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The Effects of Agricultural Change on Population Size and Territory Distribution of the Corn Bunting *Miliaria calandra*

by

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EXECUTIVE SUMMARY

1. This report presents the results of an analysis of the British Trust for Ornithology's Common Birds Census (CBC) archive data for breeding Corn Buntings, a species which suffered severe population and range declines in Britain between 1975 and 1993. The CBC records the numbers and distributions of territories of a range of common breeding birds on a large number of farmland and woodland plots every year. A total of 215 plot-years and 1,355 Corn Bunting breeding territories were included in the analyses. The aim of the analyses was to assess the effects of agricultural change on Corn Bunting populations and to examine habitat selection by this species.

2. Habitat diversity and farm structure did not differ significantly between the years of highest and lowest population in a sample of 29 farms. Areas of all crops except wheat and barley did not differ significantly between years of highest and lowest Corn Bunting population. Barley was more extensive in years of highest Corn Bunting population and wheat more extensive in years of lowest population.

3. Variations between farms in Corn Bunting density in years of peak population could not be explained by differences in habitat diversity, hedgerow length, field size, altitude nor the extent of any crop type. Ordination of all habitat data did not explain variations in breeding density.

4. Variations in numbers of breeding Corn Buntings on individual farms censused over periods of at least ten years were correlated with different factors on different farms. The most frequently positively correlated variable was the area of spring sown barley, although this was only significantly so in four out of seven farms.

5. Corn Buntings exhibited no preference in the location of breeding territories between barley and wheat and none between spring and winter sown cereals. Cereals were generally preferred to grassland, and temporary grassland was preferred to permanent pasture.

6. The Corn Bunting CBC index was positively correlated with the area of barley planted in England yearly between 1963 and 1992 and negatively correlated with the area of

wheat. However this does not necessarily indicate causation and the interpretation of these results is discussed.

7.The implications of the results of this work are discussed with reference to previous work and to this species' conservation status. It is suggested that recent population declines are unlikely to be due to changes in cropping practice and that other factors of farmland management might be responsible. These might include pesticide use, changes in harvesting dates and increased harvesting efficiency. Further schemes of work are suggested to investigate further the rapid population decline of this species.

1. INTRODUCTION

During the early 1970s, it become apparent that several farmland species (most obviously Grey Partridge *Perdix perdix*, Woodpigeon *Columba palumbus* and Rook *Corvus frugilegus*) were in decline as a result of trends in agriculture aimed at increasing farm productivity and profitability (Murton & Westwood, 1974). The two main trends implicated in these declines were changes in cropping practice (particularly the abandonment of traditional rotations in favour of continuous cereal cropping and the consequent loss of leys) and the increased use of pesticides. Long-running surveys organised by the British Trust for Ornithology (Marchant *et al.*, 1990) and the two Atlases of Breeding Birds in Britain and Ireland (Sharrock, 1976; Gibbons *et al.*, 1993) have shown that a number of other farmland species, particularly small seed-eating birds, have declined since the mid-1970s and, again, these declines have been ascribed to changes in farming practice (O'Connor & Shrubb, 1986; Fuller *et al.*, 1991). In general these declines have been most severe on arable farms, particularly in the north and east of England (Marchant & Gregory, in press).

The Corn Bunting *Miliaria calandra* has suffered severe declines in range and population since the mid-1970s (Marchant *et al.*, 1990; Gibbons *et al.*, 1993; Donald *et al.*, in press). The BTO's Common Birds Census (CBC), which uses the territory mapping method to census birds, suggests that the breeding population in 1992 was only a third of that in 1970. The 1988-91 Breeding Atlas survey revealed a 35% decline in the number of occupied 10-km squares in Britain and Ireland since the early 1970s. Declines have been most severe in the north and west of Britain and in Ireland. The areas most affected during these recent declines correspond well with those areas which were most severely affected during an earlier period of decline in the 1920s and 1930s (Donald *et al.*, in press). Population declines in Britain have been matched by declines across much of central and western Europe (Donald *et al.*, in press).

Although the causes of these recent declines are at present unclear, several possibilities have been suggested (summarised in Fuller *et al.*, 1991 and in Donald *et al.*, in press), the majority of which relate to recent changes in farming practice. Possible reasons for the observed declines include changes in the overall cropped area of barley *Hordeum spp.*, a change from spring to autumn sowing of cereals and increased regional specialisation, the last resulting in formerly mixed farms becoming more devoted to livestock in western Britain or to arable production in eastern Britain. Together with the increased use of pesticides, these changes have resulted in a decline in the diversity of flora and fauna supported by cereal fields (Potts, 1991; Fuller *et al.*, 1991).

Since the mid-1960s there has been a continuous decline in the area of barley grown in England and Wales (MAFF Published Statistical Material, 1962-1992). Barley has been shown to be the most favoured habitat of Corn Buntings in mixed arable farmland in north western England (Thompson & Gribbin, 1986), although a wide variety of other habitats is also occupied throughout the species' range (Dolman, 1992). In parts of the Netherlands, a switch towards the growing of green maize *Zea spp.* at the expense of wheat *Triticum spp.* and barley was correlated with a dramatic decline in Corn Bunting populations (Hustings *et al.*, 1990; Schepers *et al.*, 1992). It has been suggested that recent population declines in Britain have been caused by reductions in the area of barley planted (O'Connor & Shrubb, 1986).

The switch towards autumn or winter planting of cereals at the expense of more traditional spring sowing has accelerated since the 1960s to such an extent that in 1992, virtually all the wheat *Triticum spp.* crop and 75% of the barley crop in England were planted in autumn (MAFF Published Statistical Material, 1992) although in Scotland more than 80% of the barley crop remains spring sown. The switch from spring to autumn planting could have affected Corn Buntings in several ways. Firstly, the more developed sward of winter cereals might provide unsuitable nesting or feeding sites for birds at the start of the breeding season. Spring sown cereals have been shown to be preferred to winter cereals by both Lapwing *Vanellus vanellus* (Shrubb & Lack, 1991) and Skylark *Alauda arvensis* (Schlapfer, 1988; Wilson & Browne, 1993). Wilson & Browne (1993) found that Skylarks abandoned winter sown cereals often before any nesting attempts were made and correlated this with the structure of the crop. Secondly, winter cereals are harvested earlier than spring sown crops and this may lead to increased nest losses due to agricultural operations in a species with a very late breeding season (Crick *et al.*, 1991; Yom-Tov, 1992). A recent analysis of BTO Nest Record Cards has shown that nest losses accredited to agricultural operations increased from 10% of all recorded nest losses before 1970 to 43% of all recorded nest losses between 1971 and 1991 (Crick *et al.*, in prep [a]). Thirdly, the switch from spring to autumn sowing has greatly reduced the areas of stubble available to feeding birds in winter. Weed-rich stubble has been shown to be the most favoured wintering habitat of this species (Donald & Evans, in prep; Donald, 1993) and declines in stubble area have been implicated in population declines of the Cirl Bunting *Emberiza cirlus* (Evans & Smith, in press).

The effects on Corn Buntings of regional specialisation in farming and consequent loss of habitat diversity have not been assessed, although Gates *et al.* (in press) found no evidence of an optimum ratio of pasture to arable at the 10-km square level.

Corn Buntings were shown to be particularly susceptible to direct poisoning by mercury-based compounds during mass mortalities of farmland birds caused by these chemicals in Sweden during the early 1960s (Karvik 1964; Otterlind & Lennerstedt 1964). More recent research has identified what are likely to be the effects of sub-lethal poisoning, with declines in breeding success of Corn Buntings in some parts of Britain during the 1950s and 1960s coincident with intensive use of organochlorines as seed dressings (Crick *et al.*, in prep [b]). Despite this, Corn Bunting populations increased nationally throughout the 1960s and early 1970s.

Greater harvesting efficiency and the disappearance of stack-yards might have reduced winter food supplies, although recent changes in agricultural policy are likely to greatly increase the area of weed-rich stubble, the Corn Bunting's most important wintering habitat (Donald & Evans, in prep).

The present distribution and past patterns of decline of the Corn Bunting in Britain present several apparent contradictions to the theories put forward to explain its current decline. For example, declines in distribution have been most severe in Scotland, where there was an increase in the barley crop of over 500% between 1950 and 1980 (Thom, 1986) and where over 80% of the barley crop remains spring sown. Similarly an analysis of Breeding Atlas data showed that barley increased in area in about half of the 496 10-km squares which lost breeding Corn Buntings between the two Breeding Atlas periods, although 10-km squares which retained breeding birds between the two Atlases had slightly higher overall areas (Gibbons & Gates, in press). However these studies were based upon analyses of data collected at the 10-km square level and habitat selection at the field scale is poorly known. The main exception to this is the work of Thompson & Gribbin (1986), who found a marked preference for spring sown barley at a study site in north west England. Bayne (1993) also found highest densities of Corn Buntings occurring in and around barley fields on his study site in Sussex. However Hegelbach & Ziswiler (1979) found that on their Swiss study site, arable land was completely avoided in favour of marshland and wet grassland, and both Goodbody (1955) and MacDonald (1964) suggested that Corn Buntings did not exhibit preference for any crop type (grassland, cereals or root crops) in eastern Scotland.

No work has been carried out to date on the effects of changes in cropping practice on Corn Bunting populations on individual farms. This report presents the results of an analysis of data gathered by contributors to the BTO's Common Birds Census (CBC) to examine the possible causes of the observed declines at the field scale. The CBC is a suitable source of data for such an analysis since it uses mapping techniques which can relate breeding territories to individual fields. An understanding of how changes in cropping practice affect population size and territory distribution will provide further evidence to support or contradict the various theories put forward to explain the declines and will also allow the results of national surveys (*eg* Donald & Evans, in prep) and studies using Breeding Atlas data (*eg* Gibbons & Gates, in press), to be interpreted more fully. Another advantage of looking at population changes in relation to cropping practice at the level of the individual farm is that the close temporal correlation between trends in agriculture in Britain (*eg* the steady decline in the area of barley and the increase in wheat) and in the national population of Corn Buntings (a steady decline since 1975) are less apparent, allowing analysis of a more detrended data set.

2. METHODS

2.1 Data extraction

The BTO's Common Birds Census (CBC) has been running since 1961 and produces the most accurate and widely used measure of yearly population change for a wide variety of woodland and farmland species. The results of the survey up to 1989 were summarised, and the survey methods described in detail, by Marchant *et al.* (1990). The CBC is based upon a technique of territory mapping. Volunteer observers make between eight and ten visits to their survey site each breeding season and record the location of all birds seen or heard on maps. Activity codes are used to record birds in song, birds calling, territorial disputes, birds carrying food *etc.* Simultaneous observations and movements are also recorded so that analysts know whether two registrations refer to the same or to different birds. Completed maps are returned to BTO analysts who extract records for each species from visit maps to create a map for each species. By examining clusters of records and activity codes, the number of breeding territories can be calculated. Population change is measured by a chain index which is calculated by comparing between-year changes of each species at each site, allowing population changes over many years to be identified (Marchant *et al.*, 1990). Although the technique of territory mapping is very labour intensive both in terms of fieldwork and analysis, it has the advantage of being able to relate territories to specific field types, since fieldworkers are also asked to complete habitat maps at regular intervals and cropping plans yearly.

There are several weaknesses in the CBC data set which need to be considered when the data are used for analyses such as those presented in this report. The principal weaknesses lie in the crop maps which are submitted by observers with their counts. Often winter and spring cereals are not discriminated and in some cases fields are described simply as "cereals". This greatly reduces the sample sizes for analyses which concern changes in more specific land-use types. More importantly, changes in crop management are not usually documented. Thus changes in harvesting dates, applications of pesticides and in the nature of field boundaries are not usually apparent from the information supplied by observers. This report is therefore concerned solely with trying to identify any effects on Corn Bunting populations of changes in crop types and not crop management, although the effects of the latter could well outweigh those of the former.

All farms which were covered as CBC plots for a minimum of ten years and which held breeding Corn Buntings in at least five of those years were included in the analyses. The availability of habitat and cropping information and of species maps limited the size of the usable sample to 29 farms. These are henceforth referred to as "two-year plots". For all 29 farms, data on Corn Bunting populations, habitat preferences and the areas of different crop types were extracted from species and cropping maps for the years of highest and lowest numbers of Corn Bunting territories (or in many cases, the years of highest numbers and the first year of extinction). In four cases, numbers of birds increased during the period they were surveyed, and so the year of lowest numbers actually came before the year of highest numbers.

Ten of the plots, which had particularly long periods of coverage with good habitat data, were examined in more detail as case studies. These are henceforth referred to as "ten-year plots". Data were extracted for all the years the plots were surveyed or for all years in which Corn Buntings were present plus the first five years after extinction. Details of all the plots chosen, the number of territories, farm type and size are given in Tables 1 and 2.

Data on territory distribution were extracted from species maps using a system similar to that of Hudson (1985). Each territory encompasses a cluster of registrations of individual birds (from three to 12). The proportion of registrations in each territory falling on each field were calculated. Unlike the method of Hudson (1985), registrations falling on field boundaries were split between the fields on either side since Corn Buntings frequently use field boundaries simply as song posts and nest and feed in standing crops (Andrew, 1956; MacDonald, 1964). Thus it is possible to estimate the number of part territories falling within each field. A worked example of this method is shown in Figure 1.

For each plot-year included in the analyses, the following data were extracted: total plot area, altitude, total area of each of the land-use types listed in Table 3, total number of part territories falling on each crop type, average field size and average hedgerow length (calculated as the average proportion of each field boundary made up by hedgerow). The total areas of each crop type and the total number of part territories falling on each crop type were converted to proportions which were used in the analyses.

Published national agricultural statistics (MAFF Published Statistical Material, June statements, 1963-1992) were examined to identify gross changes in total area of several main crop types between 1963 and 1992. These were compared with changes in the Corn Bunting CBC index in order to investigate whether the patterns of population change in relation to cropping changes on individual farms were reflected nationally.

2.2 Data analysis

Data were analysed using the SAS statistical package (SAS, 1986).

2.2.1 Analysis of two-year plots

For all 29 two-year plots included in the analyses, Wilcoxon paired-rank tests were used to detect changes in average hedgerow lengths, in the areas of the crop types listed in Table 3 and in habitat diversity between years of highest and lowest Corn Bunting populations. A Shannon-Weaver habitat diversity index (recommended by Peet, 1974) was calculated for each plot-year based upon the proportions of five categories of land use: temporary grassland (including hay, silage and fallow land), permanent grassland, cereals, root crops and other arable crops (such as peas, beans and oil seed crops).

Differences in the density of breeding birds in the year of highest population across all farms was correlated against altitude, hedgerow length, average field size, diversity index and the extent of the main crop types.

Habitat data (altitude, slope, average field size, the areas of major crop types and average hedgerow length) from all farms in their year of highest Corn Bunting population were ordinated using principal components analysis (PCA). PCA scores for each interpretable axis were correlated against density (ie. total of part territories divided by total farm area) in order to examine habitat selection.

2.2.2 Analysis of ten-year plots

The numbers of breeding territories were compared using rank correlation against the extent of each crop type and with habitat diversity indices for each plot across all the years in which each were covered. The total number of full territories, rather than part territories, recorded in each year was used as the dependant variable since on most plots territory maps were not available to calculate the numbers of part territories in all years, leading to reduced sample sizes. Numbers of territories were also correlated against a number of calculated values which reflected the ratio of spring sown cereals to winter cereals, the ratio of temporary grassland (silage, hay and fodder crops) to all farm grassland and the ratio of barley to total cereal area. The direction of the correlation coefficient (positive or negative) was noted even in cases where it was not significant at the level of $P<0.05$ to check for consistency with the significant results.

Jacobs' preference indices (Jacobs, 1974) were calculated for each crop type occupying 10% or more of the total farm area in each plot-year in which five or more Corn Bunting territories were recorded. The threshold value of five territories was chosen arbitrarily to allow more realistic assessments of preference to be made. Preference indices for wheat were compared with those for barley, indices for total cereals with those for total grassland and indices for temporary grassland with those for permanent pasture. Plot-years in which one of the two land use types in the comparison was absent were deleted from this analysis since the absence of a land use type precluded choice. A second set of tests was used to identify any significant differences in preference for spring or winter sown barley and between all spring and winter sown cereals. Paired sample tests were used to reduce the problems of non-independence of data resulting from analysing data collected on different plots in different years.

2.2.3 Analysis of National Agricultural Statistics

The correlations between the Corn Bunting CBC index and the total area of a number of agricultural land-use types in England were examined for the years 1962 to 1992. The land use types for which data were extracted from the national agricultural statistics were wheat, barley, total cereals, total tillage, temporary grassland and permanent grassland. Agricultural data for Scotland and Wales were excluded from these analyses since the CBC index for the Corn Bunting is based almost entirely from data collected on plots in England (due to both the distribution of CBC plots and of Corn Buntings).

3. RESULTS

Data were extracted from CBC species maps for 215 plot-years which held a total of 1,355 Corn Bunting territories (Tables 1 & 2).

3.1 Results of two-year plot analysis

Of the 29 plots included in the analysis, only eight retained breeding birds throughout the period of their coverage. Densities of Corn Buntings varied between 0.02 and 0.2 pairs per hectare on occupied plots in their years of highest population.

A comparison of habitat diversity indices from the years of highest population with those from the years of lowest population (or first year of extinction) showed that on 16 farms, indices were higher in the year of highest Corn Bunting population, on 11 farms they were highest in the year of lowest population and on two farms they did not differ. There was no significant trend in the pattern of change in the habitat diversity index (Wilcoxon's test for matched pairs, $T=150$, $n=27$, $P>0.05$).

The only land-use types which differed significantly in extent between the years of highest and lowest population were wheat and barley. Wheat was significantly less extensive in the year of highest population ($T=43$, $n=19$, $P<0.025$) whereas barley was significantly more extensive ($T=68$, $n=22$, $P<0.05$). Although sample sizes were small, there was evidence that winter wheat increased between the years of highest and lowest population ($T=0$, $n=8$, $P<0.01$) and spring barley had decreased ($T=0$, $n=6$, $P<0.05$). Sample sizes were too small to allow an assessment to be made of changes in the areas of spring wheat and winter barley.

Changes in the average hedgerow length between years of highest and lowest population were recorded on just seven farms, six having less hedgerow boundary in the year of lowest population and one having more. There were no changes in average field size between the years of highest and lowest population.

The density of breeding Corn Buntings in years of peak population was not significantly correlated with field size, hedgerow length, altitude, habitat diversity or with the extent of any of the main crop types (Spearman rank correlations, $P>0.05$ in all cases).

The first principal component of ordination of habitat data clearly represented the transition from pasture to cereal farmland and accounted for 33.7% of the variance in the habitat data. The second principal component represented the transition from upland farms with fewer hedges and large areas of permanent grassland to lowland farms with more hedges and more temporary grassland and arable crops other than cereals; this component accounted for 14.3% of the variance. No clear interpretation of the remaining axes of ordination was possible. Densities of birds on farms in their years of highest population were not significantly correlated with their corresponding eigenvalues for either of the first two principal components.

3.2 Results of ten-year plot analyses

Each of the ten plots included in this analysis were covered for between ten and 30 years, with an average of 17.7 years. Results of correlations between the number of Corn Bunting territories and the relative areas of each land-use type and habitat diversity indices are given in Table 4 for each of the ten plots included in the analysis. On only one plot was the number of Corn Bunting territories positively correlated with the habitat diversity index, although in seven out of ten cases correlation coefficients were positive. The number of Corn Bunting territories was positively correlated most frequently with the extent of spring barley, with four significant correlations out of seven tests. On half of the plots, the number of Corn Bunting territories were negatively correlated with year, an expected result given the national population decline.

There was no significant difference between preference indices calculated for wheat and barley ($T=268$, $n=35$, $P>0.05$) nor between winter and spring sown cereals ($T=64$, $n=17$, $P>0.05$) in plot-years in which each crop type occupied more than 10% of the total plot area and when at least five Corn Bunting territories were present. Although sample sizes were small (since in only a few years in which the two types of barley were discriminated on the crop maps did both occupy 10% or more of farm area), there was no apparent preference for spring barley to winter barley ($T=17$, $n=8$, $P>0.05$).

Cereals were clearly preferred to grassland ($T=315$, $n=59$, $P<0.005$) and temporary grassland (which included hay, silage, fallow and leys) to permanent pasture ($T=229$, $n=44$, $P<0.005$).

3.3 Results of national agricultural data analyses

National agricultural statistics reveal a steady decline in the area of barley planted each year between 1962 and 1992 and a steady increase in the area of wheat (Figure 2). The Corn Bunting CBC index was positively correlated with the area of barley planted between 1962 and 1992 (r_s=0.85, n=30, P<0.001) and negatively correlated with that of wheat (r_s=-0.72, n=30, P<0.001) (Figure 3) but not correlated with the overall area of cereals planted annually (r_s=-0.16, n=30, P>0.05). The total area of tillage increased throughout the period and was negatively correlated with the Corn Bunting CBC index (r_s=-0.65, n=30, P<0.001). Both temporary and permanent grassland declined between 1962 and 1992 (Figure 4) and the extent of each was positively correlated with the Corn Bunting CBC index (temporary grassland: r_s=0.75, n=30, P<0.001; permanent grassland: r_s=0.69, n=30, P<0.001) (Figure 5).

4. DISCUSSION

An analysis of the habitat composition of CBC farmland plots showed that they were not representative of farmland across Britain as a whole but that they were representative of lowland farms throughout most of England (Fuller *et al.*, 1985). This must be taken into account when considering the results of the analyses presented in this report since the findings might not hold true in other parts of Britain. It should also be remembered that CBC plots are concentrated in south eastern England, where declines in distribution (although not necessarily in numbers) have generally been less severe than in northern and western areas (Donald *et al.*, in press). The caveat also needs to be added that it is not known how representative are the sub-sample of CBC plots included in the analyses presented here. Since no farms which did not hold breeding Corn Buntings were included in the analyses, the sub-sample chosen for inclusion may not be representative of CBC plots as a whole. However it is likely to be representative of CBC plots holding breeding Corn Buntings, since the majority of such plots which were covered for at least ten years were included in the analyses. Since the aim of this study is to examine population changes of Corn Buntings in relation to agricultural change, there is no reason to assume that the selection of plots has produced results which are not representative of lowland farms in England which regularly hold (or held) breeding Corn Buntings.

The results of the analyses presented in this report show that Corn Bunting population declines are unlikely to have been caused solely by changes in cropping practice or farm structure. At the level of the individual farms studied, the only significant differences in cropping between years of highest and lowest Corn Bunting population were a larger area of barley and a smaller area of wheat in the former year relative to the latter, and more specifically (although based upon small sample sizes) a larger area of spring barley and a smaller area of winter wheat in the year of highest population. The total areas of cereal, temporary grassland, permanent pasture and other arable farming did not differ between the years of highest and lowest Corn Bunting population. Although these results might appear to support the argument that Corn Bunting population declines have been due to a long-term decrease in the cultivated area of spring barley (*eg.* O'Connor & Shrubb, 1986), the results of the ten-year plot analyses show that there was no apparent preference for barley to wheat nor for spring cereals to winter cereals. Some conflicting evidence also emerged from the analyses, as Corn Bunting densities were positively correlated with the area of spring barley on four of the seven plots for which data were available, although this could have been the result of temporal similarities in declines of Corn Bunting populations and the cultivated area of spring barley and does not necessarily suggest causality. In two of these four plots, populations were also negatively correlated with year.

There was considerable variation between the ten-year plots in the number of land-use variables which were correlated with Corn Bunting numbers. On three of the ten farms, Corn Bunting numbers were not correlated with changes in the areas of any of the land-use variables included in the analyses, suggesting that on these farms Corn Bunting declines occurred independently of changes in cropping practice. However the low variance in population sizes on these farms (all of which had a maximum of less than ten territories) may have limited the power to detect correlations. On the remaining seven farms, the areas of between one and five land-use types (which were not necessarily mutually exclusive) were correlated with Corn Bunting numbers. These differences might reflect differences in habitat selection on different farm types or in different geographical areas or may reflect changes in other factors not measured by CBC observers such as the effects of cold winters or natural population fluctuations.

Analyses of national agricultural statistics show strong positive correlations between the areas of barley, temporary grassland and permanent pasture and the Corn Bunting CBC index and a strong negative correlation between the area of wheat and the CBC index. However the close temporal trends between all these variables make interpretation of these results difficult. The results do not necessarily imply causality but show that as the cultivated areas of barley and grassland have declined, so has the Corn Bunting CBC index. Analyses of data from individual farms suggest that Corn Buntings exhibit no preference for different types of cereal and there is no significant correlation between the total area of cereals planted in England and the Corn Bunting CBC index.

Although traditionally associated with cereal growing areas, Corn Bunting densities on individual farms were not correlated with total cereal area across the total sample of 29 farms in their years of highest population nor on any of the long-term plots throughout the period of their coverage. However cereals were found to be strongly preferred to grassland. The main axis of ordination of the full sample of farms in their years of highest population clearly represented a progression from exclusively grassland to exclusively cereal farms yet this was not correlated with their population densities. These results suggest that although the size of the breeding population is not limited by the availability of cereals, cereals are the preferred habitat when both cereals and grassland are available.

The preference for temporary grassland to permanent pasture where both occur is an interesting finding which has not been previously been demonstrated. The increasingly early mowing of hay and silage may have severely reduced Corn Bunting breeding success and, if so, the preference for such crops is likely to have exacerbated this effect. The more severe population declines noted in the principally pasture regions of northern and western Britain may therefore be linked to changes in times and frequency of mowing of harvested grassland. The disappearance of breeding Corn Buntings from one long-term CBC plot (061) was ascribed to progressively earlier mowing dates of silage, a habitat which was consistently preferred to permanent pasture on that farm (J.M. Butterworth, *in litt.*). Changes in grassland management have been shown to be at least partly responsible for population declines of Corncrakes *Crex crex* (Stowe *et al.*, 1993)

The results of the analyses show that populations declined in the absence of a significant reduction in habitat diversity, suggesting that increased regional specialisation towards arable or livestock production is not the sole cause of population declines. Changes in the length of hedgerow and changes in field size, which represent less direct measures of farming intensity, were also found not to be correlated with Corn Bunting population declines, which continued in the absence of either on most of the farms analysed. In a previous study of a farm where significant removals of hedgerows took place, these removals caused declines in Corn Bunting populations (Murton & Westwood, 1974) although on another farm (not occupied by Corn Buntings), other open-country species were shown to benefit from hedgerow removal (Bull *et al.*, 1976).

The data analysed above do not take account of differences in breeding success or the extent of polygyny between different crops. Thus although there was no apparent difference in preference for barley or wheat, the changes in the availability of each might be more important when the productivity of Corn Buntings is considered. Thompson & Gribbin (1986) found a higher rate of polygyny in barley than in wheat but also a higher proportion of unmated males. Differences in the productivity of Corn Buntings nesting in different crops is not known, making interpretation of the data difficult in the context of population declines.

The results of the analyses presented in this report suggest that changes in cropping practice or farm structure are not the main cause of recent population declines and that current populations are not limited by the availability of suitable habitat. Other agricultural changes which might be responsible for the declines include the increased use of pesticides, greater harvesting efficiency, the disappearance of stack-yards and earlier harvesting dates of both cereals and temporary grasslands. Such factors have been suggested as the reasons behind Corn Bunting population declines in Sweden (Jonsson, 1988), Germany (Busche, 1989) and the Netherlands (Hustings *et al.*, 1990).

5. RECOMMENDATIONS FOR FURTHER WORK

The main gap in existing information on the Corn Bunting is ecological data on feeding requirements, breeding success in different crops and the main causes of nest failure. Whether the recent severe population declines are due to increased mortality or to decreased productivity is not yet known. The results of the present report suggest that habitat change *per se* is not the main cause of population declines, but that changes in habitat management may be involved. Thus the direction that work should now take is to examine population processes, and particularly productivity in different habitats, in greater detail.

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CBC Plot no.		061*		062*		065*		078	
Plot size (ha)		83.5		51.4		81.3		63.1	
Av. field size (ha)		2.6		4.7		4.3		4.5	
Peak year	Low year	1967	1977	1978	1983	1974	1987	1971	1977
Farm type		Pasture	Pasture	Arable	Arable	Mixed	Arable	Mixed	Mixed
No. of part terrs.		9.0	0	4.39	0	10.51	0	2.0	0
Av. hedge border		0.47	0.47	0.86	0.86	0.63	0.63	0.55	0.55
Land use (proportion)	cereal	0	0	1.0	1.0	0.68	0.93	0.49	0.49
	grass	1.0	1.0	0	0	0.32	0.07	0.51	0.51
	other arable	0	0	0	0	0	0	0	0
	other	0	0	0	0	0	0	0	0

Table 1Size, structure and crop composition of all 29 farms included in the two-year analyses. Years of highest and lowest Corn Bunting populations and the number of part territories in each are also given. Plot numbers marked with asterisks are plots which were analysed on a yearly basis (ten-year plots). Each plot-year is classified as pasture, arable or mixed. If either pasture or arable constituted over 70% of total farm area, that land-use type was classified as dominant, otherwise the farm was mixed.

CBC Plot no.		102		112		159		203	
Plot size (ha)		56.9		101.1		64.9		100.6	
Av. field size (ha)		3.6		7.8		2.2		5.6	
Peak year	Low year	1972	1981	1975	1970	1978	1980	1967	1971
Farm type		Mixed	Mixed	Arable	Mixed	Pasture	Pasture	Mixed	Mixed
No. of part terrs.		4.64	3.1	7.16	1.48	2.0	0	2.0	0
Av. hedge border		0.41	0.41	0.11	0.11	0.31	0.31	0.36	0.33
Land use (proportion)	cereal	0.49	0.49	0.80	0.55	0.08	0.10	0.62	0.20
	grass	0.41	0.32	0.20	0.35	0.88	0.83	0.22	0.59
	other arable	0.07	0.14	0	0.10	0.04	0.07	0.07	0
	other	0.03	0.05	0	0	0	0	0.09	0.21

Table 1 (continued)

CBC Plot no.		209*		251*		304*		305	
Plot size (ha)		180.1		111.9		69.9		108.5	
Av. field size (ha)		7.2		6.6		4.4		6.0	
Peak year	Low year	1974	1989	1976	1991	1976	1991	1974	1965
Farm type		Mixed	Mixed	Mixed	Arable	Mixed	Arable	Arable	Mixed
No. of part terrs.		14.14	2.98	9.89	0	12.79	5.81	10.31	3.0
Av. hedge border		no data	no data	0.43	0.43	0.33	0.33	0.32	0.32
Land use (proportion)	cereal	0.43	0.48	0.54	0.41	0.32	0.64	0.71	0.64
	grass	0.45	0.40	0.36	0.26	0.43	0.10	0.26	0.36
	other arable	0	0.04	0.06	0.33	0	0.23	0	0
	other	0.12	0.08	0.04	0	0.25	0.03	0.03	0

Table 1 (continued)

CBC Plot no.		313*		315		319		380	
Plot size (ha)		83.2		68.3		78.9		67.4	
Av. field size (ha)		6.4		7.6		3.2		6.7	
Peak year	Low year	1973	1978	1973	1983	1984	1988	1981	1968
Farm type		Mixed	Mixed	Arable	Arable	Pasture	Pasture	Arable	Mixed
No. of part terrs.		11.71	2.34	10.12	2.8	7.81	0	13.76	0
Av. hedge border		0.33	0.33	0.60	0.60	0.75	0.72	0.41	0.41
Land use (proportion)	cereal	0.50	0.36	0.38	0.38	0.27	0.29	0.97	0.67
	grass	0.50	0.64	0.24	0.25	0.73	0.71	0.03	0.33
	other arable	0	0	0.38	0.37	0	0	0	0
	other	0	0	0	0	0	0	0	0

Table 1 (continued)

CBC Plot no.		415		602		660		708	
Plot size (ha)		48.6		82.9		79.5		62.1	
Av. field size (ha)		4.42		3.32		3.5		6.21	
Peak year	Low year	1975	1982	1971	1964	1965	1971	1967	1971
Farm type		Arable	Arable	Mixed	Arable	Pasture	Pasture	Arable	Arable
No. of part terrs.		5.19	0	2.5	1.0	3.0	0	1.44	0
Av. hedge border		0.28	0.48	0.14	0.14	0.2	0.2	0.46	0.46
Land use (proportion)	cereal	0.65	0.74	0.45	0.70	0.12	0.12	0.62	0.64
	grass	0	0	0.35	0.27	0.88	0.83	0.16	0.23
	other arable	0.35	0.26	0.20	0.03	0	0	0.22	0.13
	other	0	0	0	0	0	0.03	0	0

Table 1 (continued)

CBC Plot no.		711		720		772		773*	
Plot size (ha)		90.4		55.7		42.5		85.7	
Av. field size (ha)		3.9		5.1		2.7		4.3	
Peak year	Low year	1970	1978	1971	1975	1974	1978	1977	1987
Farm type		Mixed	Mixed	Mixed	Mixed	Pasture	Mixed	Mixed	Pasture
No. of part terrs.		2.63	0	1.97	0	1.72	0	9.93	0
Av. hedge border		0.74	0.74	0.04	0.04	0.88	0.88	0.42	0.42
Land use (proportion)	cereal	0.45	0.36	0.21	0.55	0.27	0.19	0.37	0.07
	grass	0.50	0.64	0.57	0.45	0.73	0.69	0.60	0.90
	other arable	0.05	0	0.22	0	0	0.12	0	0
	other	0	0	0	0	0	0	0.03	0.03

Table 1 (continued)

CBC Plot no.		809*		819		957*		964	
Plot size (ha)		57.8		64.3		67.0		27.8	
Av. field size (ha)		3.6		4.6		3.7		7.0	
Peak year	Low year	1967	1975	1978	1983	1986	1990	1984	1985
Farm type		Arable	Arable	Mixed	Arable	Mixed	Mixed	Arable	Arable
No. of part terrs.		3.29	0	5.5	0	5.25	0.78	1.0	0
Av. hedge border		0.34	0.29	0.52	0.50	0.36	0.26	0.33	0.33
Land use (proportion)	cereal	0.74	0.84	0.56	0.96	0.60	0.34	0.75	0
	grass	0.25	0.15	0.28	0.04	0.39	0.47	0.25	0.25
	other arable	0	0	0.12	0	0	0.18	0	0.75
	other	0.01	0.01	0.04	0	0.01	0.01	0	0

Table 1 (continued)

CBC Plot no.		967	
Plot size (ha)		37.2	
Av. field size (ha)		2.7	
Peak year	Low year	1979	1983
Farm type		Pasture	Mixed
No. of part terrs.		1.37	0
Av. hedge border		0.68	0.51
Land use (proportion)	cereal	0	0.51
	grass	0.93	0.45
	other arable	0.07	0.04
	other	0	0

Table 1 (continued)

	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
061		6	6	8	9	7	8	6	5	5	8	8	6	5	0	0	0	0	0											
062		3	3	0	1	0	2	0	1	2	1	4	2	4	5	5	2	1	1	0	0	0	0	1	0	0	0	0		
065			2	4	4	*	6	9	8	10	*	11				*	*	*	*	*					0	4				
209										11	15	18	18	17	15	14	9	8	14	10	10	7	6	3	4	6	4	6	5	
251	2	2	6	9	8	10	10	13	16	12	16	11	11	13	12	11	12	9		8	6	6	9	6	4	3	5	1	0	
304	10	8	13	10	10	16	13	19	21	17	20	17	18	19	13	17	11		15	14	13	13	9	9	9	9	10	9	8	10
313						15	18	12	13	7	18	12	8	9	11	3														
773												9	5	5	12	10	10	11	10	8	4	2	1	2	0	1	0			
809			2	2	5	3	4	4	3	1	1	2	0	2	0	2	1	2	4	0										
957												3	3	6	3	4	5	6	6	4	2	5	5	6	3	3		1	2	

Table 2 The number of Corn Bunting territories recorded in each year of coverage of ten-year plots. Blank spaces indicate no coverage, asterisks indicate years of coverage for which data are not available.

Diversity index
Spring wheat
Winter wheat
Total wheat (spring + winter + unspecified)
Spring barley
Winter barley
Total barley (spring + winter + unspecified)
Oats
Total cereals
Permanent pasture
Fallow
Hay
Silage
Total temporary grassland
Total grassland
Root crops
Other arable crops
Other farming

Ratio 1 = Total grassland/(Total cereals + total grassland)
Ratio 2 = Total grassland/(Total cereals + total grassland + other arable crops)
Ratio 3 = Temporary grassland/Total grassland
Ratio 4 = Winter cereals/Total cereals
Ratio 5 = Barley/(Wheat + Barley)

Table 3Crop types and ratios of crop types used in analyses of ten-year plots.

	CBC Plot Number									
	061	062	065	209	251	304	313	773	809	957
Diversity index	+	-	+	+*	+	+	-	+	+	-
Winter wheat		-		-	+	-		-	+	
Spring wheat		+			-*	+			+	
Total wheat		+	-	-	-	+	+*	-	+	+
Spring barley		+**	+*	+**	+***	+		+	-	
Winter barley		-		-	-	-		+	+	
Total barley		+	+	+**	+*	-	-	+	-	-
Oats		+				+*	+			
Winter cereals		-		-	+	-*		-	+	
Spring cereals		+**		+**	+	+		+	-	
Total cereals		+	+	-	+	+	+	-	-	+
Permanent pasture	-		+	+**	-	-	+	+	-	-
Fallow		-	+	-		+		+	+	-
Hay	+		-		+	+	-	+	+	+
Silage	+		+			-	-	-*		+
Temporary grassland	+		+	-	+	+	-	-	+	+
Total grassland		-	-	+	+	+	-	+	+	-
Roots		+	+		-	+			+	-
Other arable land		-	-	-	-	-	+	+*		-
Year	-***	-	+	-***	-**	-	-*	-***	-	-
Ratio 1		-	-	+	+	+	-		+	-
Ratio 2		-	+	+	+	+	-		+	-
Ratio 3	+		+	-**	+	+*	-		+	+
Ratio 4		-**		-**	-	-			+	
Ratio 5		+	+	+**	+	-	-		-	-

Table 4Results of rank correlations between numbers of Corn Bunting territories and a number of land-use and other variables. The direction of the correlation coefficient is shown together with significance: * P<0.05, ** P<0.01, ***P<0.005. Ratios are defined in Table 3.