.

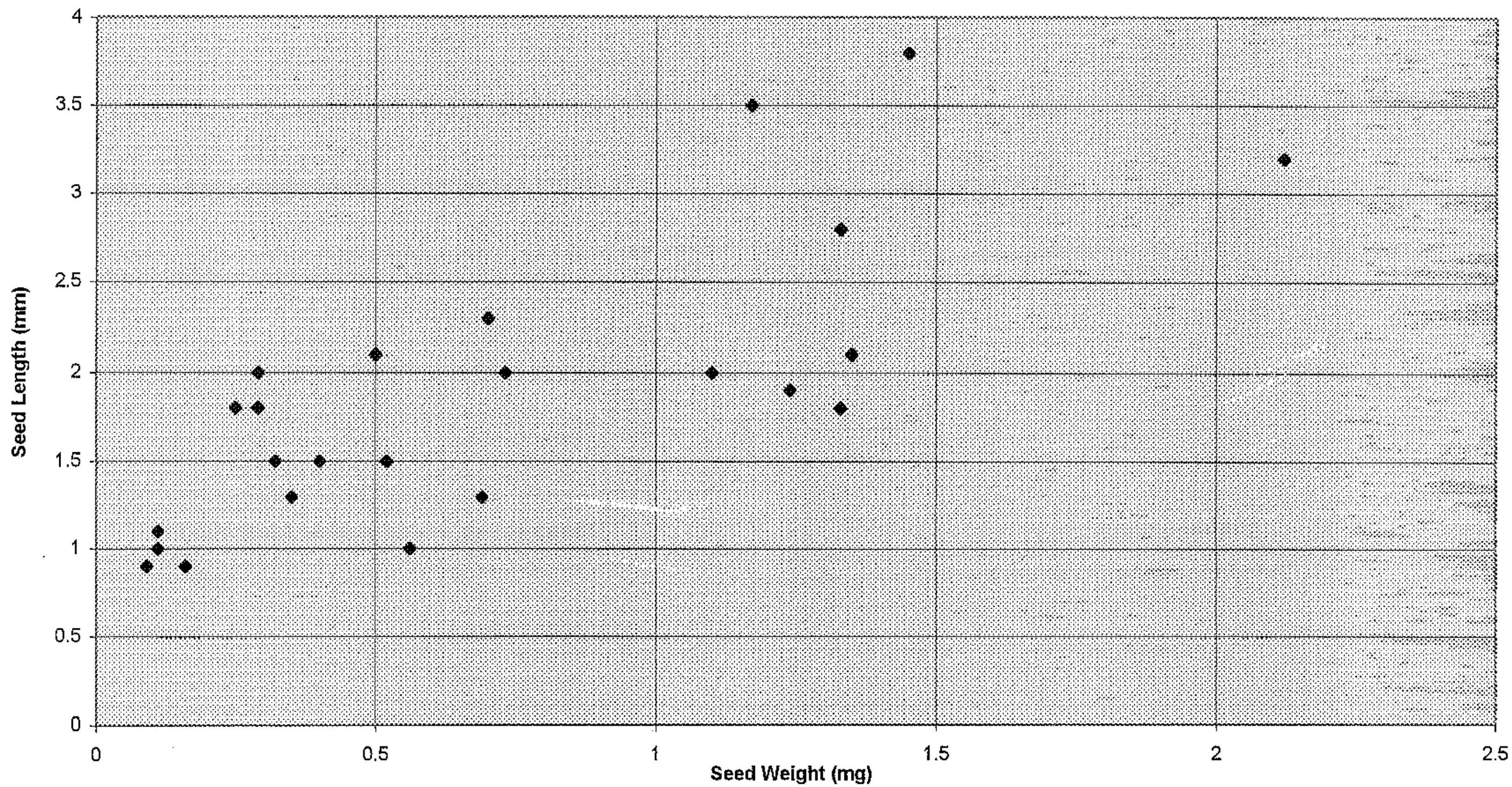

Figure 10 Relationship between seed weight and length: main dicotyledonous arable weeds.

Table 5.2 Species abundance of seeds (counts)

	Log_{10} [(Seed count)+0.5]			
	Organic	Conventional	S.E.D.	Significance
All species	5.66	5.12	0.35	
Grass only	4.15	4.75	0.6	
Broadleaved only	5.01	3.34	0.69	*

Table 5.3a (which summarises Appendix 23a and 23b) shows the main species that are above the threshold weight for skylarks (Green, 1978 and see above). Again there was no overall significant difference between the systems for all species. The influence of the management system can be seen in the dominance of *Lolium* which often forms the main break crop in organic systems. Nitrogen is supplied to this grass break by *Trifolium* which is also an important contributor of seed in organic stubbles and which was associated with large numbers of weevils (*Sitona* spp.).

Table 5.3a Main species of seeds above threshold weight for skylark

	Seed weight mg	Organic	Conventional
		Max kg/ha	Max kg/ha
Viola	0.52		80.2
Trifolium	0.6	47	
Cirsium	1.17	125	
Alopecurus	1.7	33	41.4
Lolium	2.0	340	
Geum	5.0	54	
Veronica	5.0	175	150
Avena	8.0		43
Triticum	10.0	230	

There was very great variation between organic fields but much less variation between conventional fields as Table 5.3b shows.

Table 5.3b Total abundance of seed above threshold weight for skylarks in organic and conventional fields (kg/ha).

	Coldharbour (org.)	Leaden Porch (conv.)	Home Farm (org.)	Home Farm (conv.)	Hawstead (org.)	Horsecroft (conv.)
Field 1	705	167	433	179	152	31
Field 2	524	311	10	140	79	45

5.4.2 Plant counts Plant counts were carried out in July 1992 and July 1993 and statistical analyses were carried out for both years. There was no significant difference between the years, and so tables only show comparisons between systems.

As with the seed counts there was a significant difference between the diversity of plant counts in organic and conventional systems (Table 5.4 and Appendix 24). Organic farms had a significantly higher diversity, whichever index was used.

Table 5.4 Species diversity of plants (indexes), July 1993 and 1994.

	Organic	Conventional	S.E.D.	Significance
Shannon Wiener	3.27	1.56	0.31	***
Williams alpha	3.59	1.11	0.39	***

Table 5.5 shows the species lists for plants counted in 1993 (see Appendix 25 for full details) and again it is interesting to note that the only genera with an abundance greater then 10 on conventional fields were *Alopecurus*, *Arrhenatherum*, and *Poa*, which are all grasses. Only *Stellaria* reach double figures among the dicotyledonous plants. This table also demonstrates the importance (to the ecological advantages of organic farming) of sown grasses (*Lolium and Phleum*) and the clovers both sown (*Trifolium repens* and *pratense*) and weed (*T. dubium*) which are able to compete in organic fields because of the lack of applied nitrogen. Whereas 50 species occurred on organic fields only 21 were found on conventional fields. In the survey, the rarest species to be found was *Kickxia spuria* and although it was reported that it had not been seen locally for many years it flowered on both the conventional and organic farms in the same pair.

Table 5.5 Species list for plants counted in 1993 (abundance).

		Plant Counts	
		Organic	Conventional
Agrostis	*stolonifera*	78	4
Alopecurus	*myosuroides*	243	205
Anagallis	*arvensis*	12	
Arrhenatherum	*elatius*		10
Avena		11	3
Capsella	*b-pastoris*	11	
Chenopodium	*album*	17	
Cirsium	*arvense*	64	3
Elymus	*repens*	73	
Fallopia	*convolvulus*	21	2
Lolium	*perenne*	16	
Myosotis	*arvensis*	28	
Papaver	*rhoeas*	179	
Phleum	*pratense*	10	
Poa	*annua*	11	81
Stellaria	*media*	44	12
Trifolium	*repens*	85	
Trifolium	*pratense*	139	
Trifolium	*dubium*	24	
Veronica	*persica*	63	2

The abundance of plants found which would provide seed of sufficient size to be of use to skylarks is shown in Appendix 26. Once again there are significantly more in the organic fields and the dominant species in the conventional list are grasses.

The data for percent cover of crop shows significantly higher crop cover in conventional fields. In contrast, the organic fields show more cover of weeds and bare ground (Appendix 27). The crop population was greater on the conventional fields and the crop height marginally so.

Table 5.6 indicates the number of seeds recovered per plant for those species which occurred in both systems.

Table 5.6 Recovery of seed/plant

	Conventional	Organic
	Seeds/plant	Seeds/plant
Agrostis	0.25	0.6
Alopecurus	0.25	0.1
Avena	5.7	0
Cirsium	1	1.73
Fallopia	0	0
Fumaria	0.5	0
Galium	1.25	0
Poa annua	12.55	13.1
Polygonum	2	6
Senecio	0	2.75
Stellaria	5.25	0.71
Veronica	14.5	0.33
Viola	2.36	0.18

5.5 Discussion

Organic fields had greater plant abundance and diversity than conventional fields in this survey. The fact that there was no significant difference between years for plant counts suggests that the differences could possibly be stable through time.

However, there was a wide range of diversity and abundance of plants between fields within systems and some organic fields had almost as few weeds as some conventional fields. As the industry gains experience of organic systems it seems at least possible that organic farms may achieve monoculture and lose the higher diversity and abundance of plants found in this survey. Botanical diversity may not be a fundamental characteristic of organic farming.

Details of the crop husbandry have been difficult to obtain, but it was apparent that in at least two respects husbandry affect the weediness of organic fields in general. The first was the management of farmyard manure. The presence of weeds such as *Chenopodium album*, in the middle of fields was traditionally associated with dung clamps (Gill & Vear, 1969) on which these species had been allowed to set seed. On more then one occasion weedy clamps were indeed found very close to infested fields. On one grass field, crop plants were seen dying under and close to large clumps of unrotted farmyard manure which appeared to have been spread by a machine which was unable to shred the manure sufficiently to produce a fine and even cover. Another field consisted of large patches of different weed flora some of which appeared to have come in with manure from different sources.

The second aspect of crop husbandry which appeared to give an agronomic advantage to the better organic crops was seed bed quality, especially rolling. The more vigorous, less weedy organic crops were usually in fields which appeared well rolled. The greater amount of bare ground on some organic fields also suggested vigorous mechanical weeding perhaps after severe early weed infestations.

There could be a number of reasons for the lack of a significant overall difference (Table 5.2) between the weed seed populations in the two systems including, the presence of a large seed eating fauna, or seeds of taller weeds may have been removed at harvest, though this would not have applied to shorter species such as *Poa annua, Stellaria media*, and *Viola arvensis* etc. The question of weed height invites comparison with crop height, and here it is notable that although organic farmers tend to use taller varieties (Lampkin, 1990) the measured height (Appendix 27) of the organic crops was slightly less then that of the conventional. One reason for this (which is in line with observation of these crops and experience with others) could be that the organic crops were nitrogen deficient in comparison with the conventional crops.

From the seed data we can calculate how many seeds per plant were recovered from organic and conventional weeds of the same species (Table 5.6 and Appendix 28). More seeds per plant were recovered from seven species when under conventional management. Of the five from which more seeds were recovered on organic farms two were perennial plants which would tend to reproduce vegetatively under good growing conditions and produce seed under poor conditions. It should be noted that weeds typically produce over a thousand seeds per plant and only 15 or less were recovered in this survey so that these results should be treated with caution. However this result is also consistent with the view that nine of the 12 weed species which occurred under both management systems may have been relatively resource limited on organic fields. Limited nitrogen can have this effect. This idea is supported by the fact that, of the limited sample available, seeds from organic fields were lighter then seeds of the same species collected from conventional fields.

The advantage of applying extra (nitrogen) fertilizer to conventional crops is that they produce better root systems, and more leaves which are larger and last longer, and that the result of these two changes is taller plants with more flowers which produce more or larger seeds. It is also known that many common weeds such as *Stellaria media* and *Galium aparine* also behave in this way (Grime *et al.*, 1988). (Whereas clovers such as *Trifolium dubium* which is present only in the organic fields are suppressed by nitrogen.) It is logical to assume that these larger plants with more organs provide more feeding sites for phytophagous insects then do smaller plants. Agronomists and crop physiologists have also shown that the nitrogen content of plants is sensitive to soil N (Conry, 1994).

Many phytophagous insects are extremely sensitive to changes in the available levels of N in their food, a reduction of as little as 0.1% can result in death (White, 1993). In a nitrogen-deficient organic crop, Kowalski & Visser (1981) noted that aphids arrived seven days later than on an adjacent conventional crop. White (1993) cites over 800 references in support of his contention that all animals are limited by nitrogen. He points out that in nitrogen-deficient crops flush feeders do not do as well as dehiscence feeders, a flush feeder is one that feeds on young plant tissue like buds or developing flowers and seeds, and a dehiscence feeder is one that feeds on a mature organ at the end of its useful life and takes advantage of the mobilisation and transport of nutrients out of that organ back to organs that are still developing. In nitrogen-poor conditions fewer new organs are produced and recycling is more necessary. Chinery (1989) states that the size of butterfly eggs (within species) is generally dependent on the amount of nitrogen in the diet.

If these organic fields were nitrogen deficient, some phytophagous insects would have done less well and others would not have developed. More importantly the insects that would have performed best would have been the ones that developed late in the season, and invading insects like aphids would also have arrived later. This would have meant a reduced food-source for predators and this may be the explanation of the lower than expected pitfall trap catches on the organic fields. This is in broad agreement with one of the conclusions drawn by Moreby *et al.* (1994).

However Hendry and Thorpe (1993) point out that while grass seeds contain mainly starch, dicotyledonous plants contain mainly fats and proteins. The dominance of dicotyledonous weeds in organic farms and monocotyledonous plants in conventional farms may explain why organic farms may favour highly mobile polyphagous invertebrates which can choose a variety of plant and animal food species even though more specialised phytophagous arthropods may not do as well as expected.

Even if nitrogen is not limiting the ecology of organic fields there is a more fundamental reason for the apparent failure of insects to take advantage of the more environmentally sensitive system. Firstly, it is the mere act of cultivation which breaks down natural ecosystems. As Hawkins (1994) points out in his discussion of parasitoid ecology "first cultivation reduces diversity, which will consequently reduce herbivore diversity. But second the concentration of plant resources associated with cultivation will simultaneously increase the local abundance of the herbivores using the cultivated plants.... ".

Like conventional agriculture, organic farming inevitably destroys natural ecosystems, but does not provide enough surplus resources for ecosystem redevelopment. It is not clear exactly what Hawkins means by "the concentration of plant resources" but it is clear from this survey (see Appendix 27) that crop plants on organic fields produce about 30 per cent fewer shoots per unit area and that these shoots are 10 percent shorter than conventionally grown crops. On both counts there is a lesser concentration of plant resources in organic fields. As there is more bare ground on organic fields it seems unlikely that weeds (which appear to produce less seed/plant) are making up the shortfall caused by the sparser crops.

To summarise the organic fields produced a greater plant diversity and a greater abundance of non-crop plants then conventional fields. There was no significant difference between plant diversity and abundance between the two years suggesting that this could be stable over time. The additional species on the organic farms were all common and widespread plants of arable fields, waste ground, gardens or hedgerows. The rarest species found, *Kickxia spuria*, occurred on both organic and conventional fields. Intuitively one would have expected larger insect populations to have occurred in a field with more diverse flora but this did not happen. The reason may have been to do with the sparser crop, smaller plants and extra bare ground. The probable lower nitrogen content of the organic crops (and associated flora) may have further reduced insect populations.

There were signs that differences in plant quality and abundance on organic farms were related to management practice and also that if farmers capitalized on existing management skills (within organic regulations - Lampkin, 1990) then plant quality would be increased, but that plant diversity may be reduced as a consequence. A reduction in plant diversity if accompanied by an improvement in plant quality may increase insect diversity. (Though those insects dependent on the missing plant species would be lost.)

6. PROPOSALS FOR FUTURE WORK

The findings of this project could be complemented and extended by the following proposals for future work. Replication of the pitfall trapping exercise in subsequent years would underpin the results presented here. The sampling of a wider range of farmland habitats would provide a useful additional comparison. The analyses of chick faecal sacs showed that useful qualitative information on the diet of birds can be achieved by the examination of invertebrate fragments; it would be productive to extend this technique to encompass species other than the skylark. This would provide additional information on the diet of birds to aid the interpretation of data from future invertebrate surveys. Future field studies of birds should highlight areas of farmland observed to be frequently selected by feeding birds. The intensive invertebrate sampling of such areas would give a better indication of the food-sources selected by feeding birds and of the habitats that favour them. Comparisons with areas selected at random would provide valid statistical tests of hypotheses. If breeding birds are observed feeding in such areas, this work could usefully be allied to faecal sac analyses. Chemical extraction techniques might provide better estimates of soil invertebrates, such as earthworms or tipulid larvae in such areas, although availability to birds would need to be accounted for.

Invertebrate abundance varies between farms, both for conventional or organic systems, due to differences in soil type, density of weeds on organic fields, input of pesticides on conventional fields, variation in cultivation techniques, length of time an organic farm has been established etc. Accuracy of estimated differences between farming systems requires the sampling of as wide a range of farms as possible, only then would results obtained be fully representative of the farming system as a whole. A future programme should study more farms than the current project. The botanical work could be extended by further investigation of plant nutrition on organic fields. Nitrogen depletion of soil on such fields may have implications for the provision of seed food-resources and the abundance of phytophagous insects. The testing of soil samples for nitrate content, or a closer examination of plant size and fertility, would provide a better quantification of this possible effect. Such research might provide information that could inform policy to improve soil fertility on organic farms.

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8. REFERENCES

Arnold, A.J. (1994). Insect suction sampling without nets, bags, or filters. (1994). *Crop Protection* 13:73-75.

Blackshaw, R.P. (1988). Effects of cultivations and previous cropping on leatherjacket populations in spring barley. *Research and Development in Agriculture* 5:35-37.

Brindle, A. (1960). The larvae and pupae of the british Tipulinae. *Transactions of the Society for British Entomology* 14:63-114.

Chamberlain, D., Wilson, J.D. & Fuller, R.J. (1995). *A Comparison of Breeding and Wintering Bird Populations on Organic and Conventional Farms*. BTO Research Report No. 154. PART II. To MAFF & WWF UK on Organic Farming and Birds.

Chinery, M. (1989). *Butterflies and Day-flying Moths of Britain and Europe*. Collins, ???Where???.

Clapham, A.R., Tutin, T.G. & Warburg, E.F. (1968). *Excursion Flora of the British Isles*. Cambridge University Press, London.

Conry, M.J. (1994). Comparative effect of six cultivars at four rates of nitrogen on the grain yield and quality of spring sown malting barley in Ireland. *Journal of Agricultural Science* 122:343-350.

Coulson, J.C. (1962). The biology of *Tipula subdornicus,* with comparative observations of *Tipula paludosa*. *Journal of Animal Ecology* 31:1-21.

Dawson, R.B. (1932). Leatherjackets. *Journal of Bd. Greenkp,* 2:183-195.

den Boer, P.J. (1977). *Dispersal Power and Survival, Carabids in a Cultivated Countryside.* Miscellaneous Papers No. 14, Landbouwhogeschool. Wageningen, The Netherlands.

den Boer, P.J. & den Boer-Daanje, W. (1990). On life history tactics in carabid beetles: are there only spring and autumn breeders? In: *The Role of Ground Beetles in Ecological and Environmental studies* (ed. N.E. Stork), pp. 247-258. Intercept Ltd., Andover.

Dietrick, E.J. (1961). An improved backpack motorised fan for suction sampling of insects. *Journal of Economic Entomology* 54:394-395.

Dowsett, J.R., Schlotter, P. & Bos, G. (1987). Control of Tipulinae in grassland by chlorpyrifos. *Mededelingen van de Faculteit Landbouwwetenschappen* 52:529-538.

Dritschillo, W. & Wanner, D. (1980). Ground beetle abundance in organic and conventional corn fields. *Environmental Entomology* 7:629-631.

Dunnet, G.M. (1955). The breeding of the Starling *Sturnus vulgaris* in relation to its food supply. *Ibis* 97:619-662.

Edwards, C.A. (1984). Changes in agricultural practice and their impact on soil organisms. In: *Agriculture and the Environment* (ed. D. Jenkins). pp. 56-65. Proceedings of the Institute of Terrestrial Ecology (ITE) Symposium. ITE, Cambridge.

Edwards, C.A. & Lofty, J.R. (1982). Nitrogenous fertilisers and earthworm populations in agricultural soils. *Soil Biology and Biochemistry* 14:515-552.

Evans, J., Wilson, J.D. & Browne, S. (1995). *Habitat Selection and Breeding Success of Skylarks* Alauda arvensis *on Organic and Conventional Farmland.* BTO Research Report No. 154. PART III. To MAFF & WWF UK on Organic Farming and Birds.

Fan, Y.Q., Liebman, M., Groden, E., Alford, A.R., & Randall-Alford, A. (1993). Abundance of carabid beetles and other ground-dwelling arthropods in conventional versus low-input bean cropping systems. *Agriculture, Ecosystems and Environment* 43:127-139.

Fisher, R.A., Corbet, A.S. & Williams, C.B. (1943). The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology* 12:42-58.

Flood, R.J. & Gates, C.G. (1986). *Seed Identification Handbook.* NIAB, Cambridge.

Forster, P. (1990). Effects of soil and food contaminated with insecticide on predation level and mortality of *Platynus dorsalis* (Col.: Carabidae) and *Tachyporus hypnorum* (Col.: Staphylinidae). *Mittielungen der Deutschen Tesellschaft fur Allgemiene und Angewandte Entomologie* 7:4-6.

Forster, P. (1991). Influence of pesticides on larvae and adults of *Platynus dorsalis* and adults of *Tachyporus hypnorum* in laboratory and semi-field trials. *Zietzchrift-fur-PJlanzenkran Kheitenund-PJlanzenschutz* 98:457-463.

Freeman, P. & Lane, R.P. (1985). Bibionid and Scatopsid flies. *Handbk. Ident. Br. Insects.* 9:1-74.

French, N. (1984). *Leatherjackets.* MAFF Leaflet No. 179. MAFF-ADAS, London.

Gill, N.T. & Vear, K.C. (1969). *Agricultural Botany.* Gerald Duckworth & Co. Ltd., London.

Green, R. (1978). Factors affecting the diet of farmland Skylarks. *Journal of Animal Ecology* 47:913-928.

Grime, J.P., Hodgson, I.G. & Hunt, F. (1988). *Comparative Plant Ecology: a functional approach to common British species.* Unwin Hyman, London.

Hamon, N., Bardner, R., Allen-Williams, L. & Lee, J.B. (1987). Flight periodicity and infestation size of *Sitona lineatus. Annals of Applied Biology* 111:271-284.

Hand, S.C. (1982). *The Overwintering and Dispersal of Cereal Aphids.* Unpubl. PhD Thesis, Southampton University.

Hand, S.C. (1986). The capture efficiency of the Dietrick vacuum insect net for aphids on grasses and cereals. *Annals of Applied Biology* 111:271-284.

Hawkins, B.A. (1994). *Patterns and Processes in Host Parasatoid Interactions.* Cambridge University Press, London.

Hendry, G.A.F. & Thorpe, P.C. (1993). Patterns and processes in Host Parasitoid Interactions.In: *Methods in Comparative Ecology* (ed. G.A.F. Hendry, J.P. Grime & B.A. Hawkins). Cambridge University Press, Cambridge.

Hokkanen, H. & Holopainen, J.K. (1986). Carabid species and activity densities in biologically and conventionally managed cabbage fields. *Journal of Applied Entomology* 102:353-363.

Holyoak, D. (1968). A comparative study of the food-sources of some British Corvidae. *Bird Study* 15:147-153.

Jackson, D.J. (1920). Bionomics of weevils of the genus *Sitona injurious* to leguminous crops in Britain. *Annals of Applied Biology* 7:269-298.

Keble-Martin, W. (1965). *The Concise British Flora in Colour.* Michael Joseph Ltd., London.

Kegel, B. (1990). Diurnal activity of carabid beetles living on arable land. In: *The Role of Ground Beetles in Ecological and Environmental studies* (ed. N.E. Stork), pp. 65-76. Intercept Ltd., Andover.

Kell, G.V. & Blackshaw, R.P. (1988). The influence of agricultural practices on leatherjacket populations in Northern Ireland. *Proceedings of the 12th General Meeting of the European Grassland Federation,* July 4-7th pp. 504-508.

Kennedy, T.F., Evans, G.O. & Feeney, A.M. (1986). Studies on the biology of *Tachyporus hypnorum* associated with cereal fields in Ireland. *Irish Journal of Agricultural Research* 25:81-95.

Kloet, G.S. & Hincks, W.D. (1977). *A Check List of British Insects.* Part 3. 2nd. edition. Royal Entomological Society, London.

Knauer, N. & Stachow, U. (1987). Activities of ground beetle (Carabidae Col.) in an intensively run farm - a contribution to agroecosystem analysis. *Journal of Agronomy and Crop Science* 159:131-145.

Kowalski, R. & Visser, P.E. (1981). Nitrogen in a crop pest interaction. In: *Nitrogen as an Ecological Factor* (ed. J.A. Lee, S. McNiell, S. & J. Rorison), pp. 283-300. Blackwell.

Kowalski, R. (1986). Biology of *Tachyporus hypnorum* in relation to their role as predators of cereal aphids. *Irish Journal of Agricultural Research* 25:93-95.

Lampkin, N. (1990). *Organic Farming.* Farming Press, Ipswich.

Lindroth, C.H. (1985). *The Carabidae (Coleoptera) of Fennoscandia and Denmark.* Fauna Entomologica Scandinavica. Volume 15, Part 1. E.J. Brill/Scandinavian Science Press Ltd. Leiden, The Netherlands.

Lindroth, C.H. (1986). *The Carabidae (Coleoptera) of Fennoscandia and Denmark.* Fauna Entomologica Scandinavica. Volume 15, Part 2. E.J. Brill/Scandanavian Science Press Ltd. Leiden, The Netherlands.

Luff, M.L. (1978). Diel activity patterns of some field Carabidae. *Ecological Entomology* 3:53-62.

Luff, M.L. (1993). *The Carabidae (Coleoptera) larvae of Fennoscandia and Denmark.* Volume 27. E.J. Brill, Leiden, The Netherlands.

MacDonald, R.A. (1983). *The Feeding and Breeding Ecology of the Rook* (Corvusfrugilegus L.) *in eastern Ireland.* PhD Thesis. University College, Dublin.

Mader, H.J. & Muller, K. (1984). The relationship between hedgerow length and species diversity. *Zeitschrift fur Kulturtechnik und Flurbereinigung* 25:282-329.

Magurran, Ann E. (1988). *Ecological Diversity and its Measurement.* Princetown University Press, Princetown, New Jersey.

Markkula, M. & Koppa, P. (1960). The composition of the *Sitona* population on grassland legumes and some other leguminous plants. *Annales Entomologici Fennici* 26:246-263.

Mattingly, G.E.G. (1974). The Woburn organic manuring experiment. *RES Annual Report*: 98-133.

Moreby, S.J. (1988) An aid to the identification of arthropod fragments in the faeces of gamebird chicks (*Galli formes*). *Ibis* 130:519-526.

Moreby, S.J., Aebischer, N.J., Southway, S.E. & Sotherton, N.W. (1994). A comparison of the flora and arthropod fauna of organically and conventionally grown winter wheat in southern England. *Annals of Applied Biology* 125:13-27.

Morris, H.M. (1922). The larval and pupal stages of the Bibionidae. *Bulletin of Entomological Research* 12:221-232.

Murray, P.J. & Clements, R.O., (1994). Investigations of the host feeding preferences of Sitona lineatus, found commonly on clover. *Entomology Experimental and Applied* 71:73-79.

Murton, R.K. (1971). *Man and Birds*. Collins, London.

O'Connor, R.J. & Shrubb, M. (1986). *Farming and Birds*. Cambridge University Press, Cambridge.

Pearson-Ralph, C., Nagata, S.E. & Ralph, C.J. (1985). Analysis of droppings to describe diets of small birds. *Journal of Field Ornithology* 56:165-174.

Pettifor, R.A. (1983). Seasonal variation and associated energetic implications in the hunting behaviour of the Kestrel. *Bird Study* 30:201-232.

Powell, W., the late G.J. Dean & Dewar, A. (1985). The influence of weeds on polyphagous arthropod predators in winter wheat. *Crop Protection* 4:298-312.

Purvis, G. & Curry, J.P. (1984). The influence of weeds and farmyard manure on the activity of Carabidae and other ground-dwelling arthropods in a sugar beet crop. *Journal of Applied Ecology* 21:271-283.

Ross, G.J.S. (1987). *MLP, Maximum Likelihood Programme*. Lawes Agricultural Trust (Rothamsted Experimental Station), Rothamsted.

Ross-Craig, S. (1974). *Drawings of British Plants*. G. Bell & Son, London.

Salisbury, Sir Edward (1964). *Weeds and Aliens*. Collins, London.

Schotzko, D.J. & O'Keefe, C.E. (1988). Effects of food plants and duration of hibernal quiescence on reproductive capacity of pea leaf weevil. *Journal of Economic Entomology* 81:490-496.

Scullion, J. & Ramshaw, G.A. (1987). Effects of manurial treatments on earthworm activity in grassland. *Biological Agriculture & Horticulture* 4:271-281.

Shrubb, M. (1980). Farming influences on the food and hunting of Kestrels *Bird Study* 32: 1091-1095.

Smith, K.V. (1989). *An introduction to the Immature Stages of British Flies*. Handbk. Ident. Br. Insects. 10 (14), Royal Entomological Society, London.

Taylor, L.R., Kempton, R.A. & Woiwod, I.P. (1976). Diversity statistics and the log-series model. *Journal of Animal Ecology* 45:255-271.

Thiele, H.-U. (1977). *Carabid Beetles in their Environments. Zoophysiology and Ecology.* Volume 10. Springer-Verlag, Berlin.

Thomas, M.B., Sotherton, N.W., Coombes, D.S. & Wratten, S.D. (1992). Habitat factors influencing the distribution of polyphagous predatory insects between field boundaries. *Annals of Applied Biology* 120:197-202.

Thornhill, E.W. (1978). A motorised insect sampler. *Pest Articles and News Summaries* 24:205-207.

Vickerman, G.P. (1974). Some effects of grass weed control on the arthropod fauna of cereals. *Proceedings of the 12th British Weed Control Conference* 3:929-939.

White, T.C.R. (1993). *The Inadequate Environment: Nitrogen and the abundance of animals.* Springer Verlag, Berlin.

Wiech, K. (1984). The species composition of weevils occurring on white clover, *Polskie Pismo Entomologiozae.* 54:215-226.

Wijnands, F.G. & Kroonen-Backbier, B. (1986). Report for Experimental farm Verslag OBS, *Publikatie, Outwikkeling Bedrijifs Systemen.* No. 7.

9. APPENDICES

Appendix 1 Summary of Sites and Sampling Dates for Soil Core Programme (Analyses One: Conventional/Organic Arable and Organic Grass Ley Fields)

Site and Field Details	Sampling Date			
	1	2	3	4
Boarded Barns Farm, Ongar Essex	24/3/92	1/5/92	18/5/92	21/8/92
Organic WW	+	+	+	+
Conventional WW	+	+	+	+
Organic Grass Conversion Ley 1st year	+	+	+	+
Organic Grass Conversion Ley 2nd year	+	+	+	+
Duchy Home Farm, Tetbury, Gloucestershire	9/4/92	14/5/92	11/6/92	13/8/92
Organic WW	+	+	M	+
Organic WW	+	+	+	+
Conventional WW	+	+	M	+
Conventional WW	+	+	+	+
Organic Grass Ley 1st year	+	+	+	+
Organic Grass Ley 2nd year	+	+	+	+

WW = Winter Wheat
\+ = Field sampled on this data
M = Field not sampled

Appendix 2 Summary of Sites and Sampling Dates for Soil Core Programme (Analyses Two: Conventional and Organic Arable Fields)

Site and Field Details	Sampling Date		
	1	2	3
Home Farm Castle Acre, Norfolk	30/4/92	21/5/92	9/9/92
Organic WW	+	+	+
Organic WW	+	+	M
Conventional WW	+	+	+
Conventional WW	+	+	M
Bank (Org) and Fifty (Con) Farms Mildenhall, Suffolk	23/4/92	18/6/92	14/9/92
Organic SB	+	M	+
Organic WW	+	M	+
Conventional SB	+	M	+
Conventional WW	+	M	+
Hawstead (Org) and Horscroft (Con) Farms, Bury St Edmunds, Suffolk	7/5/92	4/6/92	7/9/92
Organic SB	+	+	+
Organic WW	+	+	+
Conventional WW	+	+	+
Conventional WW	+	+	+
Village (Org) and Hall (Con) Farms Market Weston, Suffolk	7/5/92	4/6/92	18/8/92
Organic WW	+	+	+
Organic WW	+	+	+
Conventional WW	+	+	+
Conventional WW	+	+	+

WW = Winter Wheat SB = Spring Barley
\+ = Field sampled on given date
M = Field not sampled

Appendix 3 Summary of Sites and Sampling Dates for Vacuum Sampling Programme (Analyses One: Conventional/Organic Arable and Organic Grass Ley Fields)

Site and Field Details	Sampling Date			
	1	2	3	4
Boarded Barns Farm Ongar, Essex	24/3/92	1/5/92	18/5/92	21/8/92
Organic WW	+	+	+	+
Conventional WW	+	+	+	+
Organic Grass Conversion Ley 1st year	+	+	+	+
Organic Grass Conversion Ley 2nd year	+	+	+	+
Duchy Home Farm, Tetbury, Gloucestershire	9/4/92	14/5/92	11/6/92	25/8/92
Organic WW	+	+	+	+
Organic WW	+	+	+	+
Conventional WW	+	+	+	+
Conventional WW	+	+	+	+
Organic Grass Ley 1st year	+	+	+	+
Organic Grass Ley 2nd year	+	+	+	+

WW = Winter Wheat
\+ = Field sampled on this data

Appendix 4 Summary of Sites and Sampling Dates for Vacuum Sampling Programme (Analyses Two: Conventional and Organic Arable Fields)

Site and Field Details	Sampling Date		
	1	2	3
Home Farm Castle Acre, Norfolk	21/5/92	18/6/92	9/9/92
Organic WW	+	+	+
Organic WW	M	+	M
Conventional WW	+	+	+
Conventional WW	M	+	M
Bank (Org) and Fifty (Con) Farms Mildenhall, Suffolk	23/4/92	18/6/92	14/9/92
Organic SB	+	+	+
Organic WW	+	+	+
Conventional SB	+	+	+
Conventional WW	+	+	+
Hawstead (Org) and Horscroft (Con) Farms, Bury St Edmunds, Suffolk	7/5/92	2/7/92	7/9/92
Organic SB	+	+	+
Organic WW	+	+	+
Conventional WW	+	+	+
Conventional WW	+	+	+
Village (Org) and Hall (Con) Farms Market Weston, Suffolk	7/5/92	2/7/92	18/8/92
Organic WW	+	+	+
Organic WW	+	+	+
Conventional WW	+	+	+
Conventional WW	+	+	+

WW = Winter Wheat SB = Spring Barley
\+ = Field sampled on given date
M = Field not sampled

Appendix 5 Total Number of Diptera Larvae and Pupae extracted from Soil Cores.

Diptera Immature Stage	Organic Fields	Conventional Fields	Organic Grass Ley
Tipula paludosa (Tipulidae).	30	24	65
Nephrotoma maculata (Tipulidae)	4	5	6
Tipula czizeki (Tipulidae)	0	4	0
Bibio hortalanus (Bibionidae)	4	0	0
Delia coarctata pupae (Anthomyidae)	0	5	2
Anthomyidae sp. pupae.	0	8	1
Unknown Cyclorrhapha pupae.	20	27	4
Stratomyidae sp.	0	4	2
Chlorops pumilionis (Chloropidae)	0	5	2
Opomyza florum (Opomyzidae)	5	0	4
Muscidae sp.	12	0	6
Calliphoridae sp.	5	0	22
Scathophagidae sp.	6	0	0

Appendix 6 Total Number of Coleoptera Species Extracted from Soil Cores.

Coleoptera	Organic Fields	Conventional Fields	Organic Grass Ley
Tachyporus hypnorum (Staphylinidae)	14	17	0
Xantholinus linearis (Staphylinidae)	6	0	0
Staphylinid larvae	0	6	0
Pterostichus sp. larvae (Carabidae)	9	7	6
Clivina fossor (Carabidae)	0	6	12
Liestus sp. larvae (Carabidae)	0	6	0
Carabus sp. larvae (Carabidae)	0	4	0
Amara similata (Carabidae)	0	4	0
Amara sp. larvae (Carabidae)	0	0	15
Nebria brevicollis larvae (Carabidae)	5	0	0
Nebria brevicollis adults (Carabidae)	5	0	0
Sitona lineatus adults (Curculionidae)	0	5	19
Sitona sp. pupae (Curculionidae)	17	0	0
Sitona sp. larvae (Curculionidae)	11	0	0
Curculionidae sp. larvae	0	0	5
Wireworms (Elateridae)	14	4	5
Cockchafer larvae (Scarabaedae)	0	0	5

Appendix 7 Summary of Total Numbers of Invertebrates Caught in Vacuum Samples.

Invertebrate (*denotes a variant subjected to statistical analyses). Only invertebrates caught in numbers greater than three are shown.	Organic Fields	Conventional Fields	Organic Grass Ley
Total Invertebrates >5 mm*	1005	1363	444
Aphididae (Hemiptera)*	159	162	194
Metopolophium dirhodum (Aphididae)	42	56	4
Sitobion avaenae (Aphididae)	84	96	180
Rhopalosiphum padi (Aphididae)	28	2	0
Javesella pellucida (Hem; Delphacidae)	24	18	0
Collembola*	18,470	11,219	19,401
Linyphiidae (Araneae)*	295	233	102
Braconidae (Hymenoptera)*	471	425	758
Symphyta larvae (Hymenoptera)	4	6	12
Ichneumonidae (Hymenoptera)	24	18	10
Sitona lineatus (Col.: Curculionidae)*	452	40	217
Staphylinidae (Col.) > 5mm*	20	47	16
Xantholinus linearis (Staphylinidae)	13	21	4
Philonthus cognatus (Staphylinidae)	3	7	10
Tachyporus hypnorum (Staphylinidae)*	268	482	235
Aleocharinae sp. (Staphylinidae)*	287	505	586
Anotylus inustus (Staphylinidae)	24	13	8
Anotylus sculpturatus (Staphylinidae)	31	27	13
Carabidae (Col) >5 mm *	29	16	9
Amara familiaris (Carabidae)	12	10	1
Demetrias atricapillus (Carabidae)*	46	37	7
Trechus quadristriatus (Carabidae)	19	28	9
Bembidion lampros (Carabidae)	15	10	5
Bembidion obtusum (Carabidae)	15	5	4
Atomaria sp. (Col.: Cryptophagidae)	24	38	12
Total Diptera >5 mm*	495	903	193
Tipulid adults (Dip.: Tipulidae)*	109	105	136
Diptera; Sub-order Nematocera	1703	935	1179
Diptera: Sub-order Brachycera	62	268	24
Diptera Sub-order Cyclorrhapha	328	599	137
Chilopoda	12	3	8
Diplopoda	21	29	13

Appendix 8 Total Number of Invertebrates Used as Variables for Statistical Analyses-Extracted from Soil Cores.

Invertebrate Group	Organic Fields	Conventional Fields	Organic Grass Ley
Total invertebrates >5 mm	401	315	253
Lumbricidae >5 mm	144	112	65
Immature Diptera stages	87	88	116
Tipulid larvae (Diptera)	36	37	72
Coleoptera	136	108	102

Appendix 9

Crop	Date	Chick age (days)	Invertebrates Taken
C.R.S.A.	29/5/93	3	Arachnida Carabidae - unknown
05YSA	11/5/93 17/5/93 19/6/93	3 3 3	Arachnida *Loricera pilicornis* (larvae) Chrysomelidae Coleoptera - unknown Lepidoptera larvae Tipulid adults Tipulid pupae
OWW	2/6/93	3	Arachnida Curculionidae *Pterostichus* sp. Staphylinidae Lepidoptera larvae
OSW	-	-	No sample of this age
OSB	-	-	" " " "
OSO	-	-	" " " "
OWT	11/5/93	3	Arachnida Carabidae - unknown Tipulid adults Tipulid larvae
CBt	-	-	No sample of this age

cont/...

Appendix 9 (cont)

Treatment	Date	Chick age (days)	Invertebrates Taken
C.R.S.A.	25/5	4	*Pterostichus melanarius*
	30/5	4	*Pterostichus* sp.
	18/5	4	Arachnida
			Amara sp.
			Staphylinidae
			Tipulid adults
05YSA	19/5	4	Carabidae - unknown
	19/5	4	Curculionidae
	26/5	4	Arachnida
	20/6	4	Tipulid adult
			Tipulid larvae
			Staphylinidae
			P. melanarius
			Calathus sp.
			L. pilicornis - larvae
			Lepidoptera larvae
OWW	3/6	4	*Pterostichus* sp.
	2/6	4	Chrysomelidae
			Staphylinidae
			Arachnida
			Amara sp.
			Lepidoptera
OSB	22/6	4	Carabidae - unknown
			Arachnida
			Tipulid adults
OSO	-	-	-
OWT	12/5	4	Chrysomelidae
	16/5	4	Arachnida
			Tipulid adults
			Tipulid larvae
			Pterostichus sp.
			Curculionidae
			Staphylinidae

cont/...

Appendix 9 (cont)

Treatment	Date	Chick age (days)	Invertebrates Taken
C.R.S.A.	19/5	5	Carabidae *Pterostichus* sp.
			Carabid larvae
			Arachnida
05YSA	27/5	5	Carabidae *Calathus* sp.
	19/5	5	Curculionidae
	7/6	5	Arachnida
	21/6	5	Chrysomelidae
			Tipulid adults
			Tipulid larvae
			Pterostichus madidus & melanarius
			Carabid larvae - *L. pilicornis*
			Formicidae
OWW	4/6	5	Carabidae 3-4 sp unknown
	3/6	5	*Pterostichus* sp.
			Calathus sp.
			Arachnida
			Lepidoptera larvae
			Amara sp.
			Tipulid adults
			Tipulid larvae
OSB	23/6	5	*Pterostichus* sp.
			Staphylinidae
			Tipulid adults
			Arachnida + young
OSO	20/6	5	No sample
OWT	13/5	5	*Pterostichus* sp.
			Amara sp.
			Curculionidae
			Arachnida
			Tipulid pupae
			Tipulid adults
			Carabid larvae
CBt	18/6	5	*Pterostichus* sp.
			Harpalus affinis
			Staphylinidae
			Arachnida
			Orbatid mite x 1

Cont/...

Treatment	Date	Chick age (days)	Invertebrates taken
C.R.S.A.	11/5	6	Carabidae - unknown
	1/6	6	*Amara* sp.
			Staphylinidae
			Tipulid adults
			Arachnida
			Pterostichus melanarius
			Carabid larvae
05YSA	4/5	6	Calathus sp.
	21/5	6	*Amara* sp.
	28/5	6	*Arachnida*
	14/5	6	Elateridae
	22/6	6	*Harpalus affinis*
			Curculionidae
			Tipulid adults
			Pterostichus cupreus
			Pterostichus sp.
			Lepidoptera larvae
			L. pilicornis (larvae)
OWW	5/6	6	*Amara* sp.
			Pterostichus sp.
			Agonum dorsale
			Harpalus affinis
			Arachnida
OSW	8/6	6	*P. madidus*
			Nebria brevicollis
			Agonum dorsale
			Amara sp.
			Carabid larvae
			Chrysomelidae
			Staphylinidae
			Arachnida
			Tipulid adults
OSB	24/6	6	*P. madidus*
			Amara sp.
			Tipulid adults
			Arachnida
OSO	21/6		*Pterostichus* sp.
			Agonum dorsale
			Harpalus rufipes
			Tipulid adults
			Tipulid larvae
OWT	14/5	6	Carabidae
	18/5	6	Curculionidae
	14/5	6	Elateridae
			Arachnida
			Tipulid adults
			Tipulid larvae

Cont/...

Appendix 9 (cont)

Treatment	Date	Chick age (days)	Invertebrates taken
CBt	19/6	6	Carabidae - *Amara* sp.,
			Pterostichus sp.
C.R.S.A.	12/5/93	7	Arachnida
	21/5/93	7	*Amara* sp.
	28/5/93	7	*Harpalus affinis*
	2/6/93	7	*Notiophilus biguttatus*
			Pterostichus madidus
			Pterostichus melanarius
			Curculionidae
			Elateridae
			Staphylinidae
			Lepidoptera larvae
			Tipulid adults
			Tipulid pupae
05YSA	5/5/93	7	Arachnida
	7/5/93	7	*Amara* sp.
	15/5/93	7	*Calathus* sp.
	21/5/93	7	*Harpalus rufipes*
	22/5/93	7	*Harpalus affinis*
	29/5/93	7	*Pterostichus madidus*
	9/6/93	7	Chrysomelidae
	23/6/93	7	Curculionidae
			Elateridae
			Loriscera pilicornis larvae
			Lepidoptera larvae
			Tipulid adults
OWW	6/6/93	7	Arachnida
			Amara sp.
			Carabidae
OSW	9/6/93	7	Arachnida
			Amara sp.
			Harpalus affinis
			Pterostichus sp.
			Elateridae
			Tipulid adults
OSB	-	-	No sample of this age
OSO	22/6/93	7	Arachnida
			Amara sp.
			Harpalus rufipes
			Pterostichus madidus
			Staphylinidae
			Tipulid adults
OWT	15/5	7	Arachnida
			Carabidae unknown
			Carabid larvae
			Curculionidae
			Staphylinidae
			Tipulid adults

Cont/...

Appendix 9 (cont)

Treatment	Date	Chick age (days)	Invertebrates Taken
CBt	20/6	7	*Amara* sp.
			Pterostichus melanarius
C.R.S.A.	27/4	8	Carabidae
	13/5	8	Tipulid adults
	29/5	8	*Pterostichus* sp. *P. melanarius*
	22/5	8	Thysanoptera
	3/6	8	Pentiatomidae
			Arachnida
			Amara sp.
			Harpalus affinis
			Agonum dorsale
			Elateridae
			Lepidoptera larvae
			Cicindellidae *C. campestris*
05YSA	6/5	8	*Pterostichus* sp. cf. *P. cupreus*
	23/5	8	Curculionidae
	30/5	8	Chrysomelidae
	16/5	8	Tipulida adults + larvae
	22/5	8	*H. affinis*
	10/6	8	Arachnida
	24/6	8	*Agonum dorsale*
			Elateridae
			Lepidoptera larvae
			P. melanarius
			P. madidus
			Calathus sp.
			Carabid larvae
OWW	7/6	8	*Amara* sp.
			Agonum dorsale
			Tipulid adults
			Arachnida
OSW	10/6	8	*Amara* sp.
			Pterostichus sp.
			Agonum dorsale
			Lepidoptera larvae
			Tipulid larvae
			Arachnida
OSO	23/6	8	*Pterostichus madidus*
			Pterostichus sp.
			Amara sp.
			Tipulid adults
			Tipulid pupae
			Arachnida
			Mollusca
OWT	16/5	8	*Pterostichus* sp.
			Curculionidae
			Arachnida

Cont/...

Appendix 9 (cont)

Treatment	Date	Chick age (days)	Invertebrates Taken
CBt	21/6	8	*Pterostichus melanarius*
			Arachnida
C.R.S.A	14/5	9	*Pterostichus* sp. *P. melanarius*
	23/5	9	*Amara* sp.
	17/5	9	*Harpalus affinis*
	25/5	9	Arachnida
			Tipulid adults
			Tipulid pupae
			Curculionidae
			Harpalus affinis
			Notiophilus biguttatus
	24/5	9	Arachnida
	23/5	9	Carabidae - unknown
	12/5	9	*H. affinis*
			Amara sp.
			Curculionidae
			Tipulid adults
			Lepidoptera larvae
			Chrysomelidae
	21/5	9	Carabidae - unknown
			Tipulid adult
CRSA	11/5		
		12	Carabidae - unknown
			Arachnida
			Pentatomidae

Appendix 10 Invertebrates Present in Skylark Faecal Sacs (1994 Analyses).

Treatment	Date	Invertebrates taken
WB1	14/5/94	Arachnida
		Carabidae
		Notiophilus biguttatus
		Unknown x 2
		Carabid larvae
		Curculionidae
		Diptera
		Scarabaeidae
		Histeridae
		Staphylinidae
WB1	15/5/94	Arachnida
		Carabidae
		Loricera pilicornis
		Notiophilus biguttatus
		Agonum sp.
		Unknown x 1
		Curculionidae
		Lepidoptera larvae
		Staphylinidae
		Tipulidae - Adults/larvae
WB1	16/5/95	Arachnida
		Carabidae
		Elateridae
		Lepidoptera - larvae
		Pentatomidae
		Staphylinidae
		Tachyporus sp.
		Tipulidae - adults
WB2	20/5/94	Arachnida
		Carabidae
		Agonum sp
		Pterostichus cupreus
		Carabid larvae
		Elateridae
		Tipulidae - adults
WB5	29/5/94	Arachnida
		Coleoptera - unknown
		Carabidae
		Agonum sp
		Tipulidae - adults

Cont/...

Appendix 10 (cont)

Treatment	Date	Invertebrates taken
WB5	31/5/94	Arachnida
		Carabidae
		Amara sp
		Loricera pilicornis
		Cicindellidae
		Cicindella campestris
WB5	31/5/94	Coccinellidae
		Propylea-14-punctata
		Curculionidae
		Mollusca
		Scarabaeidae
		Histeridae
		Staphylinidae
		Tipulidae - adults
WO3	25/5/94	Arachnida
		Carabidae
		Amara sp
		Carabid larvae
		Tipulidae - adults
WO5	25/5/94	Arachnida
		Carabidae
		Amara sp
		Calathus sp
		Pterostichus sp
		Chrysomelidae
SU1	23/5/94	Arachnida
		Coleoptera unknown
		Tipulidae - adults/pupae
SU1	24/5/94	Arachnida
		Coleoptera unknown
		Tipulidae - adults
SA3	19/5/94	Arachnida
		Lepidoptera - larvae
		Tipulidae - adults/larvae
SA4	15/5/94	Arachnida
		Carabidae
		Amara sp
		Curculionidae
		Tipulidae - adults/larvae
		Lepidoptera - larvae

Cont/...

Appendix 10 (cont)

Treatment	Date	Invertebrates taken
SA4	16/5/94	Arachnida Coleoptera - unknown Chilopoda Elateridae Tipulidae - adults/larvae
GL2	16/5/94	Arachnida Carabidae Coleoptera - unknown Elateridae Tipulidae - adults/larvae
GL2	18/5/94	Arachnida Carabidae Elateridae Lepidoptera - larvae Staphylinidae Tipulidae - adults/larvae
GL2	19/5/94	Arachnida Coleoptera - unknown Lepidoptera - larvae Tipulidae - adults/larvae
GL3	14/5/94	Carabidae Coleoptera - unknown Elateridae Tipulidae - adults/larvae
GL3	14/5/94	Arachnida Carabidae Pentatomidae Tipulidae - adults/larvae Staphylinidae
N1	14/6/94	Arachnida Carabidae Curculionidae Staphylinidae
Label destroyed	10 or 16/5/94	Arachnida Carabidae *Pterostichus* sp Lepidoptera - larvae Staphylinidae Tipulidae - adults/larvae

Key to Treatments

WB	-	Winter Barley (conventional)	
WO	-	Winter Oats (conventional)	Hall Farm
SU	-	Sugar Beet (conventional)	
SA	-	1 year set-a-side (organic)	Village Farm
GL	-	Grass/Clover Ley (organic)	

Appendix 11 Species of Carabid Identified in Faecal Sacs

Species	Farming Conventional	Regime Organic
Amara sp. Bonelli	+	+
Agonum dorsale (Pontoppiidan	-	+
Caluthus piceus (Marsham)	-	+
Harpalus affinis (Schrank)	+	+
Harpalus rufipes (Deger)	-	+
Loricera pilicornis (Fabricius)	+	-
Nebria brevicollis (Fabricius)	-	+
Notiophilus biguttatus (Fabricius)	+	-
Pterostichus cupreus (L.)	-	+
Pterostichus madidus (Fabricius)	+	+
Pterostichus melenarius (Illiger)	+	+

Appendix 12 Major Invertebrate Groups Identified from Fragments.

Order/Family		Lifestages
Arachnida	-	Adults and spiderlings
Coleoptera		
Carabidae	-	Adults and larvae
Chrysomelidae	-	Adults
Curculionidae	-	Adults
Elateridae	-	Adults
Staphylinidae	-	Adults
Hymenoptera		
Formicidae	-	Adults
Lepidoptera	-	Larvae
Diptera		
Tipulidae	-	Adults, pupae, larvae and eggs
Thysanoptera	-	Adults
Acarina	-	Adults

Appendix 13 Autumn Pitfall Trapping: Eastbrook Farm, Bishopstone, Wilts.

	Organic			Conventional		
	A	B	TOT.	A	B	TOT.
CARABIDAE:	**55**	**45**	**100**	**138**	**372**	**510**
Pterostichus melenarius	0	0	0	24	0	24
Nebria brevicollis	4	0	4	33	66	99
Trechus quadristriatus	19	20	39	17	253	270
Notiophilus biguttatus	3	1	4	10	12	24
Trechus micros	0	1	1	1	0	1
Bembidion obtusum	4	7	11	0	9	9
Pterostichus strenuus	0	1	1	0	0	0
Loricera pilicornis	0	1	1	0	0	0
Clivina fossor	0	0	0	1	0	1
Nebria brevicollis (larvae)	24	10	34	49	17	66
Pterostichus madidus (larvae)	1	0	1	2	15	17
Amara sp. (larvae)	0	0	0	1	0	1
Harpalus rufipes (larvae)	0	4	4	0	0	0
STAPHYLINIDAE:	**36**	**77**	**113**	**22**	**40**	**62**
Xantholinus linearis	15	5	20	7	6	13
Aleocharinae sp.	5	6	11	6	14	20
Anotylus inustus	3	26	29	0	3	3
Staphylinus olens	0	3	3	0	0	0
Othius laeviosculus	4	0	4	0	7	7
Xantholinus glabratus	0	17	17	0	0	0
Stenus subaeneus	3	0	3	3	6	9
Stenus similis	0	1	1	0	0	0
Lestiva longo-elytrata	1	1	2	2	0	2
Philonthus cognatus	0	0	0	1	0	1
Phlonthus varians	0	1	1	1	1	1
Quedius cinctus	0	3	3	2	0	2
Quedius latteralis	1	0	1	0	0	0
Quedius tristis	0	2	2	0	0	0

Appendix 13 (cont)

	Organic			Conventional		
	A	B	TOT.	A	B	TOT.
Anotylus rugosus	0	0	0	0	1	1
Anotylus sculpturatus	0	2	2	0	0	0
Staphylinid larvae	0	7	7	0	2	2
Omalium caesium	3	2	5	0	0	0
Tachyporus nitiduls	1	0	1	0	0	0
Rugilus orbiculatus	0	1	1	0	0	0
HYDROPHILIDAE: *Helophorus rufipes*	52	3	55	6	7	13
LEIODIDAE: *Choliva* sp.	5	9	14	3	2	5
CURCULIONIDAE: *Sitona linaetus*	0	1	1	1	0	1
NITIDULIDAE: *Meligethes aneus*	2	0	2	0	0	0
CHRYSOMELIDAE: *Psylloides chrysocephala*	0	0	0	1	1	2
TOTAL COLEOPTERA:	**150**	**135**	**285**	**171**	**421**	**593**

Cont/...

Appendix 13 (cont)

	Organic			Conventional		
	A	B	TOT.	A	B	TOT.
OTHER INVERTEBRATES						
Araneae; Linyphiidae	63	51	114	72	86	158
Hymenoptera; Sawfly larvae	1	2	3	4	1	5
Chilopoda sp.	0	4	4	0	4	4
Diplopoda sp.	0	14	14	0	0	0
Cantharidae; larvae	0	4	4	0	0	0
Harvestmen	2	0	2	2	0	2
Woodlice	0	1	1	0	1	1
Araneae; Lycosidae	0	1	1	0	0	0
DIPTEROUS LARVAE;	**409**	**2**	**411**	**2**	**0**	**2**
Stratomyidae sp.	0	0	0	2	0	2
Sciaridae sp.	37	0	37	0	0	0
Chironimidae sp.	370	0	370	0	0	0
Calliphoridae sp.	0	2	2	0	0	0
Bibionidae sp.	2	0	2	0	0	0
TOTAL INVERTIBRATES:	**625**	**214**	**839**	**251**	**513**	**764**
(EXC.DIPTEROUS LARVAE)	216	212	428	249	513	762

Appendix 14 A Comparison of the Three Sampling Methods - Vacuum, Soil Sampling and Pitfall Trapping.

	Vacuum 1992	Vacuum 1993	Soil cores 1992	Soil cores 1993	Pitfall traps 1994
No. samples	610	161/320	1950	675/1700	690
No. invertebrates	3107 (> 5 mm)	-	1059 (> 4 mm)	46	-
No. invertebrates/ 100 samples	509.3	-	54.3	6.8	(>7000?)
No. carabids/ 100 samples	17.4	12.4	3.4	0.4	4347.8
No. tipulids/ 100 samples	18.5 (adults)	25.5 (adults)	6.6 (larvae+ pupae)	0.2 (larvae+ pupae)	7.3 (larvae+ adults)
No. spiders (*) or earthworms (+)/ 100 samples	217.4*	291.9*	16.9+	4.4+	1345.4*

*Spiders (Linyphiids and Lycosidae, all sizes) +Earthworm fragments

Appendix 15 Site and Crop Details of Sample Sites Used for Diversity Comparisons

Organic	Field A	Field B	Conventional	Field A	Field B	Collection dates
Coldharbour	WW	WW	Leadenporch	WW	WW	27/6, 7/7, 22/7, 5/8
Eastbrook	WW	WB	Eastbrook	WW	WB	13/5, 27/5, 10/6, 27/6, 7/7, 22/7, 4/8
Step	WW	WW	Colleymore	WW	WW	27/5, 10/6, 27/6, 7/7, 22/7, 4/8
Village	WW	WB	Hall	SO	WW	11/5, 29/5, 14/6, 28/6, 12/7, 27/7
Hall (Lincs.)	WO	WO	Hall (Lincs.)	WB	WW	5/5, 19/5, 31/5, 13/6, 28/6, 12/7
Batchley	WO	WB	Grendon Manor	WO	WB	9/7, 21/7, 10/8
-	-	-	Overtons	WW	SB	4/5, 19/5, 14/6, 28/6, 12/7,
IGER	WW	-	IGER	WW	-	8/7, 22/7

WW = Winter Wheat; WB = Winter Barley; SB = Spring Barley; WO = Winter Oats; SO = Spring Oats; SB = Sugar Beet

Appendix 16; Species ranks of carabids for organic and conventional systems.

ORGANIC				CONVENTIONAL			
Rank	Species	Nos. caught	% catch.	Rank	Species	Nos. caught	% catch
1	*Pterostichus melanarius*	12,574	59.996	1	*Pterostichus melanarius*	7,330	60.533
2	*Pterostichus madidus*	2,120	10.115	2	*Agonum dorsale*	2,038	16.830
3	*Agonum dorsale*	1,261	6.017	3	*Trechus quadristriatus*	504	4.162
4	*Pterostichus cupreus*	1,025	4.891	4	*Harpalus rufipes*	261	2.155
5	*Trechus quadristriatus*	854	4.075	5	*Nebria brevicollis*	242	1.999
6	*Pterostichus niger*	788	3.760	6	*Calathus fuscipes*	239	1.974
7	*Nebria brevicollis*	767	3.660	7	*Pterostichus madidus*	229	1.891
8	*Harpalus rufipes*	750	3.579	8	*Bembidion lampros*	226	1.866
9	*Harpalus affinis*	135	0.644	9	*Loricera pilicronis*	209	1.726
10	*Bembidion lampros*	129	0.616	10	*Pterostichus cupreus*	194	1.602
11	*Loricera pilicronis*	114	0.544	11	*Pterostichus niger*	172	1.420
11	*Calathus fuscipes*	114	0.544	12	*Agonum muelleri*	120	0.991
13	*Agonum muelleri*	87	0.415	13	*Pterostichus strenuus*	69	0.570
14	*Notiophilus bigattatus*	55	0.262	14	*Harpalus affinis*	42	0.347
15	*Bembidion obtusum*	29	0.138	15	*Bembidion obtusum*	31	0.256
16	*Pterostichus strenuus*	22	0.105	15	*Notiophilus bigattatus*	31	0.256
17	*Bembidion lunulatum*	20	0.095	17	*Calathus piceus*	19	0.157
18	*Amara similita*	19	0.091	18	*Bembdion guttula*	18	0.149
19	*Bembidion tetracolum*	18	0.086	19	*Demetrias atricappillus*	15	0.124
20	*Demetrias atricappillus*	15	0.072	20	*Amara familiaris*	11	0.091
21	*Bembdion guttula*	11	0.052	20	*Amara similita*	11	0.091
22	*Clivina fossor*	6	0.029	20	*Synuchus nivalis*	11	0.091
22	*Abax parallelepipedus*	6	0.029	23	*Carabus violaceous*	10	0.083
24	*Pterostichus nigrita*	5	0.024	24	*Bembidion tetracolum*	9	0.074
25	*Pterostichus macer*	4	0.019	25	*Bembidion lunulatum*	8	0.066
25	*Harpalus rufibarbis*	4	0.019	25	*Harpalus rufibarbis*	8	0.066
25	*Amara plebeja*	4	0.019	27	*Calathus cinctus*	7	0.058
28	*Amara eurynota*	3	0.014	27	*Amara plebeja*	7	0.058
28	*Amara aenea*	3	0.014	29	*Amara aenea*	6	0.050
30	*Synuchus nivalis*	2	0.010	30	*Abax parallelepipedus*	5	0.041
30	*Stomis pumicatus*	2	0.010	30	*Calathus melanocephalus*	5	0.041
30	*Pterostichus vernalis*	2	0.010	32	*Amara lunicollis*	4	0.033
30	*Bembidion quadrimaculatum*	2	0.010	33	*Bembidion quadrimaculatum*	3	0.025
34	*Pterostichus longicollis*	1	0.005	33	*Pterostichus nigrita*	3	0.025
34	*Laemostenus terricola*	1	0.005	35	*Stomis pumicatus*	2	0.017
34	*Carabus violaceous*	1	0.005	35	*Amara communis*	2	0.017
34	*Carabus granulatus*	1	0.005	37	*Amara ovata*	1	0.008
34	*Calathus piceus*	1	0.005	37	*Amara eurynota*	1	0.008
34	*Amara lunicollis*	1	0.005	37	*Clivina fossor*	1	0.008
34	*Amara bifrons*	1	0.005	37	*Agonum obscurum*	1	0.008
34	*Amara familiaris*	1	0.005	37	*Amara apricaria*	1	0.008
				37	*Amara aulica*	1	0.008
				37	*Asaphidion flavipes*	1	0.008
				37	*Leistus spinbarbis*	1	0.008
	S = 41	N = 20,958			S = 44	N = 12,109	

Appendix 17 Species List of Carabids Recorded from Organic and Conventional Systems.

SUPERFAMILY: CARABOIDEA
FAMILY: CARABIDAE
SUBFAMILY: CARABINAE

Species	Habitat affinity	Breeding period	Adult diel activity
Tribe AMARINI			
Amara aenea (Degeer)	xerophilous, grassland, arable land	spring	diurnal
A. apricaria (Paykull)	eurytopic, xerophilous, preferring cultivated soils	autumn	(unknown)
A. aulica (Panzer)	eurytopic, in open country and arable land	autumn	(uncertain)
A. bifrons (Gyllenhall)	eurytopic, xerophilous, sandy soils in grasslands and arable land	autumn	nocturnal
A. communis (Panzer)	eurytopic, especially open country	spring	diurnal
A. eurynota (Panzer)	eurytopic, open country, often on clay soils with tall vegetation	autumn	(unknown)
A. familiaris (Duftschmid)	eurytopic, open country	spring	diurnal
A. lunicollis Schiødte	eurytopic, mainly peat or sandy soils in open countryside	spring	diurnal
A. ovata (Fabricius)	eurytopic, xerophilous, open country with tall vegetation	spring	(unknown)
A. plebeja (Gyllenhall)	eurytopic, open country with clay soils	spring	(unknown)
A. similita (Gyllenhall)	eurytopic, meadows, grassland, arable land	spring	diurnal
Tribe BEMBIDINI			
Asaphidion flavipes (Linnaeus)	hygrophilous, mainly thin deciduous woodland and meadows	spring	nocturnal
Bembidion obtusum Audinet-Serville	clay soils in agricultural land	spring	(uncertain)
B. quadrimaculatum (Linnaeus)	eurytopic, mainly clay soils	spring	diurnal
B. lampros (Herbst)	eurytopic, sandy soils in open ground or arable land	spring	diurnal

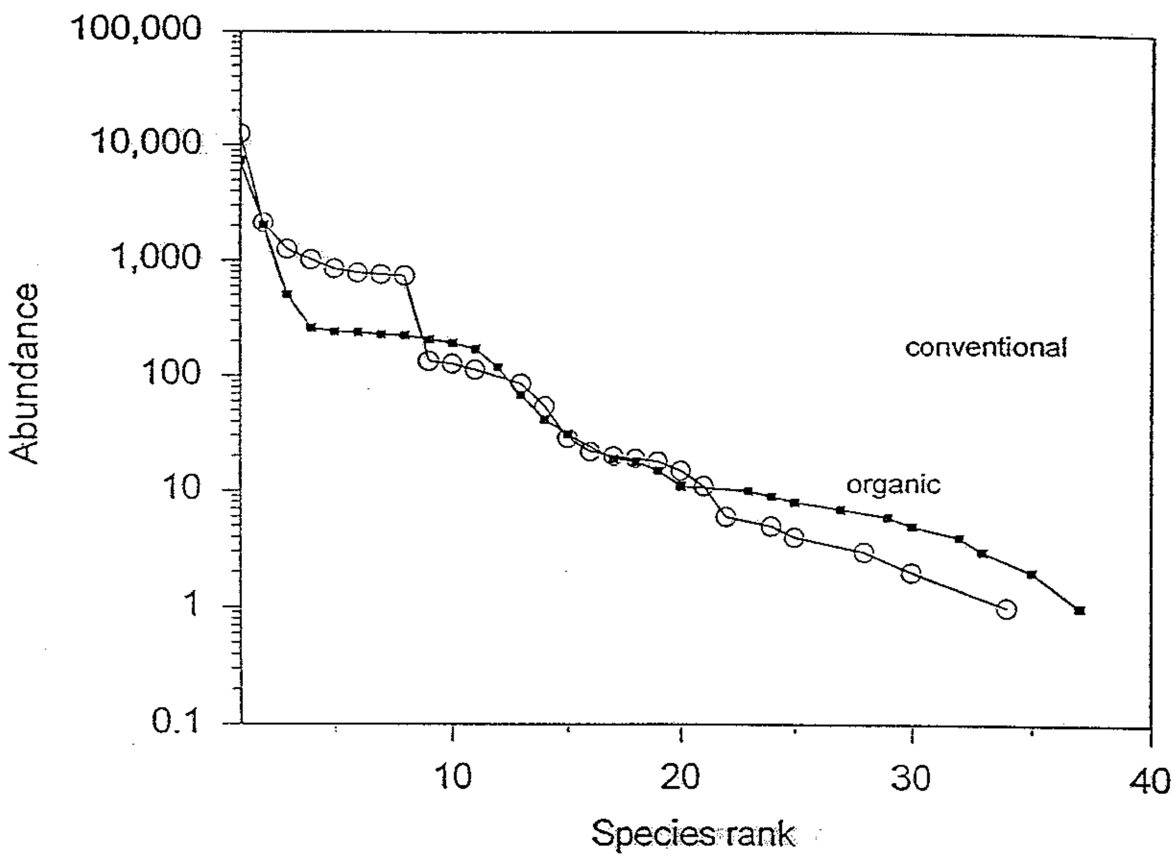
Species	Habitat affinity	Breeding period	Adult diel activity
B. tetracolum Say	very eurytopic, mainly clay soils in open ground and arable land	spring	diurnal
B. guttula (Fabricius)	clay soils near fresh water	spring	(unknown)
B. lunulatum (Fourcroy)	humid clay soils	spring	(unknown)
Tribe CARABINI			
Carabus granulatus Linnaeus	hygrophilous, mainly decidous wodland and arable land	spring	nocturnal
C. violaceous Linnaeus	eurytopic, mainly decidous and coniferous forests	autumn	nocturnal
Tribe HARPALINI			
Harpalus affinis (Schrank)	eurytopic, mainly sandy soils and open ground	spring	nocturnal
H. rufibarbis (Fabricius)	eurytopic, preferring open country and humus-rich soils	spring	(unknown)
H. rufipes (Degeer)	eurytopic, mainly clay soils and open ground	autumn	nocturnal
Tribe LEBIINI			
Demetrias atricappillus (Linnaeus)	eurytopic, in open country including marshes and meadows	spring	diurnal
Tribe LORICERINI			
Loricera pilicornis (Fabricius)	eurytopic, mainly arable land	spring	nocturnal
Tribe NEBRIINI			
Nebria brevicollis (Fabricius)	eurytopic, mainly decidous woodland and open land	autumn	nocturnal
Leistus spinbarbis (Fabricius)	hygrophilous, gardens and woodland	autumn	(not known)
Tribe NOTIOPHILINI			
Notiophilus biguttatus (Fabricius)	eurytopic, mainly decidous and coniferous forests	spring	diurnal
Tribe PTEROSTICHINI			
Pterostichus cupreus (Linnaeus)	eurytopic, open and arable land	spring	diurnal
P. longicollis (Duftschmid)	bare ground near water, especially on calcareous soils (Notable B)	(not known)	(not known)

Species	Habitat affinity	Breeding period	Adult diel activity
P. macer (Marsham)	humus-rich soils in open country and arable fields	spring	nocturnal
P. madidus (Fabricius)	eurytopic, mainly wooland and open country	autumn	nocturnal
P. melanarius (Illiger)	very eurytopic, especially arable land	autumn	nocturnal
P. niger (Schuller)	eurytopic, mainly woodland and arable land	autumn	nocturnal
P. nigrita (Paykull)	hygrophilous, humus-rich clay soils	spring	nocturnal
P. strenuus (Panzer)	eurytopic, woodland and open country	spring	nocturnal
P. vernalis (Panzer)	hygrophilous, preferring fens and moist meadows	spring	(not known)
Calathus fuscipes (Goeze)	eurytopic, mainly meadows and grassland	autumn	diurnal
C. cinctus	eurytopic	autumn	nocturnal
C. melanocephalus (Linnaeus)	eurytopic, open country and sandy soils	autumn	nocturnal
C. piceus (Marsham)	eurytopic, mainly deciduous forests	autumn	nocturnal
Abax parallelepipedus (Piller & Mitterpacher)	eurytopic, mainly clay soils in woodland	autumn	(uncertain)
Agonum dorsale (Pontoppidan)	eurytopic, open meadows, grasslands, arable land	spring	nocturnal
A. muelleri (Herbst)	eurytopic, mainly arable land with clay soils	spring	diurnal
A. obscurum (Herbst)	hygrophilous, mainly in deciduous or mixed forests and marshes	spring	(unknown)
Stomis pumicatus (Panzer)	eurytopic, on clay soils in open country and deciduous forests	spring	nocturnal
Laemostenus terricola (Herbst)	troglophilous, in burrows, hollow trees, caves and farmyards	autumn	nocturnal
Synuchus nivalis (Illiger)	eurytopic, xerophilous, in open country	autumn	diurnal
Tribe SCARATINI			

Appendix 17 (cont)

Species	Habitat affinity	Breeding period	Adult diel activity
Clivina fossor (Linnaeus)	eurytopic, usually in open country with slightly dry soils, subterranean	spring	nocturnal
Tribe TRECHINI			
Trechus quadristriatus (Schrank)	very eurytopic, in open country, short grassland and arable land	bivoltine, but mainly in spring	nocturnal

Appendix 18 Rank Abundance Curves for Carabids.



Appendix 19 Abundance, Species Richness, Diversity and Dominance of Pooled Samples.

	N	*S*	∝	*S. E. (∝)*	*% P. melanarius*
Organic	20958	41	4.9	0.82	60.0
Conventional	12109	44	5.7	0.93	60.5
combined	33,067	50	5.8	0.87	60.4

Appendix 20 Abundance, Species Richness, Diversity and Dominance by Farm and Treatment.

System	Farm	*N*	*S*	∝	*S.E. (∝)*	*% P. melanarius*
Organic	Village	2941	20	2.9	0.70	3.5
	Coldharbour	3935	21	2.9	0.68	71.6
	Eastbrook	3371	23	3.3	0.75	71.0
	Step	4474	28	4.0	0.81	64.5
	Hall (Lincs.)	2636	20	2.9	0.71	77.4
	Batchley	3123	19	2.7	0.67	65.6
	IGER	478	15	2.9	0.85	59.4
Conventional	Hall	1607	22	3.6	0.84	69.0
	Leadenporch	121	21	7.3	1.96	13.2
	Eastbrook	1602	18	2.8	0.73	62.3
	Colleymore	3111	28	4.2	0.87	44.9
	Hall (Lincs.)	826	29	5.9	1.21	48.2
	G. Manor	1875	19	2.9	0.73	84.4
	Overtons	1521	23	3.8	0.88	47.5
	IGER	1446	19	3.1	0.77	76.6

Appendix 21 Vortis Seed Samples (9/93): Diversity.
Appendix 21a Shannon Wiener Diversity Index.

Conventional				
	H	*H* MAX	*E*	SPP
Home Farm 1	2.9	3.8	0.8	14
Home Farm 2	2.8	3.8	0.74	14
Horsecroft 1	1.5	1.6	0.94	3
Horsecroft 2	1.8	2.3	0.78	5
Leadenporch 1	2.7	3.3	0.8	10
Leadenporch 2	3	3.5	0.87	11
MEAN	2.45	3.05	0.82	9.5
Organic				
	H	*H* MAX	*E*	SPP
Home Farm 1	3.5	3.6	0.97	12
Home Farm 2	4.3	4.6	0.94	24
Hawstead Place 1	3.1	3.2	0.97	9
Hawstead Place 2	2.8	3.2	0.89	9
Cold Harbour 1	3.2	3.6	0.89	12
Cold Harbour 2	3.8	4.2	0.91	18
MEAN	3.45	3.73	0.93	1

Appendix 21b: **Williams' Log Series Alpha**

Conventional		
	Alpha	SE
Home Farm 1	2.9	0.83
Home Farm 2	1.8	0.73
Horsecroft 1	0.7	0.46
Horsecroft 2	2.2	1.00
Leadenporch 1	2.5	0.92
Leadenporch 2	2.3	0.74
MEAN 2.07		
Organic		
	Alpha	**SE**
Home Farm 1	3	0.83
Home Farm 2	4.4	0.98
Hawstead Place 1	3.7	1.57
Hawstead Place 2	1.9	0.77
Cold Harbour 1	2.2	0.69
Cold Harbour 2	3.6	0.97
MEAN 3.13		

Appendix 22 Vortis Seed Samples (9/93)
Seed Abundance Per Species

Genus	Species	Wt mg per Seed	Total	Numbers
			Conventional	Organic
Agrostis	*stolonifera*	0.02	1	47
Allium		4.27	1	
Alopecurus	*myosuroides*	1.7	51	48
Anagallis	*arvensis*	0.47	1	1
Aphanes	*arvensis*	0.19		7
Arenaria	*serpyllifolia*	0.06		31
Atriplex	*patula*	1.79	10	3
Avena		8	17	
Bidens	*tripartita*	5		8
Bromus	*mollis*	2.35	5	12
Capsella	*b-pastoris*	0.1		36
Carduus		1.8		1
Centaurea	*nigra*	2.2	2	
Cerastium	*fontanum*	0.1		4
Chenopod ..	*album*	1	9	10
Cirsium	*arvense*	1.17	3	111
Conyza	*canadensis*	0.1	2	354
Crepis	*capillaris*	0.21		16
Elymus	*repens*	3	3	3
Euphorbia	*exigua*	0.47	1	
Festuca	*rubra*	0.8		1
Filago		0.7	1	
Fumaria	*officinalis*	3.3	1	
Galium	*aparine*	8	5	
Geranium	*molle*	1.3	7	10
Geum	*urbanum*	5	2	74
Kickxia	*spuria*	0.4		1
Lamium				2
Lapsana	*communis*	0.7	1	

Appendix 22 (cont)

Genus	Species	Wt mg per Seed	Total	Numbers
			Conventional	Organic
Linaria	*vulgaris*	0.14		1
Lolium	*perenne*	2		241
Matricaria	*matricarioides*	0.2		257
Myosotis	*arvensis*	0.27	15	148
Papaver	*rhoeas*	0.1	3	865
Phleum	*pratense*	0.15		211
Poa	*annua*	0.26	1017	144
Polygonum	*aviculare*	2.5	2	18
Prunella	*vulgaris*	3.6	6	
Rumex	*crispus*	1.33	2	6
Senecio	*vulgaris*	0.25		22
Silene	*alba*	6		1
Sonchus	*arvensis*	0.3	3	1
Stellaria	*media*	0.35	63	31
Taraxacum	*officinale*	0.7	1	
Trifolium	*repens*	0.6		80
Triticum		10	265	82
Urtica		0.29	6	2
Veronica	*persica*	0.55	29	21
Veronica	*hederifolia*	5	30	35
Veronica	*arvensis*	0.11	260	9
Viola	*arvensis*	0.52	210	28
Total numbers of seeds			2035	2983

Appendix 23a Vortis Seed Samples (9/93)
Total Abundance Above Threshold Seed Weight: Organic Fields

	Weight	Total weight Kg/ha (estimated from seed counts)						
	mg	H1	H2	HA1	HA2	CH1	CH2	TOTAL
Stellaria	0.35	5.3	0.4	3.2	1.4	0.4	0.4	10.9
Viola	0.52	7.3	0.5				6.8	14.6
Veronica	0.55	10.0			0.5			10.5
Trifolium	0.6	0.6					47.4	48.0
Festuca	0.8						0.8	0.8
Chenopodium	1.0	11.2					2.8	14.0
Cirsium	1.17	125.0	2.3				2.3	130.0
Geranium	1.3	11.7	1.3					13.0
Rumex	1.33	7.0					1.4	8.4
Alopecurus	1.7			1.8	33.4	2.8	4.6	44.5
Atriplex	1.79	4.0						4.0
Carduus	1.8		1.2					1.2
Lolium	2.0					340	93.6	434.0
Bromus	2.35			26.1			8.7	34.8
Polygonum	2.5	21.0		8.4		8.4		37.8
Elymus	3.0		4.0		2.0			6.0
Bidens	5.0			40.0				40.0
Geum	5.0				54.0			54.0
Veronica	5.0						175.0	175.0
Silene	6.0				1.1			1.1
Triticum	10.0	230.0			60.0	350.0	180.0	820.0
TOTAL WEIGHT KG/HA		433.10	9.70	79.50	152.40	701.60	523.80	1902.60
AVERAGE WEIGHT KG/HA								317

FIELD CODES: H1, H2 = Home Farm Little Mink and West Mink
HA1, HA2 = Hawstead Place 1 and 2
CH1, CH2 = Cold Harbour Farm 1 and 2

Appendix 23a Summary

Table of Means (seeds > 0.35 mg) $\text{Log}_{10}[(\text{seed count})+0.5]/10\ \text{m}^2$

Organic	Conventional	SED
5.1	4.72	0.64

Appendix 23b Vortis Seed Samples (9/93)
Total Abundance > Threshold Seed WT: Conventional Fields

GENUS	WT m gm per seed	Total weight kg /ha by field						
		H1	H2	HC1	HC2	LP1	LP2	TOTAL
Stellaria	0.35	22.1						22.1
Euphorbia	0.47	0.5						0.5
Viola	0.52	80.2	26.6			2.1	0.5	109.0
Veronica	0.55	14.0	1.0					15.0
Chenopodium	1.0	9.45					2.7	12.2
Cirsium	1.17		3.5					3.5
Geranium	1.3		9.1					9.1
Rumex	1.33	2.2						2.2
Alopecurus	1.7					41.4	28.9	70.3
Atriplex	1.79	2.7	9.3			1.33		13.3
Centaurea	2.2		5.1					5.1
Bromus	2.35			14.5				14.5
Polygonum	2.5	1.45				1.45		2.9
Elymus	3.0						6.0	6.0
Fumaria	3.3	3.2						3.2
Prunella	3.6	4.3						4.3
Allium	4.27				4.3			4.3
Geum	5.0		1.4					1.4
Veronica	5.0						150.0	150.0
Avena	8.0					43.3	28.9	72.2
Galium	8.0	14.5					21.8	36.3
Triticum	10.0	29.0	80.0	30.0	27.0	77.0	72.0	315.0
TOTAL WEIGHT KG/HA		179	140	44.5	31.3	167	311	872
AVERAGE WEIGHT KG/HA								145

FIELD CODES: H1, H2 = Home Farm Pigeon Pit and Nurseries
HC1, HC2 = Horsecroft Farm 1 and 2
LP1, LP2 = Leaden Porch Farm

Appendix 23b Summary

Table of Means (Seeds > 0.35 mg) Log_{10}[(seed count)+0.5]/10 m^2

Organic	Conventional	SED
5.1	4.72	0.64

"($F_{1,8}$ =0.36 P= 0.566)"

Appendix 24a Diversity of Plant Counts. Sept 1992 and 1993 Shannon Wiener.

Organic								
Field		1992				1993		
		H	*H* Max	*E*		*H*	*H* Max	*E*
H1		3.48	4.1	0.86		3.3	4.18	0.81
H2		3.08	3.82	0.83		3.66	4.1	0.91
HA1		3.53	4.01	0.86		3.64	4.01	0.96
HA2		3.48	4.1	0.87		3.21	3.82	0.86
CH1		N/A	N/A	N/A		2.85	3.01	0.95
CH2		N/A	N/A	N/A		3.13	3.71	0.87

Conventional								
Field		1992				1993		
		H	*H* Max	*E*		*H*	*H* Max	*E*
H1		1.67	2.59	0.72		1.78	2.59	0.76
H2		2.05	2.33	0.88		1.11	1.59	0.699
HO1		0.68	1.59	0.67		0.78	1.59	0.77
HO2		Population too small				Population too small		
LP1		N/A	N/A	N/A		1.25	1.59	0.78
LP2		N/A	N/A	N/A		2.42	2.59	0.93

Field Codes:

Organic
H = Home Farm
HA = Hawstead Place
CH = Cold Harbour Farm

Conventional
H = Home Farm
HO = Horsecroft
LP = LeadenPorch

Appendix 24b Williams' Alpha Diversity Index Plant Counts

Organic							
Field	1992				1993		
	alpha	SE	Z		alpha	SE	Z
H1	4.7	1.35	3.58		4.5	1.21	4.04
H2	2.5	0.74	5.6		4.2	1.16	4.05
HA1	4.6	1.22	4.1		4.2	1.21	3.82
HA2	4.6	1.34	3.51		2.8	0.84	4.95
CH1	N/A	N/A	N/A		2.4	1.02	3.29
CH2	N/A	N/A	N/A		2.9	0.91	4.47
Conventional							
Field	1992				1993		
	alpha	SE	Z		alpha	SE	Z
H1	1.4	0.66	4.24		1.4	0.66	4.22
H2	1	0.51	4.92		0.6	0.39	4.92
HO1	0.9	0.58	3.52		0.5	0.35	5.48
HO2	0.4	0.35	4.51		2.6	3.38	0.76
LP1	N/A	N/A	N/A		0.6	0.41	4.76
LP2	N/A	N/A	N/A		2	0.96	3.07

Field Codes:

Organic
H = Home Farm
HA = Hawstead Place
CH = Cold Harbour Farm

Conventional
H = Home Farm
HO = Horsecroft Farm
LP = Leaden Porch Farm

Appendix 25 Abundance: Plant Counts

			Conventional			Organic	
Genus	**Species**		**1993**	**1992**		**1993**	**1992**
Achillea	*millefolium*						6
Agrostis	*stolonifera*		4			78	15
Alopecurus	*myosuroides*		205	24		243	81
Anagallis	*arvensis*					12	23
Aphanes	*arvensis*					2	25
Arrhenatherum	*elatius*		10				
Avena			3	56		11	10
Bellis	*perennis*						2
Bromus	*sterilis*		5	2			
Capsella	*b-pastoris*					11	2
Carduus							1
Cerastium	*fontanum*					3	
Chenopodium	*album*					17	
Cirsium	*arvense*		3	4		64	20
Convolvulus	*arvensis*			1			89
Conyza	*canadensis*					9	
Crepis	*capillaris*						1
Elymus	*repens*			22		73	8
Euphorbia	*exigua*					9	
Festuca	*rubra*		2				
Fallopia	*convolvulus*		2			21	2
Fumaria	*officinalis*		2			1	
Galium	*aparine*		4	16		1	2
Hieracium							9
Hordeum				1		1	
Kickxia	*spuria*			1			22
Lolium	*multiflorum*			3			
Lolium	*perenne*					16	34
Matricaria	*matricarioides*						217
Minuartia	*hybrida*						15
Myosotis	*arvensis*					28	
Papaver	*rhoeas*					179	9
Phleum	*pratense*					10	
Plantago	*major*						5

Appendix 25 (cont)

			Conventional			Organic	
Genus	**Species**		**1993**	**1992**		**1993**	**1992**
Poa	*annua*		81	112		11	15
Poa	*trivialis*					7	
Polygonum	*aviculare*		1	1		3	34
Raphanus	*raphanistrum*					1	
Senecio	*vulgaris*		1			8	1
Silene	*alba*					5	4
Sonchus	*arvensis*					2	5
Stellaria	*media*		12	3		44	20
Sisymbrium	*officinale*						3
Sinapis	*arvensis*					2	
Trifolium	*repens*					85	128
Trifolium	*pratense*					139	
Trifolium	*dubium*					24	
Tripleurospermum	*inodorum*					8	2
Urtica						3	1
Veronica	*persica*		2	7		63	55
Veronica	*arvensis*						1
Viola	*arvensis*		89	44		152	274

Table of Means Log_{10}[(plant counts)+0.5]

Organic	Conventional	S.E.D
5.27	4.1	0.385

"($F_{1,8}$ = 9.15 $P<0.02$)"

Appendix 26: Plant Abundance Above Threshold Seed Size

			Conventional			Organic	
GENUS	SPECIES		1993	1992		1993	1992
Plantago	*major*						5
Stellaria	*media*		12	3		44	20
Tripleurosperm	*inodorum*					8	2
Kickxia	*spuria*			1			22
Anagallis	*arvensis*					12	23
Euphorbia	*exigua*					9	
Trifolium	*dubium*					24	
Viola	*arvensis*		89	44		152	274
Veronica	*persica*		2	7		63	55
Trifolium	*repens*					85	128
Festuca	*rubra*		2				
Chenopodium	*album*					17	
Cirsium	*arvense*		3	4		64	20
Trifolium	*pratense*					139	
Alopecurus	*myosuroides*		205	24		243	81
Carduus							1
Fallopia	*convolvulus*		2			21	2
Lolium	*multiflorum*			3			
Lolium	*perenne*					16	34
Polygonum	*aviculare*		1	1		3	34
Arrhenatherum	*elatius*		10				
Elymus	*repens*			22		73	8
Fumaria	*officinalis*		2			1	
Bromus	*sterilis*		5	2			
Hordeum				1		1	
Silene	*alba*					5	4
Avena			3	56		11	10
Galium	*aparine*		4	16		1	2
Raphanus	*raphanistrum*					1	
Convolvulus	*arvensis*			1			89
Hieracium							9
Minuartia	*hybrida*						15

Table of Means $Log_{10}[(\text{plant counts})+0.5]$

Organic	Conventional	S.E.D
4.893	3.730	0.452

"($F_{1,8}$ = 6.63 $P<0.033$)"

Appendix 27 Mean Crop Measurements.

	CONVENTIONAL				ORGANIC		
	1993		1992		1993		1992
%CROP COVER	97.1		90.8		81.6		74.8
%WEED COVER	6		5.3		25.8		29
%BARE GROUND	2.4		3.9		14.5		16.3
CROP POPULATION SHOOTS/ SQ M*	430.4		537		359.7		363.8
CROP HEIGHT M*	0.88		NA		0.8		NA
WEED HEIGHT M*	NA		NA		0.58		NA

* Crop population, crop and weed height measured in only 2 SPs in each transect.

Table of Means

	Org	Con	S.E.D	Significance
%Weed	22.8	4.6	5.02	**
%Crop	79.5	94.3	2.27	***
%Bare	16.1	2.8	2.48	***

Appendix 28 Relative Seed Set Per System.

Species	Conventional			Organic			
	Nos Plants	Nos seeds	Seeds/ plant	Nos Plants	Nos seeds	Seeds/ plant	
Agrostis	4	1	0.25	78	47	0.6	+
Alopecur.	205	51	0.25	243	48	0.1	-
Avena	3	17	5.7	11	0	0	-
Cirsium	3	3	1	64	111	1.73	+
Fallopia	2	0	0	21	0	0	
Fumaria	2	1	0.5	1	0	0	-
Galium	4	5	1.25	1	0	0	-
Poa annua	81	1017	12.55	11	144	13.1	+
Polygon .	1	2	2	3	18	6	+
Senecio	1	0	0	8	22	2.75	+
Stellaria	12	63	5.25	44	31	0.71	-
Veronica	2	29	14.5	63	21	0.33	-
Viola	89	210	2.36	152	28	0.18	-
MEAN			3.51			1.97	