BTO Research Report no. 579

The Influence of Vegetable Production on Farmland Bird Populations

Authors

Gavin M. Siriwardena and Mark F. Hulme

A report by the British Trust for Ornithology
under contract to the Horticultural Development Council

February 2011

British Trust for Ornithology, The Nunnery, Thetford, IP24 2PU
Charity No. 21665

British Trust for Ornithology

The Influence of Vegetable Production on Farmland Bird Populations

BTO Research Report No. 579

Gavin M. Siriwardena and Mark F. Hulme

Published in February 2011 by the British Trust for Ornithology
The Nunnery, Thetford, Norfolk, IP24 2PU, UK

ISBN 978-1-906204-90-7

CONTENTS

Page No.

LIST OF TABLES

Page No.

LIST OF FIGURES

Page No.

1. SUMMARY

There is reason to believe that horticultural cropping provides high quality habitat for a range of farmland bird species, but objective evidence for this has not yet been published. Here, the scientific literature relevant to this issue is reviewed and national bird population data from the BTO/JNCC/RSPB Breeding Bird Survey (BBS) are analysed to look for differences in bird numbers ("abundance"), population trends over time and species diversity between farmland with and without horticultural crops, as indicated by the presence of HDC-registered growers in the local area.

The literature review revealed that a number of the features of vegetable cropping are likely to benefit farmland birds, notably spring-sowing (both direct effects and indirect via the potential for over-wintered stubble/crop residue), more complex crop structure (e.g. compared to cereals) with access for birds to bare ground and smaller crop units with a concomitant increase in crop variability within fields and farms. Farmland birds can, broadly, be divided into those that nest and feed in open fields, those that feed there and nest in hedges and those that feed and nest in hedges. Both of the former two categories have the potential to be affected positively by horticultural cropping.

BBS data from 1994-2009 for 18 bird species that use open field habitats (corn bunting, goldfinch, greenfinch, grey partridge, jackdaw, kestrel, lapwing, linnet, reed bunting, rook, skylark, starling, stock dove, tree sparrow, turtle dove, whitethroat, yellow wagtail and yellowhammer) were analysed, considering only survey areas (1km squares) with 50% or more tilled land by area, comparing areas with HDC-registered farms (identified by postcode) to areas without. The latter were identified as areas within 50km of postcodes with registered HDC growers to ensure that like farmland was compared with like.

Average bird counts differed between HDC and non-HDC survey squares for 17 of the 18 species (not for goldfinch) and were higher in HDC squares for all except jackdaw and starling, two species associated with human habitation and grassland. Formal analyses also showed that population trends over time were more positive on HDC squares for nine species (grey partridge, jackdaw, lapwing, rook, skylark, stock dove, tree sparrow, yellow wagtail and yellowhammer) and more negative for only four species (goldfinch, greenfinch, reed bunting and turtle dove), all of which depend heavily on non-cropped habitats. Comparisons of population trends by eye did not show such clear differences in trends as the formal analyses, but combination of the trends into a version of the Farmland Bird Index confirmed a positive association with horticulture across species.

Differences in abundance and trends between areas in which specific vegetable crops are registered and nearby farmland were less clear-cut, although all crops had more positive associations with the abundance of individual species than negative associations and most species were more often positively than negatively associated with individual crops. However, odd patterns in the results for trends with respect to individual crops and uncertainty over whether registrations of interest in a crop in 2010 is a good indicator of the presence of that crop throughout the period 1994-2009 mean that the results for individual crops should be treated with caution.

There was no detectable effect of horticultural cropping in general or of individual crops on the diversity of all bird species in survey squares. This probably shows a dominating influence of non-cropped habitats on the numbers of species present and that the variations in abundance of open-field species detected, although statistically significant, were actually quite small in absolute size.

Overall, this study shows that areas in which horticultural crops are grown, as indicated by HDC registration in 2010, have been associated with higher abundance and more positive population trends of open-field bird species during 1994-2009. This does not prove a causal link, however, because other features of the areas classified as HDC and non-HDC might also have differed. Although there are theoretical reasons why such differences might be expected, as the literature review reveals, further research is required to confirm that associations with horticultural cropping are due to effects of the crops themselves and not other, correlated factors. In addition, the results here provide no information on best practice for crop management that would maximize the value for birds.

2. INTRODUCTION

Farmland biodiversity has been the subject of considerable conservation concern for more than a decade, notably because of large and continuing declines in bird populations. Despite conservation action aimed at reversing these declines, sustained recoveries have yet to occur and new challenges to the farmland environment, such as the removal of Common Agricultural Policy support for set-aside and increasing pressure on land to produce food and energy, continue to arise. This means that novel ways to promote farmland biodiversity are needed urgently, while also ensuring that farmland retains its primary purpose of food production. The Campaign for the Farmed Environment (www.cfeonline.org) represents one means of doing this, namely through farmers enhancing environmental management on their land, basically through a sense of shared environmental responsibility and peer pressure from the rest of the farming community. Clearly, any other mechanisms that could assist or complement this approach would be valuable and any branch of agriculture that could be shown to provide such a mechanism would be worthy of support and, if appropriate, encouragement towards wider uptake nationally. It has been suggested that horticultural cropping might provide just such a mechanism but, to date, no definitive evidence exists to support this suggestion. This report summarizes research aiming to assess the available evidence base on this subject and investigating the relevant information available from analyses of ongoing national bird survey data.

3. REVIEW: THE LIKELY IMPORTANCE OF VEGETABLE CROPPING FOR FARMLAND BIRDS

Horticultural cropping as a whole covers only a small proportion of the total arable area in the UK and less than half of that at the end of the second world war: 165,000ha in 2007 (down from 360,000ha; Wilson et al. 2009). In the context of more than 4,000,000ha of arable land in England alone, this means that the influence of horticulture on national bird populations must be limited. Even for species like woodpigeon that actually feed on the crops themselves, and can therefore be considered as nuisances or pests, vegetable crops are likely only to have a small influence on wider populations. This does not, however, preclude local-scale benefits and it is also quite possible that the addition of horticultural crops to a landscape dominated by standard arable rotations (or, indeed, pastoral farming) could have positive impacts disproportionate to the area they cover.

To date, the scientific research into the impacts of vegetable farming on birds has been very limited, probably in proportion to its likely importance to national populations. This means that there is little or no information on the particular benefits and disadvantages of specific horticultural crops or specific husbandry practices for bird populations as a whole or for particular bird species. There has been a great deal of research, however, on the general features of crop management that tend to be positive or negative for various farmland bird species. Many such practices are relevant to the horticultural sector and potentially inform about the likely influences of vegetable cropping.

Vegetables are spring crops and are often grown in smaller fields or as smaller patches than major arable crops. Spring cropping promotes farmland bird presence and abundance in two ways. First, it promotes the retention of stubbles or crop residues over the preceding winter, enhancing food availability for many bird species through spilled crop seed, weed seed and/or invertebrates supported by crop litter (e.g. Evans et al. 1994, Gillings et al. 2005, Gilroy et al. 2010). Such uncropped winter fields provide better feeding habitat than ploughed fields or fields sown with winter crops for most species and their presence may be sufficient to turn locally declining into stable populations (Gillings et al. 2005). Second, spring crops are at earlier stages of growth than winter crops throughout the growing season. This means that they add heterogeneity in vegetation structure and, critically, provide a relatively open structure compared to winter crops in mid-/late summer, allowing access to bare ground (i.e. food and nest sites) for birds like skylark. This means that skylarks and yellow wagtails benefit from being able to make late season nests in vegetable fields, having made earlier nesting attempts in winter crops (Wilson et al. 1997, Donald 2004, Gilroy et al. 2009). Further, these additional breeding attempts could be critical to allow local populations to produce enough young to be self-sustaining (Wilson et al. 1997, Siriwardena et al. 2001).

The simple presence of vegetable crops in a landscape dominated by the common arable crops will provide habitat heterogeneity. As a general rule, the smaller the scale at which crops or other habitats vary, the better for birds. This is because greater variation within, say, a bird's potential territory area, increases the likelihood that food resources or nesting cover will be present at all times (e.g. Fahrig et al. 2011). The presence of strips of bare ground within and at the edge of vegetable crops that allow access for crop management and harvest provides further local heterogeneity and another potential benefit for birds at the scale of individual territories. Thus, individual birds may find everything they need within smaller territories and local abundance may therefore be higher. In addition, more species may be supported by a given farmed area. A caveat to these general effects of cropping heterogeneity and field size is that different species respond differently to field boundary structure: open field species such as skylark tend to avoid vertical structures (Donald et al. 2001, Donald 2004) but to select areas with more diverse cropping in their absence (Schläpfer 1988). Species that use hedges for nesting or as perches for singing or refuge from predators tend to show the opposite response to hedge structure, as would be expected (e.g. Green et al. 1994), but may well also respond positively to increased in-field heterogeneity.

Farmland birds fall into two broad categories: (i) birds that depend, at one or more times of year, on habitat features that are only found in cropped land and (ii) birds that are found in farmland but depend on peripheral areas not directly involved in production. The latter are typically birds that are found in hedges, such as dunnock, chaffinch and robin. Species like this are unlikely to respond strongly to vegetable cropping. The former set of species, however, are those that horticulture has the potential to affect. Not all effects will be positive, because some species may prefer features of conventional arable cropping (e.g. the dense vegetation and rich source of potential insect food provided by oilseed rape: e.g. Burton et al. 1999), but there are various potential positive influences, as described above.

In fact, there are rather few bird species in Britain that depend entirely on field centre, i.e. cropped, habitats, especially in the breeding season. However, some of these species are among the most iconic "farmland birds", such as skylark, corn bunting and grey partridge, although even the latter typically nest in dense, herbaceous field boundary vegetation, rather than in crops themselves (Potts 1986). Other field centre species include Montagu's harrier, stone curlew and corncrake (reviewed in Wilson et al. 2009), which are all now extremely rare and localized in their distributions in the UK and each unlikely therefore to receive significant benefits from similarly localized vegetable cropping. Montagu's harriers might benefit from the greater penetrability of spring-sown vegetables compared to winter cereals, for example, but their small mammal prey is likely to avoid exposure in vegetable crops, so any such benefit is unlikely to be large.

Of more common species, reed bunting and whitethroat are two that have begun to nest in crops in recent years, but only in the exceptionally dense cover provided by mature oilseed rape (Burton et al. 1999). Horticultural crops are unlikely to provide such a resource for these species. Corn bunting is a formerly common species that prefers open field habitats but, as its name suggests, selects cereal fields (as well as weedy field margin habitats; Donald & Evans 1994, 1995; Hartley & Shepherd 1994). Skylark, lapwing and yellow wagtail are probably the farmland species that are both found only in open fields and likely to respond positively to vegetable farming.

Lapwings prefer to nest on sparsely vegetated ground that gives them some cover, but also wide visibility and access to bare ground, on which they forage for large invertebrates on or close to the soil surface (Barnard & Thompson 1985). Spring-sown vegetable crops therefore provide this species with exactly the habitat it needs for breeding, especially later in the season. Crop heterogeneity is also likely to benefit lapwings because the chicks leave the nest early and move to areas of denser cover; predominantly bare ground leaves them too exposed to predators. Such habitat combinations were commonly found in mixed farming in the past, with chick-rearing habitat being provided by grassland and nesting habitat by arable (Galbraith 1988), but such habitat juxtapositions have become much rarer with the decline in mixed farming. Thus, small fields of vegetables in a predominantly winter-sown landscape could have a clear benefit in habitat suitability for lapwing.

Skylarks and yellow wagtails are likely to benefit from vegetable cropping for the reasons described briefly above: late season breeding attempts are made possible by later-harvested spring crops and the more open vegetation structure that they provide (Wilson et al. 1997, Donald 2004, Gilroy et al. 2009), as well as general benefits from habitat heterogeneity increasing the range of foraging opportunities available.

Despite the small number of species that depend *entirely* on in-field habitats, many other species use them only for feeding, in winter, summer or both. For finches and buntings such as goldfinch and yellowhammer, different food resources are likely to be important in different seasons: seed in winter and invertebrates in the breeding season (Wilson et al. 1999). Vegetable crops have the potential to improve the availability of both, in winter through the presence of weed or crop seeds on the soil surface or just below it in a crop stubble that precedes a spring crop and, in spring, through access to bare ground in a sparse crop structure or the microclimates created by broadleaved plants that promote soil moisture and provide habitats for invertebrates. The latter is also likely to benefit thrushes, dunnock and wagtails, both in the breeding season and later in the year, if crops or crop residues are left in place.

A caveat to the potential benefits of vegetable cropping summarized above is that benefits are always likely to be affected by crop husbandry. For example, if applications of broad-spectrum pesticides or herbicides on vegetable crops are more frequent than on conventional arable crops, any benefits of access to bare ground for foraging might be counteracted by a reduction in the invertebrate or weed seed food resources present. Similarly, if fields need to be ploughed earlier to prepare a seed bed suitable for a vegetable crop, this would remove all of the winter benefits of adding spring cropping to a rotation. Finally, an additional caveat is that there can clearly be conflicts between birds and vegetable cropping, for example with species like woodpigeon potentially causing economically significant damage to crops and introducing a need for control or scaring measures. These measures could discourage the use of vegetable fields by species of conservation interest as well as the problem birds.

Overall, therefore, there is reason to believe that vegetable cropping might provide better habitat than conventional arable cropping and might therefore be associated with higher abundance and/or more positive population trends for a range of farmland bird species. The limited scale of these crops in the UK and uncertainties around the precise benefits of the practices associated with growing them mean that specific study is required to measure the effects on birds in practice. This project provides an initial investigation of this using existing survey data held by the BTO.

4. DATA SOURCES

Data on bird populations come from the BTO/JNCC/RSPB Breeding Bird Survey, which has collected data on terrestrial bird populations across the whole of the UK since 1994 (Risely et al. 2010). Each year, a random sample (stratified by observer density) of over two thousand 1km national grid squares is surveyed by skilled volunteer observers. Birds are recorded in distance bands (0-25m, 25-100m and 100m+) from two 1km transects on each of two visits each year: one between 1 April and 15 May and a second between 16 May and 30 June. Data from 1994 to 2009 were extracted from the BBS archives for 18 key farmland bird species that make frequent use of open field habitats: corn bunting, goldfinch, greenfinch, grey partridge, jackdaw, kestrel, lapwing, linnet, reed bunting, rook, skylark, starling, stock dove, tree sparrow, turtle dove, whitethroat, yellow wagtail and yellowhammer. BBS squares dominated by arable land-use (>50% cropped land as determined by the Centre for Ecology and Hydrology Land Cover Map 2000) were then selected from the complete data set.

Areas with vegetable cropping were identified by the first half of growers' postcodes (XXnn, where "X" denotes a letter and "n" a number), provided by HDC. These postcodes were also divided by the various crop types in which growers had registered interest in 2010, making crop-specific analyses of the BBS data possible. It is important to note that the rest of this report assumes that the distribution of HDC-registered growers is an accurate representation of the distribution of both vegetable growing as a whole and the specific vegetable crops considered. If significant vegetable cropping occurs outside postcode areas with HDC members or a significant proportion of the postcodes registered as being interested in specific crops (or, indeed, vegetable cropping as a whole), the validity of the analyses presented and, therefore, the conclusions reached, would be questionable. A similar caveat applies to the availability of only 2010 HDC registrations to define areas. If there have been significant changes in the geographical distributions of vegetable crops since 1994 such that classifications of postcodes as "HDC" or "non-HDC" from 2010 (see below) might not be an accurate representation of where vegetables were grown in previous years, the validity of the results would again be in doubt.

The geographical distribution of postcodes in Britain was taken from the "Code-Point Open" data set supplied by the Ordnance Survey (www.ordnancesurvey.co.uk/opendata).

5. METHODS

Each arable-dominated BBS 1km square was assigned its nearest postcode by plotting the locations of both data sets in the ArcMap 10 GIS software package (ESRI 2008). All BBS squares with HDC postcodes were then classified as "HDC squares". Buffers of radius 50km were then drawn around the centroid point of the area covered by each postcode. The overlaps between these buffers and other postcode centroids identified postcodes that are within 50km of HDC postcodes. These postcodes were then filtered to identify those that do not include HDC-registered farms themselves. BBS squares falling within the latter "non-HDC postcodes" were then classified as "non-HDC squares". All this produced a data set of BBS squares for analysis consisting of squares within HDC areas and those near HDC areas but without local HDC cropping, i.e. like-with-like farmland datasets with and without registered horticulture. This ensured that the non-HDC sample of BBS squares was comparable with the HDC one in terms of broad landscape and soil type. In practice, only six arable-dominated BBS squares were not within 50km of an HDC postcode, so the data analyses included squares covering all arable farmland in Britain.

The same square classification procedure was followed for each individual vegetable crop type, producing data sets of BBS squares from postcodes where that crop was registered with the HDC and squares from different postcodes that were less than 50km away from such areas, the latter possibly also having registered HDC farms, but not farms with an interest registered in the specific crop type concerned.

Three types of analysis were conducted: abundance, trends and diversity. Abundance analyses compared mean counts for each species between HDC and non-HDC squares, trend analyses compared long-term population trends (fitted as quadratic functions of year to allow for curvilinear patterns of change, i.e. not assuming that changes have been linear) and diversity analyses compared Simpson's diversity index values drawn across 50 species found on farmland (including non-farm-specialists and species too rare to be analysed individually). The latter is a standard index measuring the number of species present and the evenness with which the total number of individuals present is spread amongst those species.

All analyses were conducted using generalized linear models in SAS (SAS Institute, Inc. 2008), using a repeated measures approach to allow for inter-annual correlations in counts on the same square where appropriate.

6. RESULTS

6.1 Sample sizes

The numbers of BBS 1km squares used in the analyses are shown in Table 6.1. Note that not all squares had records of all species and that most squares were not covered in all the years of the analyses (although this is accounted for by the analytical methods used).

Table 6.1 Sample sizes. "HDC squares" shared a postcode with a registered HDC grower (or, for individual crops, with a grower who had registered that specific crop). "Non-HDC squares" were those within 50km of an HDC postcode but with no registered HDC grower (or no registration of the specific crop) in their own postcodes.

Crop	HDC squares	Non-HDC squares
All HDC	773	1150
Aliums	313	1599
Asparagus	139	1652
Brassicas	277	1635
Bulb Onions	235	1535
Cucurbits	174	1484
Edible Herbs	172	1562
Legumes	254	1624
Propagated	154	1610
Salad	238	1643
Umbellifers	255	1586

6.2 Abundance in HDC and non-HDC squares

Mean bird counts differed significantly between HDC squares and nearby arable-dominated squares for 17 of the 18 species considered and 15 of these differences were positive, i.e. counts were higher in HDC squares (Table 6.2, shown graphically in Figure 6.1). The differences varied from a marginal one for the relatively rare, range-restricted tree sparrow (only found in a small number of squares, hence the low mean counts), to a difference of 1.71 counted individuals for skylark (Table 6.2). HDC squares featured significantly lower average counts only for jackdaw and starling (Table 6.2). Note that the figures in Table 6.2 do not represent total local populations; they are just the average numbers of birds seen by observers on their standardized survey routes and almost certainly represent underestimates of real populations. Nevertheless, they should be broadly proportional to local populations, given that habitats do not differ appreciably between the habitat types.

Considering individual crops, there was more variation in the patterns of variation in bird counts, with a greater proportion of negative results, i.e. of lower counts in HDC squares, but the balance was in favour of higher counts in HDC squares for all crop types (Table 6.3). However, this overall pattern masks rather equal balances of positive and negative patterns across species for Aliums and Brassicas (Table 6.3). In addition, there were uniformly negative associations with HDC registration for starling, tree sparrow and jackdaw, and preponderances of negatives for yellowhammer, tree sparrow and rook (Table 6.3). Conversely, however, the patterns were uniformly positive for corn bunting, goldfinch, grey partridge, lapwing, reed bunting, skylark, stock dove, turtle dove, whitethroat and yellow wagtail, as well as being predominantly positive for linnet (Table 6.3).

Table 6.2 Average bird counts in HDC versus non-HDC squares. Predicted counts are averaged across all years in which BBS squares were surveyed between 1994 and 2009 and the test results refer to the difference between the predictions for the two categories of survey square.

Species	Predicted average counts			Score test χ^2_1	P
	HDC Squares	Non-HDC Squares	Difference		
Corn Bunting	0.52	0.26	0.26	722.9	<0.001
Goldfinch	2.84	2.89	-0.04	2.7	0.099
Greenfinch	3.28	3.22	0.06	4.2	0.042
Jackdaw	5.09	5.82	-0.73	390.0	<0.001
Kestrel	0.43	0.39	0.04	14.6	<0.001
Lapwing	2.21	1.85	0.36	265.6	<0.001
Linnet	3.61	3.26	0.35	143.0	<0.001
Grey Partridge	0.49	0.27	0.22	508.2	<0.001
Reed Bunting	0.67	0.44	0.23	382.5	<0.001
Rook	14.34	13.56	0.78	175.5	<0.001
Skylark	7.19	5.48	1.71	1879.8	<0.001
Stock Dove	1.73	1.23	0.50	683.6	<0.001
Starling	8.81	9.76	-0.95	390.3	<0.001
Turtle Dove	0.36	0.15	0.21	738.7	<0.001
Tree Sparrow	0.37	0.35	0.02	6.7	0.017
Whitethroat	2.42	2.06	0.36	234.5	<0.001
Yellowhammer	3.64	3.14	0.51	306.8	<0.001
Yellow Wagtail	0.52	0.24	0.28	887.1	<0.001

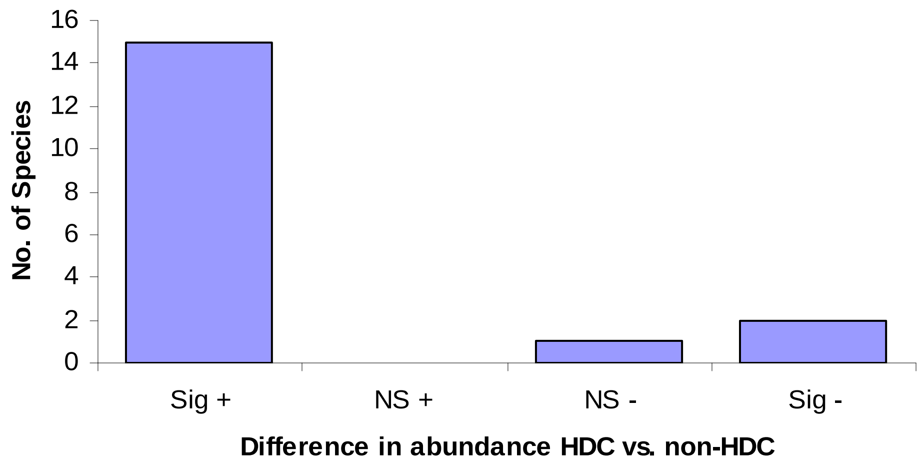


Figure 6.1. Summary of positive and negative associations (Table 6.2) of farmland bird abundance with HDC cropping across species.

6.3 Population trends in HDC and non-HDC squares

Considering simplified, quadratic population trends, nine species showed significantly more positive population trends on HDC squares than on non-HDC squares, while only four showed significantly more negative trends (Table 6.4, summarized graphically in Figure 6.2). The other species either did not differ significantly in trend between the two sets of squares or showed no clear overall effect (modelled linnet and starling: trends tended to rise and fall in one category and to fall and rise in the other, with no net difference).

That real trends are actually much more complex than simple quadratic functions is shown clearly in Figure 6.2: the differences in actual abundance between HDC and non-HDC squares are much less obvious and there are rather small differences between the two trends for many species. This does not affect the validity of the comparisons of quadratic trends in Table 6.4, however, because the latter summarize all the data and are unbiased, having the potential to reveal patterns that are not obvious to the human eye. This is supported by calculation of an average trend, equivalent to the Farmland Bird Index (but omitting woodpigeon, which was not considered in this study), from the real population trends in Figure 6.3: there was a clear divergence between HDC and non-HDC farms, with much higher average index values in HDC squares in recent years (Figure 6.4).

Considering individual crops revealed a pattern across species that is difficult to explain: 126 of the 180 crop- and species-specific statistical tests conducted gave rise to a statistically significant result at the 5% level or less (Table 6.5), but all of the patterns indicated were for more positive trends in non-HDC squares, similar to that shown for skylark and squares with and without Alium growers in Figure 6.6. It is highly unlikely that this pattern reflects real biological variation and it is more likely to be due to geographical biases in the sets of grower postcodes to which these crops were registered in 2010, so these results are not discussed further.

Table 6.3 Summary of the average bird counts in HDC versus non-HDC squares, considering individual crops. Empty cells in the table show where there was no detectable difference between squares in HDC areas with the relevant crop, while plus signs show significantly positive differences (higher counts with the specific HDC management) from Score χ^2 tests and minus signs significantly negative differences. Results were derived from data for all years in which BBS squares were surveyed between 1994 and 2009 and the test results refer to the difference between the predictions for the two categories of survey square.

Species	Sign of Difference									
	Aliums	Asparagus	Brassicas	Bulb Onions	Cucurbits	Edible Herbs	Legumes	Propagated	Salad	Umbellifers
Corn Bunting	+	+	+	+	+	+	+	+	+	+
Goldfinch		+							+	+
Greenfinch	-		-	-			+			-
Grey Partridge	+		+	+		+	+	+	+	+
Jackdaw	-	-	-	-	-	-	-	-	-	-
Kestrel										
Lapwing	+		+	+		+		+		+
Linnet	-	+	+		+	+				
Reed Bunting	+		+	+	+	+	+	+	+	+
Rook	-	+	-	-	-	-	-	+	-	+
Skylark	+	+	+	+	+	+	+	+	+	+
Starling	-		-	-	-	-	-	-	-	-
Stock Dove	+	+		+	+	+		+		
Tree Sparrow	-			-	-			-		
Turtle Dove	+	+		+	+		+			+
Whitethroat		+		+	+	+		+		+
Yellow Wagtail	+	+	+	+	+	+	+	+	+	+
Yellowhammer	-	-	-	-	-		-			+
Total + by crop	8	9	7	9	8	9	7	9	6	11
Total - by crop	7	2	5	6	5	3	4	3	3	3

Table 6.4. Significance and broad direction of population trends in HDC and non-HDC squares. Population trends were modelled as quadratic (simply curvilinear) functions of year and the statistical results show the significance of the differences between the trends between the two categories of square. Where these tests were significant, the "difference" is reported as a plus if the trend was more positive on HDC squares and as a minus if the HDC squares trend was more negative. "()" is shown where the trends were different in shape but there was no clear resulting difference in terms of overall population consequences (i.e. the simplified quadratic population trends tended to start and end at the same points, but to show different patterns in between: one increasing and then declining, one declining and then increasing).

Species	Difference	χ^2_2	P
Corn Bunting		1.7	0.418
Goldfinch	-	68.4	<0.001
Greenfinch	-	20.0	<0.001
Grey Partridge	+	6.9	0.051
Jackdaw	+	8.9	0.012
Kestrel		1.7	0.421
Lapwing	+	190.9	<0.001
Linnet	()	34.7	<0.001
Reed Bunting	-	8.9	0.012
Rook	+	271.8	<0.001
Skylark	+	34.5	<0.001
Starling	()	197.9	<0.001
Stock Dove	+	37.0	<0.001
Tree Sparrow	+	21.4	<0.001
Turtle Dove	-	19.4	<0.001
Whitethroat		3.4	0.187
Yellow Wagtail	+	18.6	<0.001
Yellowhammer	+	53.2	<0.001

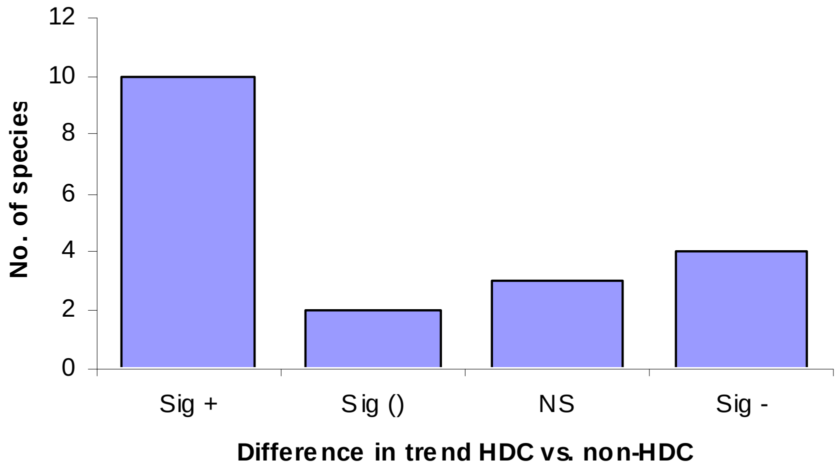
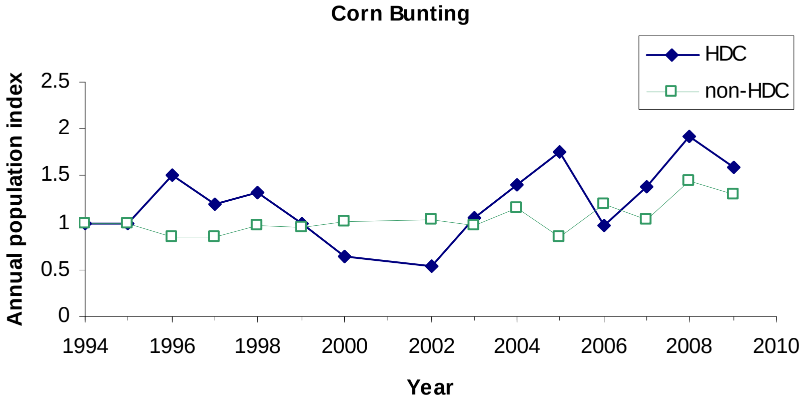
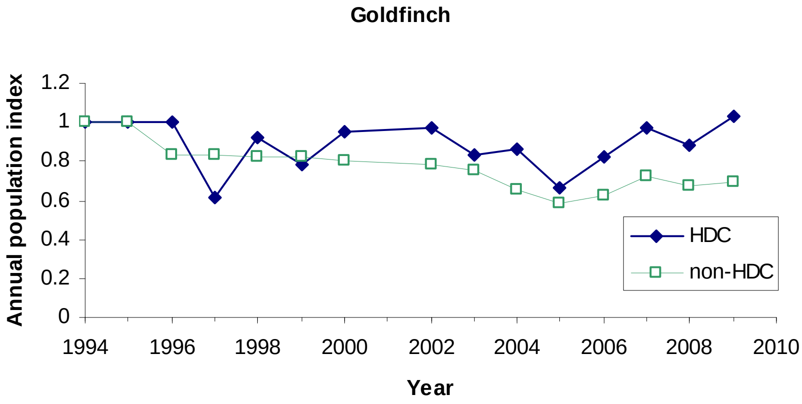
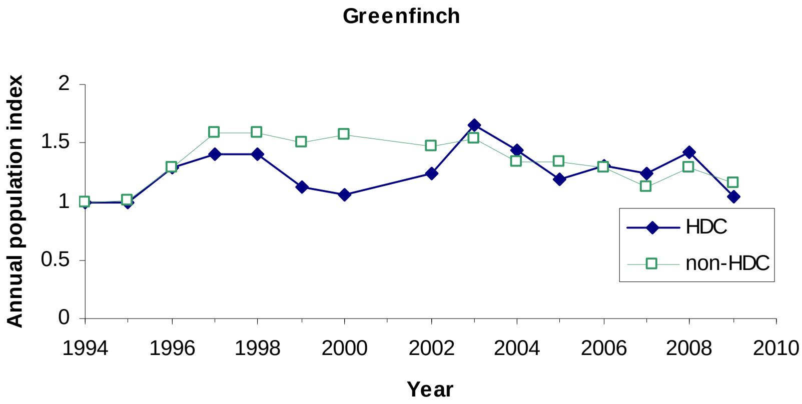


Figure 6.2. Graphical summary of differences in patterns of population change between HDC and non-HDC squares (Table 6.4). "Sig" denotes significant differences, "+" a positive association with HDC cropping, "-"a negative one and "()" no net effect.

Figure 6.3, part 1







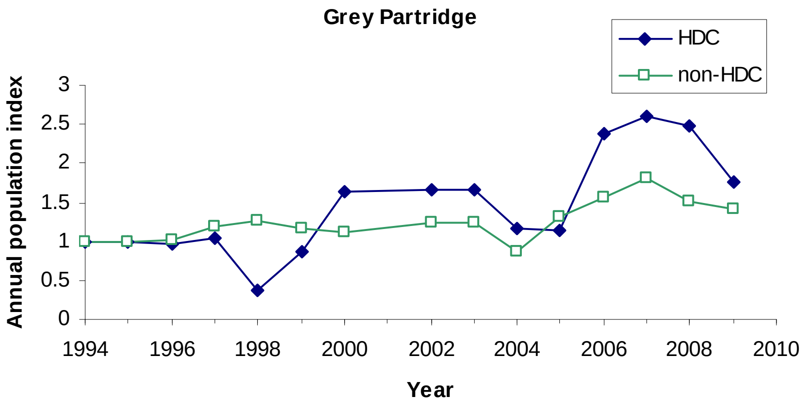
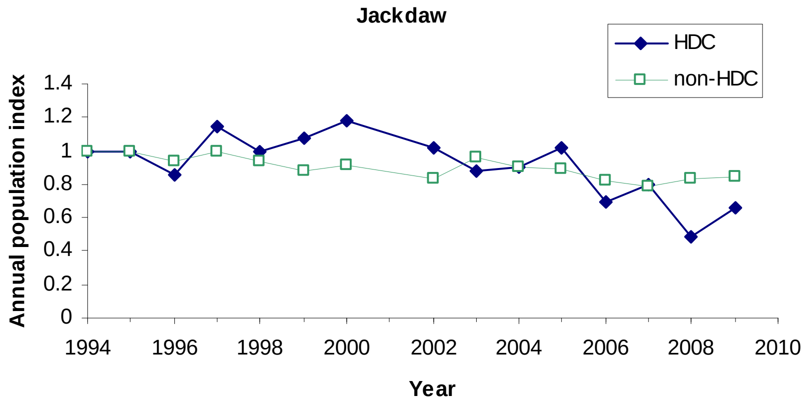
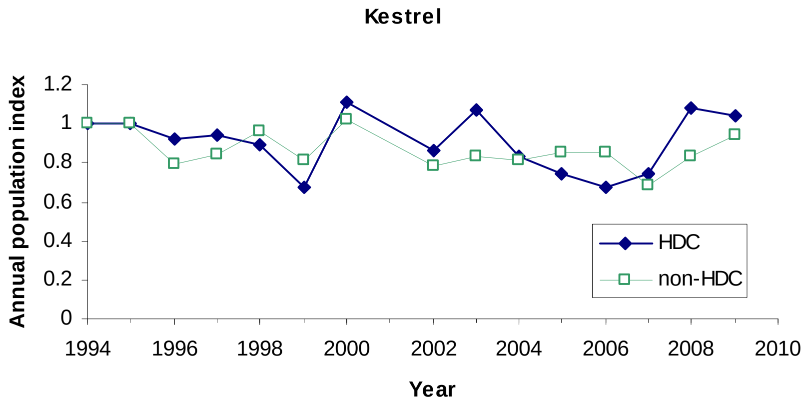
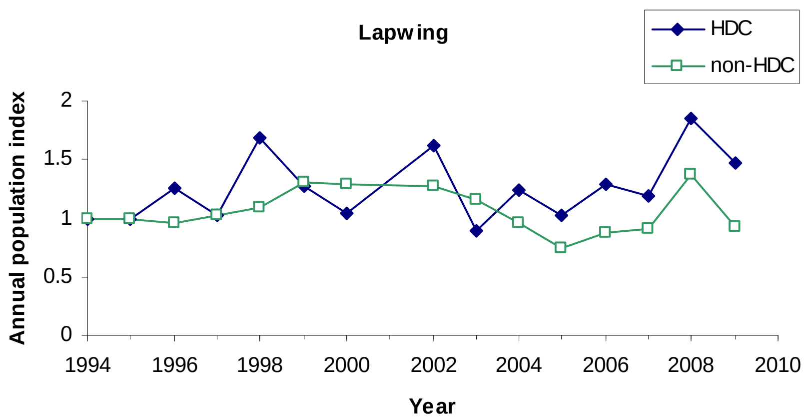


Figure 6.3, part 2







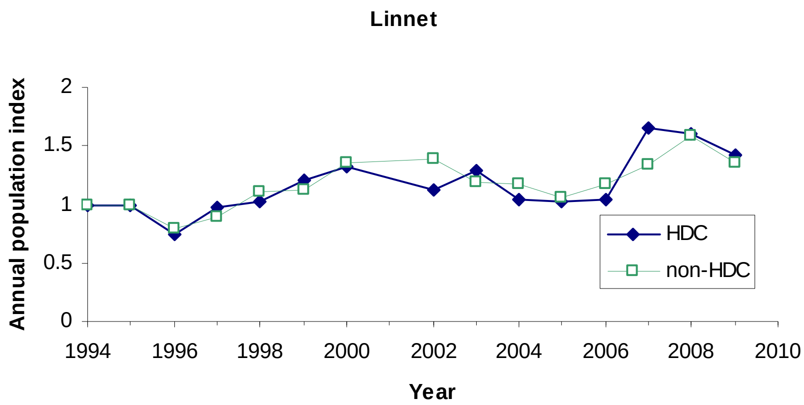
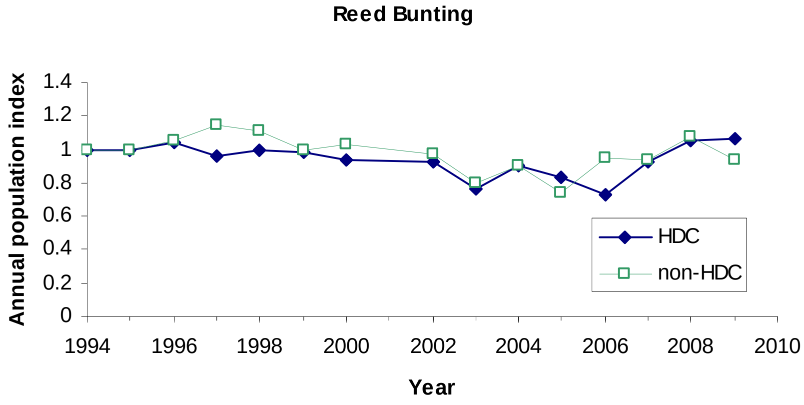
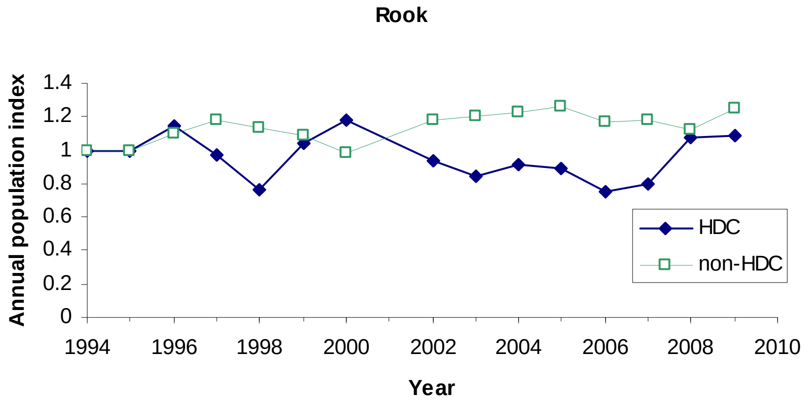
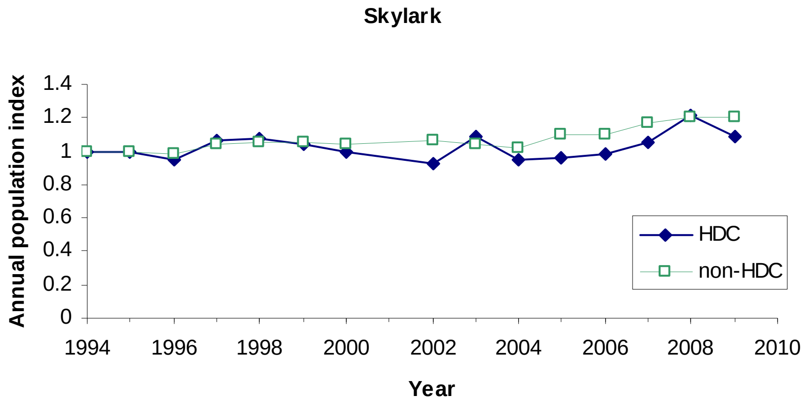


Figure 6.3, part 3







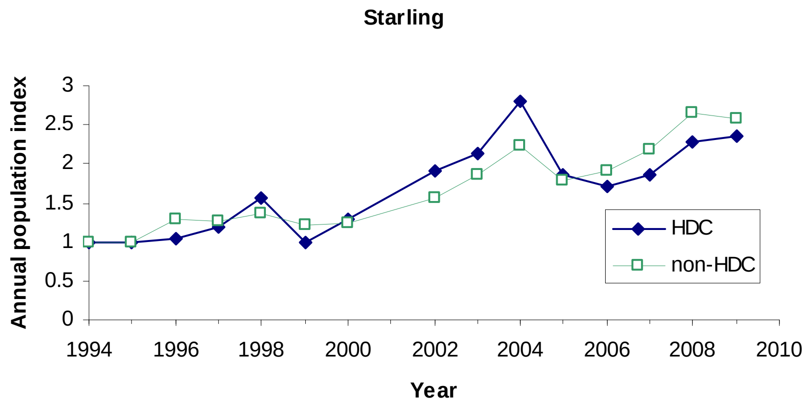
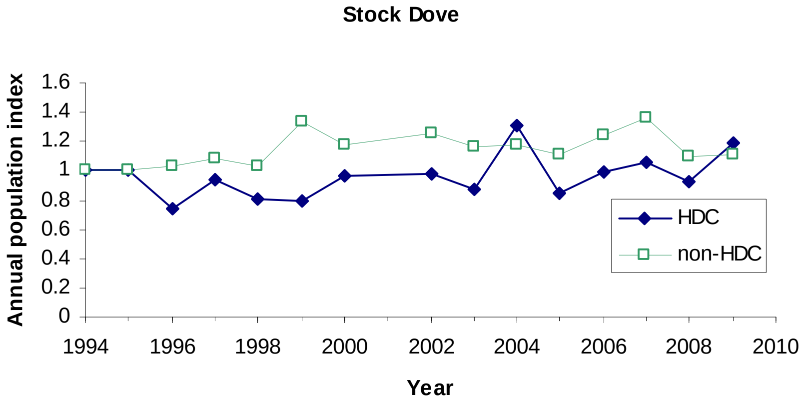
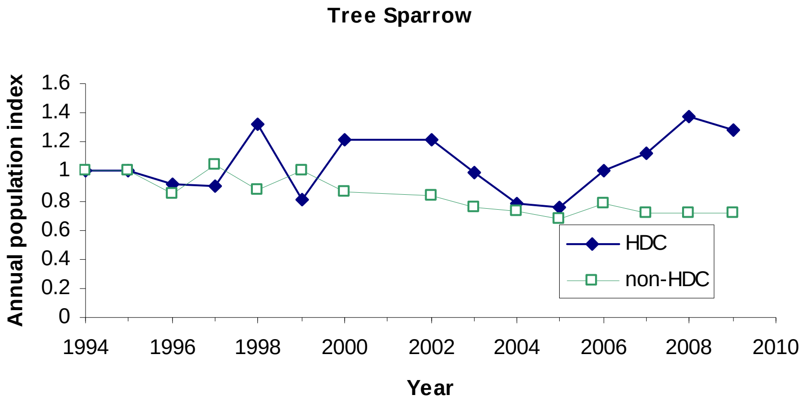
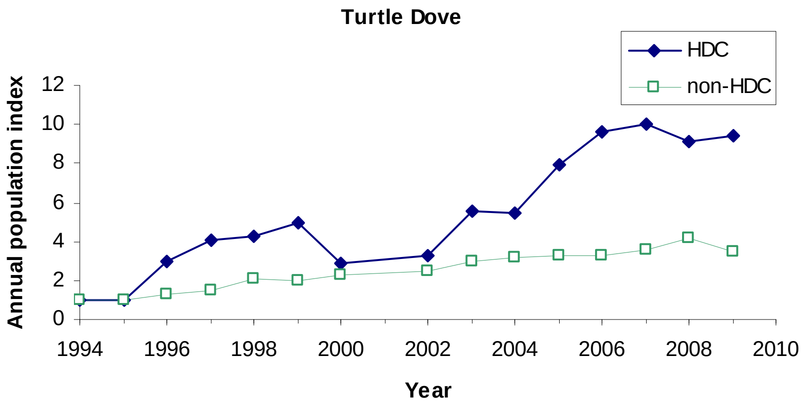
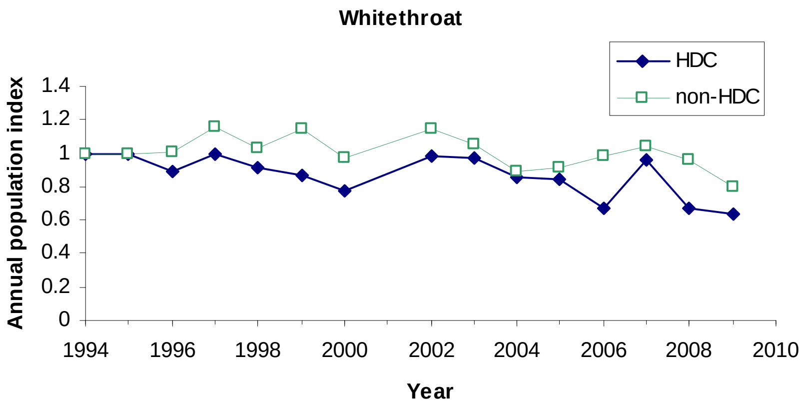


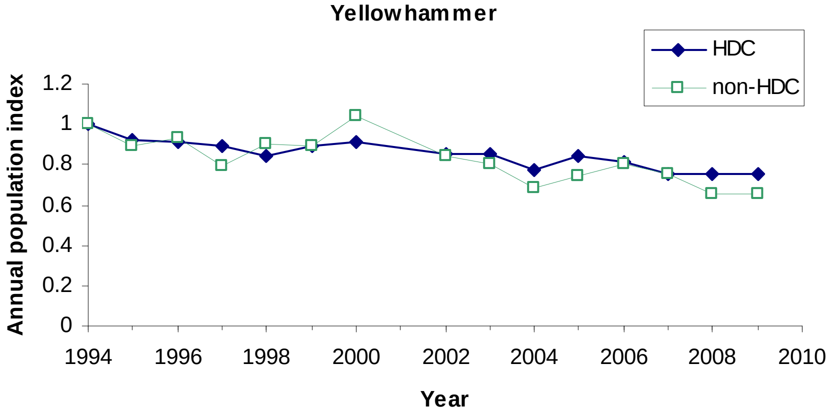
Figure 6.3, part 4











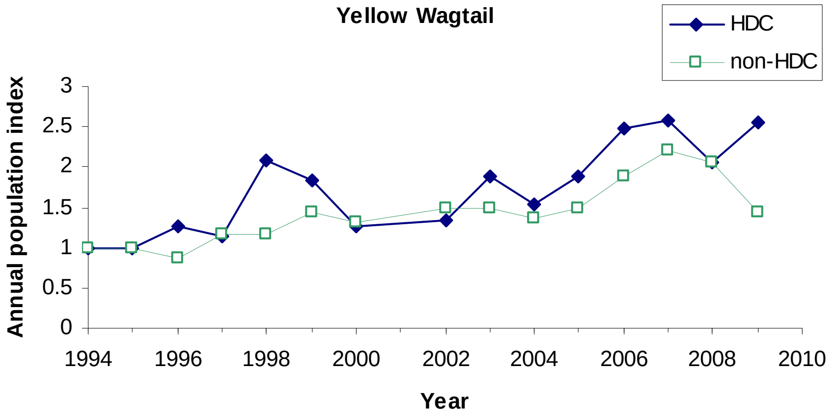


Figure 6.3. Population trends on HDC and non-HDC squares. Graphs show annual indices of abundance standardized to begin at a value of one in 1994. There were statistically significant differences between the indices for HDC and non-HDC squares for all species except whitethroat and kestrel.

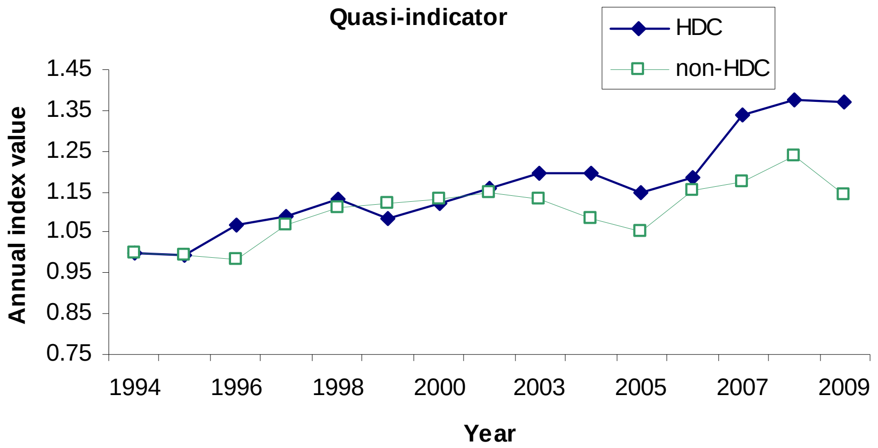


Figure 6.4. Summary of the 18 population trends in Figure 6.1 as an average trend equivalent to the Farmland Bird Index, spilt between HDC and non-HDC squares.

Table 6.5. Summary of the significance of differences between quadratic trends in farmland bird abundance, considering squares with and without registrations of specific horticultural crops. Test results (from likelihood-ratio tests) are presented simply with asterisks representing the level of significance of the difference between the trends in the two sets of squares. All the differences were negative (more negative trends in HDC squares than elsewhere).

Species	Significance for individual crops and species: * P<0.05, ** P<0.01, *** P<0.001									
	Aliums	Asparagus	Brassicas	Bulb Onions	Cucurbits	Edible Herbs	Legumes	Propagated	Salad Vegetables	Umbellifers
Corn Bunting	*	**	***	**			*	***		***
Goldfinch	***	***	***	*	***	***	***	***	***	***
Greenfinch		*		**	*	***		***		
Grey Partridge	*			***	***				**	
Jackdaw		**	**		***	***	***	***	**	***
Kestrel					*					
Lapwing	***		***	***	***	***	***	***	***	***
Linnet	***	***	**	***	**	**		**	*	***
Reed Bunting		**	*				*	*	*	**
Rook	***	***	***	***	***	***	***	***	***	***
Skylark	**	**	***	*		***	**	***	***	**
Starling	***	***	***	***	***	***	***	***	***	***
Stock Dove	***	***	***	***	*	**	**	***	**	***
Tree Sparrow	***	**		***	*	*	*		***	
Turtle Dove		*						*	***	
Whitethroat									**	**
Yellow Wagtail	**		***	***	***	***	*	**	***	***
Yellowhammer	**		***			***	*	***	***	**

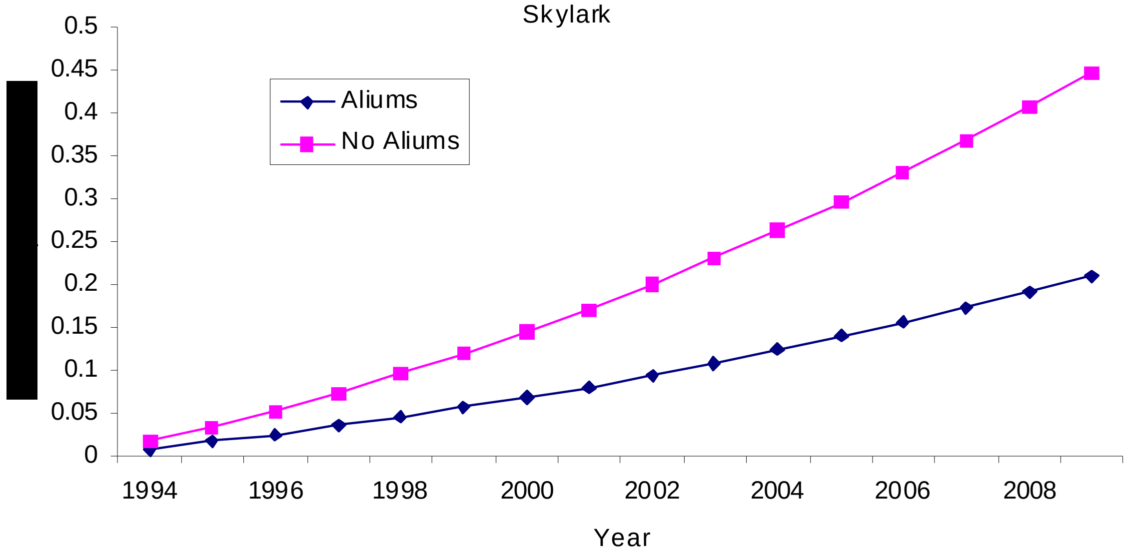


Figure 6.6. Modelled quadratic population trends for HDC squares with growers who had registered Aliums and other nearby squares. The patterns for squares with and without crops were similar for all other crops and species.

6.4 Diversity

Although there was a trend for higher species diversity in HDC BBS squares, this failed to reach statistical significance (P=0.194; Table 6.6). There were also no significant differences in diversity when squares within and outside areas with specific HDC crops were considered (Table 6.6), although it should be noted that statistical power was lower for these tests because fewer survey squares were involved (Table 6.1).

Table 6.6. Average diversity index values for HDC and non-HDC squares, together with score test χ^2 results of the differences, for HDC farming as a whole and for each crop individually.

Crop		Diversity Index	SE	Score χ^2_1	P
All HDC	non-HDC	11.06	0.09	1.68	0.194
	HDC	11.26	0.12		
Aliums	non-HDC	11.14	0.08	0.01	0.916
	HDC	11.12	0.18		
Asparagus	non-HDC	11.18	0.08	0.46	0.498
	HDC	10.99	0.27		
Brassicas	non-HDC	11.16	0.08	0.81	0.367
	HDC	10.97	0.21		
Bulb Onions	non-HDC	11.12	0.08	0.46	0.499
	HDC	11.27	0.21		
Cucurbits	non-HDC	11.10	0.08	0.34	0.557
	HDC	11.25	0.24		
Edible Herbs	non-HDC	11.15	0.08	0.07	0.785
	HDC	11.22	0.26		
Legumes	non-HDC	11.14	0.08	0.37	0.545
	HDC	10.99	0.23		
Salad	non-HDC	11.16	0.08	0.01	0.939
	HDC	11.14	0.23		
Propagated	non-HDC	11.15	0.08	0.74	0.389
	HDC	10.90	0.28		
Umbellifers	non-HDC	11.16	0.08	0.39	0.531
	HDC	11.02	0.21		

7. DISCUSSION

The results of this project suggest that both the abundance and the population trends of farmland birds that use field centre habitats are positively associated with the incidence of horticultural cropping near BBS squares, but that the wider species diversity of the farmland bird community is unaffected. These patterns are not uniformly positive, there being a few negative associations as well as positive ones, but the balance of effects across species was for positive effects. When specific crops were considered, however, the patterns were much less clear and some odd results tend to suggest that the crop-specific classifications of growers, and therefore BBS squares, may not be reliable.

Considering effects on bird abundance alone, most species were clearly more common in squares near to HDC growers. The species that were negatively associated with HDC cropping were jackdaw and starling, both of which are species associated with human habitation and grassland rather than tilled land, so this result probably reflects a general avoidance of the areas where horticultural cropping occurs. The failure of the general pattern for higher abundance in HDC squares to be reflected in an effect on diversity across all farmland birds probably reflects an overriding influence of non-field centre species, which are less affected by in-field management, especially in terms of simple species' presences.

Long-term population trends are affected by many factors, of which in-field habitat quality is just one. This is reflected in the complex variations in abundance over time visible in Figure 6.3. Nevertheless, there was a predominantly positive association between overall population trends and nearby HDC cropping when the difference was tested formally (Figure 6.2). Positive associations with HDC cropping included grey partridge, lapwing, skylark, yellowhammer and yellow wagtail, some of the most farmland-specialist and in-field associated species considered, while negative associations included greenfinch, goldfinch, reed bunting and turtle dove, all species that are strongly associated with non-farmland as well as farmland habitats (gardens for the finches, wetland and scrub, respectively, for the others), potentially weakening relationships between abundance and the details of farmland habitat condition. This suggests that there is a tendency for the habitat in BBS squares with associated HDC cropping to provide better habitat, in the sense that it supports more positive, or healthier population trends, for the majority of in-field foraging/nesting farmland birds. This, or the pattern of variation in abundance, does not prove that the differences have been caused by horticultural cropping *per se*, but it is consistent with this explanation.

The general pattern in abundance across species was not clearly reflected in the results for all individual crops. Too much should not read into this difference, however, because the links between HDC registration for particular crops in 2010 and actual cropping on the ground throughout the whole BBS period (1994-2009) are not clear. It is also not contradictory to find an overall positive association with HDC registration and only negative associations with individual crops (e.g. as found for tree sparrow and yellowhammer) because the individual crop analyses were based on different samples (and smaller numbers) of squares. In fact, it seems likely that HDC squares that do not actually also feature registrations of these individual crops were associated with higher counts of many species, and more positive population trends, than those where these crops were registered. Without more detailed knowledge of the relationships between crop registration and what crops are actually planted or other features to the farms concerned (e.g. are they concentrated in a particular region or landscape for some reason), it would be pure speculation to consider further why the differences exist.

Overall, it is clear that HDC registration in general is associated with higher bird counts and more positive population trends in local areas for most species, and thus the bird assemblage associated with open field habitats as a whole. As discussed in the literature review (Section 2), there are a number of mechanisms by which such an effect could occur, each of which affects a different range of species. However, the research presented here, while consistent with these mechanisms being important, does not prove that they are. That there is uncertainty is shown by the mixed apparent responses to individual crops in the crop-specific analyses. Further research is required to investigate whether there are patterns of field use by birds that support the existence of real relationships with horticultural cropping that are consistent with the broad-scale patterns found here. A combination of landscape-scale associations and consistent farm-scale relationships would be powerful evidence that horticultural cropping has effects on farmland birds that could have a significant influence on their national populations. For example, if vegetable crops themselves drive population-level differences in abundance or population trend, these effects should be detectable locally in terms of differences in density between the vegetable crops and other crops, showing that birds actually do select them and use them preferentially. Comparison of the crop fields that are used more and those that are used less would also help to produce specific recommendations for best practice in crop management to benefit the widest range of farmland bird species. In turn, implementing these recommendations would assist HDC growers in contributing to the targets of the Campaign for the Farmed Environment.

Acknowledgements

We thank the Horticultural Development Council for funding this work (as project FV385), and especially Cheryl Brewster and Robin Buck for all their help and advice. We are also indebted to Jim Egan from the Farming and Wildlife Advisory Group for helping to develop this project. The BBS is funded by a partnership of the BTO, the Joint Nature Conservation Committee and the Royal Society for the Protection of Birds, but depends critically on the efforts of thousands of volunteer observers, whom we thank for making this study possible.

References

Barnard, C.J. & Thompson, D.B.A. 1985. Gulls and Plovers. Croom Helm, London.

Burton, N.H.K., Watts, P.N., Crick, H.P.Q. & Edwards, P.J. 1999. The effects of preharvesting operations of Reed Buntings Emberiza schoeniclus nesting in oilseed rape Brassica napus. *Bird Study* **46,** 369-372.

Donald, P.F. 2004. The Skylark. Poyser, London.

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

Donald, P.F. & Evans, A.D. 1995. Habitat selection and population size of corn buntings Miliaria calandra breeding in Britain in 1993. *Bird Study* **42,** 190-204.

Donald, P.F., Evans, A.D., Buckingham, D.L., Muirhead, L.B. & Wilson, J.D. 2001. Factors affecting the territory distribution of skylarks Alauda arvensis breeding on lowland farmland. *Bird Study* **48,** 271-278.

ESRI 2008. ArcMap, v. 10. ESRI, www.esri.com.

Evans, A., Vickery, J. & Shrubb, M. 2004. Importance of overwintered stubbles for farmland bird recovery: a reply to Potts. *Bird Study* **51,** 94-96.

Fahrig, L., Baudry, J., Brotons, L., Burel, F.G., Crist,, T.O., Fuller, R.J., Sirami, C., Siriwardena, G.M. & Martin, J.-L. 2011. Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. *Ecology Letters* **14,** 101–112

Galbraith, H. 1988. Effects of agriculture on the breeding ecology of Lapwings Vanellus vanellus. *Journal of Applied Ecology* **25,** 487-503.

Gillings, S., Newson, S.E., Noble, D.G. & Vickery, J.A. 2005. Winter availability of cereal stubbles attracts declining farmland birds and positively influences breeding population trends. *Proc. Roy. Soc. B.* **272,** 733-739.

Gilroy, J.J., Anderson, G.Q.A, Grice, P.V., Vickery, J.A. & Sutherland, W.J. 2010. Mid-season shifts in the habitat associations of Yellow Wagtails Motacilla flava breeding in arable farmland. *Ibis* **150,** 90-104.

Gilroy, J.J., Anderson, G.Q.A, Grice, P.V., Vickery, J.A., Watts, P.N. & Sutherland, W.J. 2009. Foraging habitat selection, diet and nestling condition in Yellow Wagtails Motacilla flava breeding on arable farmland. *Bird Study* **56,** 221–232.

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

Hartley, I.R. & Shepherd, M. 1994. Nesting success in relation to timing of breeding in the corn bunting on North Uist. *Ardea* **82,** 173-184.

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

Risely, K., Baillie, S.R., Eaton, M.A., Joys, A.C., Musgrove, A.J., Noble, D.G., Renwick, A.R. and Wright, L.J. 2010. The Breeding Bird Survey 2009. BTO Research Report 559. - British Trust for Ornithology.SAS Institute, Inc. 200?

SAS Institute, Inc. 2008. The SAS System v. 9.2. Cary, NC, USA.

Schläpfer, A. 1988. Populationsökologie der Feldlerche Alauda arvensis in der intensiv genutzen Agrarlandschaft. *Ornithologische Beobachter* **85,** 309–372.

Siriwardena, G.M., Wilson, J.D., Baillie, S.R. & Crick, H.Q.P., 2001. Can the decline of the skylark be "recovered" using present-day habitat preferences and changes in agricultural land-use? Proceedings of the RSPB/BTO Skylark Workshop, Southampton 1999.

Wilson, J.D., Evans, J., Browne, S.J. & King, J.R. 1997. Territory distribution and breeding success of skylarks Alauda arvensis on organic and intensive farmland in southern England. *Journal of Applied Ecology* **34,** 1462-1478.

Wilson, J.D., Morris, A.J., Arroyo, B.E., Clark, S.C., Bradbury, R.B. 1999.Areview of the abundance and diversity of invertebrate and plant foods of granivorous birds in northern Europe in relation to agricultural change. Agriculture, *Ecosystems and Environment* **70,** 13–20.

Wilson, J.D., Evans, A.D. & Grice, P.V. 2009. Bird Conservation and Agriculture. Cambridge University Press.