The importance of cereal fields to breeding and wintering Skylarks *Alauda arvensis* in the UK

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Although agri-environment schemes and surplus reduction measures (particularly set-aside) create valuable wildlife habitats within the arable landscape, the area of land under intensively managed cereals remains huge, and territory densities of Skylarks *Alauda arvensis* are low in cereals compared with set-aside. However, simple comparisons of Skylark densities in different crop types take account neither of the relative area of each habitat (and therefore the importance of each to the overall population) nor of differences between habitats in measures of quality such as reproductive output. In this paper we combine data from recent studies by RSPB and BTO to show that cereal crops represent the single most important habitat for Skylarks in the UK in terms of the overall numbers of breeding pairs they support. Productivity at the level of the individual nesting attempt was higher in cereals than other crops or set-aside. However, the density of birds supported by cereals declined significantly through the breeding season and Skylarks may therefore make fewer nesting attempts in a season in cereals than in other crops. Higher densities of Skylarks were found in spring-sown than in autumn-sown cereals and this difference could be explained wholly in terms of differences in the physical structure of the two crops. Crop development also had an influence on nest positioning and productivity; as the crop develops, so birds are forced to nest closer to tramlines with a consequent increase in nest predation rate. In winter, cereal stubbles were strongly selected by Skylarks, probably owing to the presence of spilt grain and regenerating weeds, but the area of stubbles has declined greatly in recent years. We suggest that beneficial changes to the management of cereals are likely to reverse the recent decline of this species and outline a number of ways in which such changes could be achieved.

In recent years, the populations of many farmland birds have declined greatly across much of western Europe (Tucker & Heath 1994, Fuller 2000). These declines have coincided with fundamental changes in agricultural practice (Chamberlain *et al.* 1999), and similar patterns of overall decline have not been observed in the bird assemblages of other habitats, strongly suggesting that agricultural change is at least partly responsible (Fuller *et al.* 1995, Campbell *et al.* 1997, Siriwardena *et al.* 1998). Agricultural intensification is now regarded as the greatest single threat to species of high conservation concern throughout Europe (Tucker & Heath 1994).

The Skylark *Alauda arvensis* has declined in abundance across most of western Europe, declines being particularly severe (exceeding 50%) in Germany (Busche 1989), the Netherlands (Oseick & Hustings 1994) and the UK, where the population collapsed in the early 1980s (Siriwardena *et al.* 1998, Fig. 1). In the UK, declines have been more severe on farmland than in other habitats and in regions associated with intensive agriculture (Chamberlain & Crick 1999). Tucker & Heath (1994) classified the Skylark as a SPEC 3 species (unfavourable conservation status in Europe due to recent large declines, but with the world population not concentrated in Europe) and the species is on the UK Red Data list of birds of highest conservation priority (Gibbons *et al.* 1996). The Skylark is one of the few farmland passerines to nest and feed exclusively in open fields away from hedgerows and other tall structures

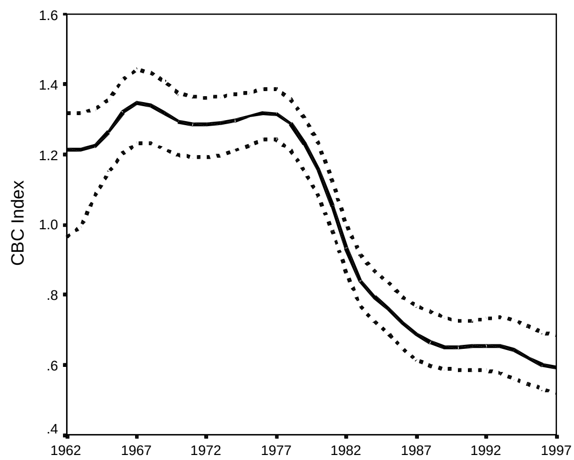

Figure 1. Skylark CBC index, 1962-1997. The graph shows the smoothed Mountford index (solid line) with 95% confidence limits (dotted lines). From Siriwardena *et al.* (1998).

and so is likely to be particularly vulnerable to changes in crop management.

Cereals occupy around 3.3 million ha in the UK, around 35 million ha across the European Community (EC) and around 700 million ha globally (Potts 1991, MAFF 1998, Scottish Office 1998). The percentage of total land area given over to cereals in the UK (12.4%) is very similar to the average across the first 12 member states of the EC (12.9%), so the UK can be viewed as typical of many other western European countries in this respect. The conservation interest of cereals is a product of the very large area they occupy and the large number of rare or declining species they support, many of them reduced from former abundance by changes in cereal management (Potts 1991, 1997). Many such species represent the vestiges of open country ecosystems which have largely disappeared (Potts 1991). Lowland farmland, of which cereals represent the largest single component, provides a breeding or wintering habitat for nearly 120 bird species of European conservation concern, the largest number of such species supported by any habitat (Tucker & Heath 1994).

In this paper we combine data collected from intensive studies by the Royal Society for the Protection of Birds (RSPB) and extensive studies by the British Trust for Ornithology (BTO) to assess the use of cereals by breeding and wintering Skylarks in the UK. We assess the importance of cereals in terms of the number of birds supported by them in summer and winter. We then assess the quality of cereals as a breeding or wintering habitat. The results are used to suggest practical conservation measures that could be used to enhance Skylark populations in Britain and, by inference, other European countries where populations are in decline. We discuss the relative merits of "extensification", defined as a general reduction in the intensity of management, and "set-aside", a small reduction in the area of crops grown with no reduction in the intensity of management of the remaining crops (Potts 1991, Sotherton 1998). The extent to which current and potential agri-environment schemes could be used to improve cereal management for Skylarks is considered.

Changes in cereal agriculture

A number of studies have reviewed the likely effects of historical changes in cereal agriculture on bird populations (e.g. O'Connor & Shrubb 1986, Potts 1991, 1997, Stoate 1995, 1996, Shrubb 1997). Since the early 1950s, when pesticides came into widespread use, the management of cereals has changed greatly. An increasing specialisation into intensive arable (in eastern and southern Britain) and grassland (in western and northern Britain) systems led to the loss of cereals from many western and upland areas and increased field sizes and shortened rotations in eastern regions. At the same time, two major changes in the way cereals were grown took place. The first was the replacement of spring-sown cereals with autumn-sown crops. Between 1968 and 1996, the UK area of spring-sown cereals fell from nearly 3 million ha (73% of total cereal area) to 0.5 million ha (around 16% of total cereal area). This led to a dramatic reduction in the area of winter stubbles, earlier harvesting dates and changes in crop structure. The loss of winter stubbles was exacerbated by the loss of mixed farming, which in many cases relied on winter stubbles as a precursor, through undersowing, to a grass ley. The second important change was the increased use of pesticides and inorganic fertilisers, leading to reduced populations of many invertebrates and plants (Aebischer 1991, Donald 1998) and faster growing and denser crops. Autumn-sown wheat crops receive, on average, ten pesticide applications throughout their growth, with fewer applications to barley, the difference being due largely to differences in fungicide and insecticide applications (Thomas *et al.* 1997). Many species of plant and invertebrate, some of them important food sources for farmland birds, have declined in number (Donald 1998) and the indirect effects of pesticides have been implicated in some bird population declines (Campbell *et al.* 1997). Changes in cereal management since the 1950s, along with the development of more productive and disease-resistant varieties, have resulted in an almost exponential rise in cereal yields (see Fuller 2000). However the intensity of management means that cereal fields are now likely to be more inimical to wildlife than at any time previously (Potts 1991, 1997).

METHODS

The RSPB Skylark Project

The RSPB Skylark Project was an intensive study that examined the ecology of Skylarks on lowland farmland during three breeding seasons (1996, 1997 and 1998) and two winters (1996/97 and 1997/98). The study was undertaken on a total of 24 farms across southern England in three regions (East Anglia, Oxfordshire and Dorset), although not all farms were studied in all years or seasons. To obtain a sample of farms encompassing the widest possible range of farming types, questionnaires were sent to around 200 landowners asking for details of cropping practice. From the replies received, the study farms were selected, without prior knowledge of their Skylark populations, to cover as wide a range of lowland farming types as possible within three regions small enough to allow all farms within them to be covered by one fieldwork team. Farms ranged from wholly arable farms through mixed arable and grass systems to farms consisting entirely of grassland. A total of 995 nests was found during the three breeding seasons of the project. Nests were revisited at regular intervals between finding and when the chicks left the nest or when the nest failed to assess nest survival rates with the Mayfield method (Mayfield 1975) using logit-linear models (Donald *et al.* 1998). Measurements of chick weight and tarsus were taken to assess growth rates, and body condition and faecal samples collected to assess diet. Estimates of egg volume, egg hatching rates and partial brood losses during the fledgling period were also made. In addition to nest finding, breeding season fieldwork methods included regular field-by-field counts of birds in different habitat types using standard territory mapping methods (Marchant *et al.* 1990) and measurements of vegetation height and density.

In 1997 and 1998, efforts were also made to try to assess the proportion of the pairs present in each field that were actively nesting and so to assess the lengths of the active breeding seasons in different crop types. Areas of around 5 ha (the maximum area over which it was thought possible to detect signs of active nesting from a single vantage point), comprising either whole fields or parts of larger fields, were selected from a wide range of crop types. The areas covered were selected randomly within each main crop type subject to the proviso that all parts of each could be clearly seen from a single vantage point. During watches of 30 minutes made from the same vantage point, the number of active nesting attempts and the number of birds present were recorded. The detection of nesting attempts followed a standardised set of criteria that had to be met before nesting was assumed, to correct for any possible biases between crop types or observers. Such criteria included seeing birds carrying nesting material returning to the same spot and seeing birds carrying food items returning to either the same spot (chicks assumed to be still in nest) or to different places near each other (chicks assumed to have left the nest). In 1997, 101 5-ha blocks were covered weekly; in 1998 the number of blocks covered was increased to 258 and counts undertaken every two weeks. Crop measurements were taken from ten evenly spaced parts of each 5-ha block after each 30-minute watch using double sward sticks. These measured the height of the vegetation and provided an index of the vertical density of the crop by comparing the heights at which two discs of different diameter were arrested by the vegetation.

In winter, Skylark numbers were counted on the same farms as the breeding study and were related to field structure and crop type to assess habitat preferences (Donald *et al.* in press b). All points in each field were visited to within 50 m and numbers of birds recorded. The direction and numbers of flushed flocks were noted on maps to avoid double counting. Faecal samples were collected to assess diet and soil samples taken and analysed to provide a measure of seed density within the top 5 mm of the soil surface. Faecal pellets were broken up and examined under a x45 binocular microscope following the methods and applying the correction factors of Green (1978).

BTO National Skylark Surveys

The BTO National Breeding Skylark survey (Browne *et al.* 2000) was carried out in 1997. Volunteer observers surveyed 608 1-km squares from a total of 1000 selected using randomised stratified sampling from the National Grid. Squares selected were stratified using the Institute of Terrestrial Ecology's (ITE) Landscape Classification (Barr *et al.* 1993) such that each of four broad landscape types (arable, pastoral, marginal upland and upland) was represented in the final sample of squares in the same proportion as they are found at the national level. This approach avoids over- or under-estimating the population of a species by sampling a disproportionately high number of squares from one particular habitat type. Observers visited each part of each square four times, with visits evenly spread between mid-April and mid-June, and mapped the locations of all singing Skylarks on recording forms. Detailed habitat information was collected for each square by dividing squares into distinct habitat patches, and allocating each patch a standard BTO habitat code (Crick 1992).

An intensive survey of breeding Skylarks was also carried out (Chamberlain *et al.* 1999), following Common Birds Census methods (Marchant *et al.* 1990) on 59 farmland plots in lowland England. Plots averaged 72 ha in size and were visited ten times between late March and early July. All observations of singing Skylarks were plotted onto large-scale (1:2500) maps. In addition to habitat data recorded as for the national survey crop heights were recorded for each visit classified into one of five categories: bare ground, <10 cm, 10-30 cm, 30-50 cm and >50 cm.

The BTO National Wintering Skylark survey was carried out in the winter 1997/98 (Gillings & Fuller in press). As for the breeding survey, the sampling units were 1-km grid squares that were selected using a stratified random sampling approach from within the Skylark's winter range. Squares were stratified using ITE Landscape Classification into four landscape types: arable, pastoral, marginal upland and saltmarsh. Saltmarsh was included as a separate category in the winter survey since there was evidence from the Winter Atlas (Lack 1986) that this habitat held high concentrations of birds. Three evenly spaced visits were made to each square between mid-November and mid-February, and bird and habitat recordings were carried out in each distinct habitat patch. All areas of each patch were approached to within 150 m and the number of Skylarks on each recorded. Detailed habitat information was collected as for the breeding survey, although the standard BTO habitat codes were expanded to cover additional winter habitats.

RESULTS

Distribution by crop of breeding Skylarks in the UK

Results of the BTO national survey suggested a UK breeding population of around one million pairs (Browne *et al.* 2000). Of these, 71% were associated with lowland farmland and around 50% with arable land (Table 1), clearly demonstrating the importance of tillage to this species. The results of the BTO national survey supported the finding of other studies (e.g. Wilson *et al.* 1997, Henderson *et al.* 1998, Poulsen *et al.* 1998, Vickery & Buckingham in press) that set-aside holds significantly higher densities of breeding Skylarks than other farmland habitats, including cereals (Table 1). However amongst those other farmland habitats, cereals did not hold lower densities than other field types, the perceived low densities of Skylarks in cereals arising through comparison only with set-aside (Chamberlain *et al.* 1999). Furthermore Chamberlain *et al.* (1999) found that cereal fields, particularly spring-sown cereals, had high rates of occupancy by Skylarks relative to other arable field types at the national scale. When densities were multiplied by the relative areas of each crop type, the very large area of cereals meant that cereals held higher overall numbers of Skylarks than any other crop type in England and Wales and higher numbers than any habitat other than grazed pasture in Scotland (Table 1). Cereals held 40% of farmland Skylarks in England and Wales and 34% in Scotland, whereas set-aside held only around 10%. There was a significant positive correlation across ten UK regions between mean Skylark territory density and the proportion of each region made up by cereals (Fig. 2). Although this relationship may not be causal, it does demonstrate the association of high Skylark densities with cereal-dominated landscapes.

Temporal changes in territory density in cereals

Results from the RSPB standardised watches revealed a significant decline during the breeding season in the territory density of Skylarks in cereals, densities in July being around half those in April (Fig. 3). Previous authors (e.g. Schläpfer 1988, Jenny 1990, Wilson *et al.* 1997) recorded similar temporal patterns of territorial activity and attributed them to rapid crop development, the higher and denser sward structure of modern autumn-sown cereal fields becoming unattractive or unsuitable for

Table 1. Territory densities (territories per ha) of Skylarks in different crop types, the percentage of farmland made up by each crop type and the percentage of total Skylark population found in each crop type. Data for Scotland are presented separately owing to differences in the way agricultural statistics are collected. Crop data from MAFF (1998) and Scottish Office (1998), Skylark data from BTO National Breeding Skylark Survey (Browne *et al.* 2000).

Crop	Density	% area	% of population
England & Wales			
Cereals	0.108	30	40
Improved grass	0.054	47	31
Set-aside	0.296	3	10
Rough grazing	0.059	10	7
Root crops	0.119	3	5
Brassicas	0.095	4	4
Legumes	0.129	2	3
Scotland			
Grazed pasture	0.084	45	39
Cereals	0.115	28	34
Mown grass	0.076	19	15
Set-aside	0.360	2	9
Brassicas	0.051	4	2
Root crops	0.054	2	1

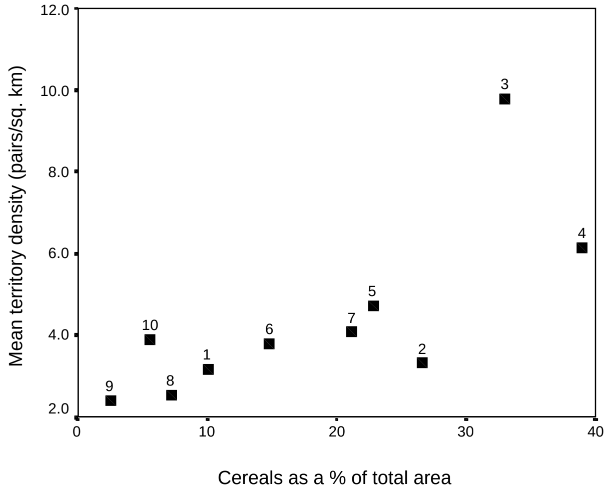

Figure 2. Relationship between Skylark territory density and extent of cereals as a percentage of total regional area in ten regions of the UK in 1998 (r_s = 0.77, n =10, P < 0.01). Regions follow the standard NUTS (Nomenclature of Terrestrial Units for Statistics) regions of the EC (1 North England, 2 Yorkshire/Humberside, 3 East Midlands, 4 East Anglia, 5 South-east England, 6 South-west England, 7 West Midlands, 8 North-west England, 9 Wales, 10 Scotland). Skylark data from BTO National Breeding Skylark Survey (Browne *et al.* 2000), cereal data from MAFF (1998) and Scottish Office (1998).

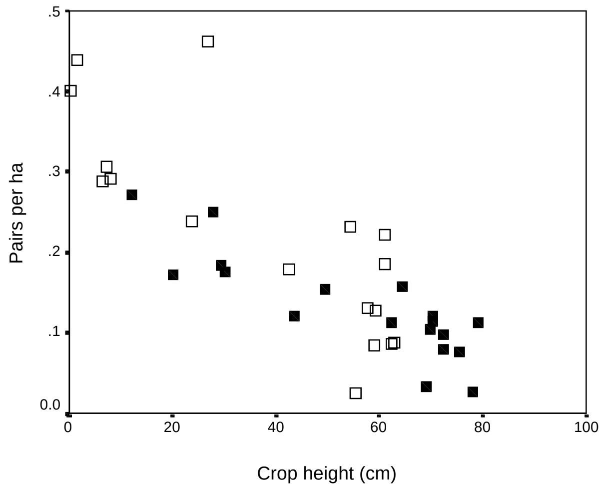

Figure 4. Relationship between Skylark territory density and crop height in autumn-sown (closed symbols) and spring-sown (open symbols) cereals (r_s = -0.82, n = 35, P < 0.0001). The intercepts and slopes of least squares linear regressions of transformed density on crop height for the two types of cereal separately did not differ (t_{34} = 1.47, ns). Points represent 2-weekly means from 2 breeding seasons (1997 and 1998). Each point represents the mean of a large number (mean = 46) of fields. Data from RSPB Skylark Project.

Skylarks as nesting habitats early in the breeding season. Results from the BTO breeding Skylark survey lent further support to the suggestion that this is linked to rapid crop development in modern autumn-sown cereals (Chamberlain *et al.* 1999). The probability of occupancy by Skylarks was found to be significantly higher in crops shorter than 30 cm than in taller crops. Vegetation height increased with season in all crops but autumn-sown cereals reached a height of 30 cm approximately 23 days earlier than did spring-sown cereals and, as a result, became less suitable much earlier in the season.

Although population densities declined during the breeding season in both cereal types, densities were higher in spring-sown cereals throughout the season. This was found by both the RSPB project (Fig. 3) and the BTO surveys (Chamberlain *et al.* 1999). A plot of territory density on cereal height (Fig. 4) revealed a very strong correlation between the two, although it should be noted that the points are not statistically independent since each relates to a particular 2-week period during one of two breeding seasons. However, the plot suggested that the observed differences in territory density between spring- and autumn-sown cereals could be explained entirely in terms of differences in crop height, since points for both cereal types fell along the same regression line. Furthermore, within the observed range of crop heights, the relationship was linear.

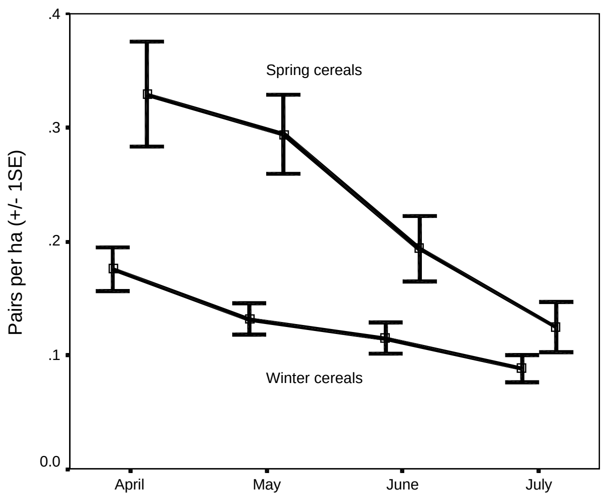

Figure 3. Seasonal changes in Skylark territory density (pairs/ha, ± 1 se) in spring- and autumn-sown cereals. ($F_{5,684}$ = 50.4, P < 0.0001). Data from RSPB Skylark Project.

Cereals as a nesting habitat

Results from the RSPB's standardised watches showed that, although territory density in both cereal types declined with increasing crop height during the breeding season, the proportion of birds present that were recorded as actively breeding actually increased (Fig. 5). In this case the intercepts of regressions differed significantly between autumn- and spring-sown cereals, with a higher proportion of birds present in spring-sown cereals actively nesting at a given vegetation height than was the case in autumn-sown cereals. The reasons for this difference are unclear but may be related to lower pesticide applications and consequently greater food abundance, or to differences in sward structure between winter and spring crops and

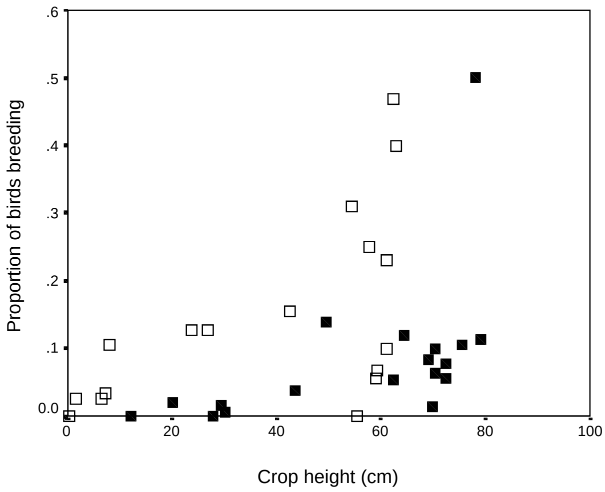

Figure 5. Relationship between proportion of Skylark pairs actively nesting and crop height in spring-sown (open symbols; $r_s = 0.63$, $n = 17$, $P = 0.007$) and autumn-sown cereals (closed symbols; $r_s = 0.7$, $n = 18$, $P = 0.001$). ANCOVA using general linear modelling with weighted binomial errors revealed a highly significant difference in the intercepts (but not the slopes) of spring- and autumn-sown cereals ($\chi^2 = 32.7$, df = 1, $P < 0.0001$). Points represent 2-weekly means from 2 breeding seasons (1997 and 1998). Each point represents the mean of a large number (mean = 46) of fields. Data from RSPB Skylark Project.

consequently differences in food availability (both were noted by Odderskær *et al.* 1997a,b). The higher proportion of birds breeding later in the season seemed likely to be due to non-breeding birds leaving the crop or ceasing to hold territories, leaving only those birds attempting later nests. As no significant increase was detected in the density of birds in other crops, it was assumed that birds leaving cereals moved to non-farmland habitats or, more likely, became undetectable due to a cessation of breeding activity and territoriality.

There were no significant differences between nests in cereals and set-aside in egg volume, hatching rates or partial brood starvation, although nests in cereals had significantly smaller clutch sizes than those in set-aside in one month (May) of the breeding season (Donald *et al*. in press a). This suggests that the intensive management of cereal crops does not adversely affect these parameters when compared with unmanaged set-aside. Mayfield models showed that nest survival rates were significantly higher in cereals than in other crops, including set-aside, owing primarily to lower rates of predation (Table 2). This meant that nests in cereals were the most productive in terms of the number of chicks produced per nest (Table 2), despite their slightly lower average clutch sizes. The reasons for this are unclear but stem largely from the high predation rates in set-aside, possibly the result of density-dependent predation. The higher productivity of Skylark nests in cereals reflected the findings of Weibel *et al.* (unpubl.) who, with a similarly large sample size from Switzerland, also found the highest nest survival rates to be in cereals. However Wilson *et al.* (1997), from a smaller sample, found nest survival rates to be higher in set-aside than in cereals.

Although the productivity of nests was higher in cereals, it is important to stress that, owing to the rapid fall in territory densities in cereals during the breeding season, there are likely to be differences between crops in the number of nesting attempts made in a season. Several studies have shown that densities in set-aside remain relatively unchanged through the breeding season, suggesting that there is at least an opportunity for more broods in that habitat. It is possible that the opportunity for more nesting attempts in set-aside compensates for low nesting success at the scale of the individual nest (P.F. Donald unpubl.).

The growth and development of cereal crops appeared to have a significant effect on the location of nest sites, with a marked trend towards nesting next to tramlines (the bare, permanent tractor tracks found in most modern cereal fields) as the crop developed during the breeding season (Fig. 6). This result was not related to ease of nest-finding, since nests were found not by cold searching but by observation of nesting activity; once a nesting attempt

Table 2. Nest survival rates and numbers of chicks produced per nesting attempt in four main crop types. Nest survival rates (expressed here as the percentage of nests surviving to produce at least one chick) were calculated using Mayfield modelling and differed significantly between crops ($\chi^2 = 11.9$, df = 3, $P < 0.001$). The number of chicks produced per nest was calculated by multiplying the nest survival rate by mean clutch size and adding factors to control for failure of eggs to hatch and partial brood losses to starvation. The crop category "Other" includes a relatively small number of nests found in a variety of habitats, such as broadleaved crops, grassy tracks and field margins. Data from RSPB Skylark Project.

Crop	*n*	Nest survival rate (%)	Chicks produced per nesting attempt
Cereals	192	38.2	1.25
Grass	196	19.2	0.63
Set-aside	545	21.8	0.78
Other	62	28.5	0.97

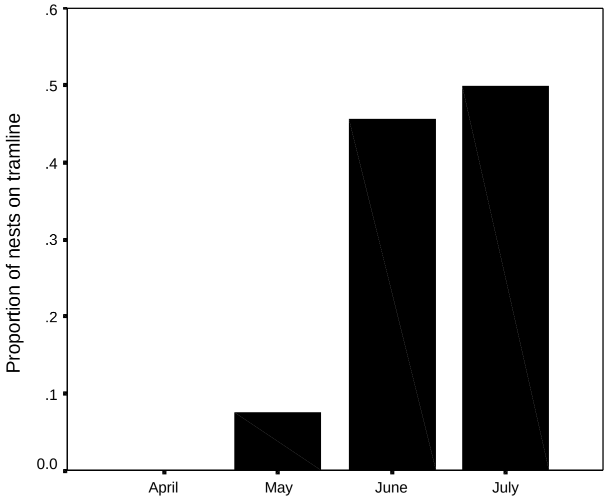

Figure 6. Changes in the position of Skylark nests in cereal crops. Bars represent the proportion of nests built within 10 cm of a tramline. Sample sizes were 25, 83, 65 and 24 for April to July respectively. There was a highly significant difference between months in the proportion of nests built on tramlines ($\chi^2 = 30.4$, df = 3, $P < 0.0001$). This trend was probably even more pronounced than the data suggest, since nests nearer tramlines suffered higher predation rates (see text) and were thus less likely to be found. Data from RSPB Skylark Project.

had been detected, for example through birds carrying food to nestlings, the nest was almost always found. A lower proportion of nests in spring-sown cereals was built on tramlines than was the case in autumn-sown cereals ($\chi^2 = 11.6$, df = 1, $P < 0.001$), probably a result of the sparser sward structure of spring-sown crops. Over the whole season, 34% of all nests found in autumn-sown cereals were built next to tramlines whereas in spring-sown cereals this figure was only 8%. These figures are likely to be underestimates of the true figures, since nests on tramlines were more likely to be predated before they could be found. The distance of the nest to the nearest tramline had a significant effect on nest survival rates, with nests nearer to tramlines being more likely to fail during incubation than nests further into the crop ($\chi^2 = 14.6$, df = 1, $P < 0.001$). It thus appears that the rapid development of cereal crops, particularly autumn-sown ones, forces birds to nest in areas where nests are significantly more likely to be predated. It may be this increased risk of nest failure that causes birds to abandon territories as the season progresses. A similar selection of tramlines and of unsown plots or areas of stunted growth within cereal fields and the avoidance of the crop itself by feeding birds was noted by Odderskær *et al.* (1997b) and Schön (1999), despite the fact that the density of invertebrates was higher in the growing crop. This adds weight to the suggestion that the structure of cereal swards is of prime importance in determining field use and nesting success.

The relationship between Skylark breeding population trends and changes in the area of spring-sown cereals in the UK is very striking (Fig. 7). It shows that historical trends are consistent with the results of our research, namely that spring-sown cereals are better for Skylarks than winter-sown cereals. Population levels were stable at high levels when the spring cereal area was around 2.5 million ha and at low levels when the spring cereal area was less than 1 million ha. Between these levels, population size was linearly correlated with spring cereal area. Although a correlation might be expected between these two variables, since both showed similar temporal trends, partial correlation showed that the correlation between spring cereal area and Skylark CBC trend retained significance when the correlation of both with year was controlled ($r_{\text{partial}} = 0.65$, $P < 0.001$). Siriwardena *et al.* (in press) used similar data to suggest that the switch from spring to autumn sowing could explain much of the decline of the Skylark in Britain.

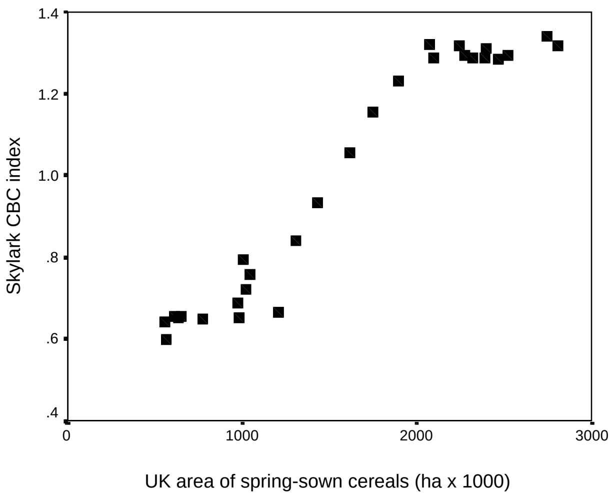

Figure 7. Relationship between Skylark CBC index and UK area of spring-sown cereals, 1968-1996. The two were significantly correlated ($r_{36} = 0.97$, $P < 0.0001$). CBC index from Siriwardena *et al.* (1998), cereal data from Home Grown Cereals Authority (1993).

Cereals as a wintering habitat

Both the BTO national survey of wintering Skylarks and the RSPB study reinforced the results of previous work (e.g. Díaz &Tellería 1994, Wilson *et al.* 1996, Wakeham-Dawson & Aebischer 1998, Buckingham *et al.* 1999) in showing a high degree of selectivity for cereal stubbles, particularly weed-rich stubbles (Fig. 8). However the two surveys differed slightly in their interpretation of the use made by Skylarks of autumn-sown cereals. The BTO national survey suggested that cereals were used in proportion to their availability (Gillings & Fuller in press, Fig. 8), whereas the RSPB project suggested a slight preference for autumn-sown cereals to some other crop types but showed that individual fields were used infrequently (Donald *et al.* in press b). In contrast, Wilson *et al.* (1996) detected strong avoidance by Skylarks of both organic and conventional autumn-sown cereals (although they used these habitats more than did other farmland

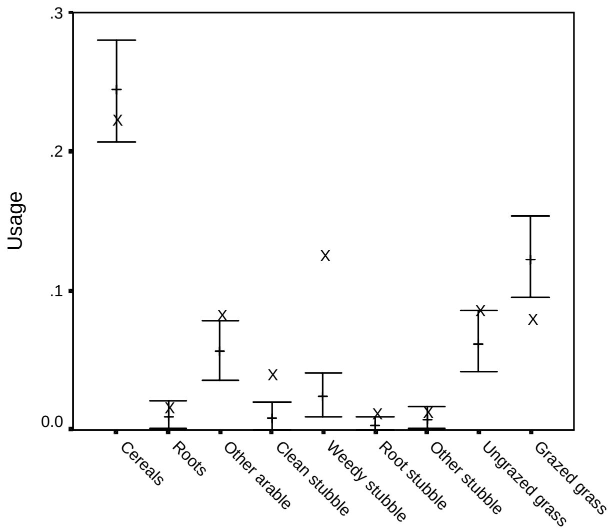

Figure 8. Habitat selection by Skylarks in winter, assessed from a randomisation model. The vertical bars show the expected usage (median with 95% confidence limits) if birds were distributed randomly across all habitat types. The crosses represent the actual usage as recorded in the field. Crosses falling above or below the 95% confidence limits indicate that the habitat was significantly selected or avoided respectively. Data from BTO National Wintering Skylark Survey (Gillings & Fuller in press).

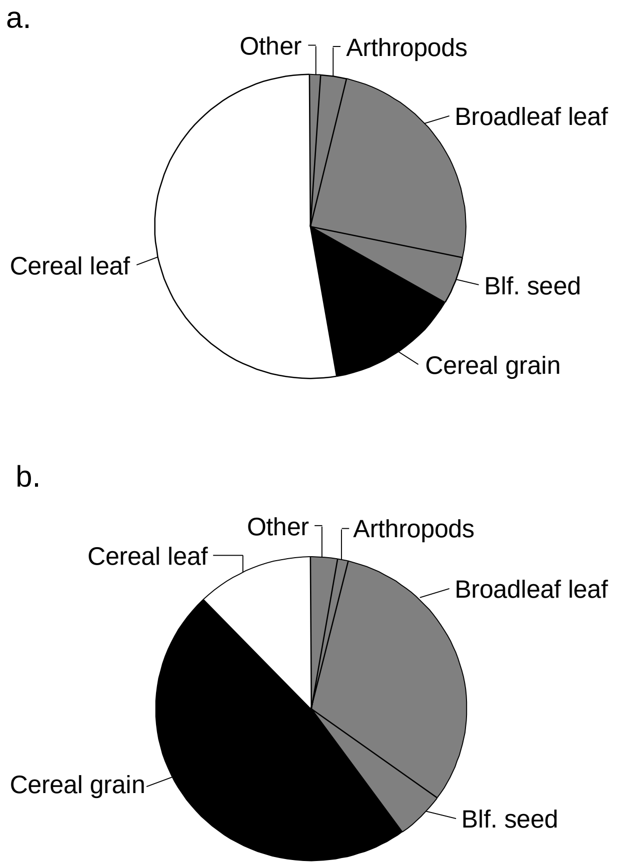

Figure 9. Diet of wintering Skylarks in (a) autumn-sown cereals and (b) cereal stubbles. Data from RSPB Skylark Project (Donald *et al.* in press b).

passerines). Field size was found by both the RSPB and BTO studies to have a significant independent effect on the likelihood of occupancy, with larger fields being preferred to smaller ones. This effect was independent of crop type (Gillings & Fuller in press, Donald *et al*. in press b) and is likely to be related to predation avoidance (Robinson & Sutherland 1997). The RSPB research project detected a significant preference for barley to wheat stubbles (Donald *et al*. in press b), possibly due to the observed higher diversity of weed species and lower cover by cereal volunteers (self-seeding plants) in barley stubbles.

Information on the diet of wintering Skylarks was collected by the RSPB project through the analysis of faecal samples. There were significant differences between crops in the main food items taken and significant seasonal effects within some crops (Donald *et al*. in press b). In autumn-sown cereal crops, the diet consisted mostly of cereal leaf, although a far higher proportion of the diet consisted of broadleaved plant leaves in early winter than were available on the ground, suggesting strong selection for the latter (Fig. 9a). The diet in cereal stubbles comprised mostly cereal grain and broadleaved plant leaves (Fig. 9b). Weed seeds made up only a very small proportion (< 5%) of the diet in all crops, yet both Wakeham-Dawson & Aebischer (1998) and Donald *et al*. (in press b) demonstrated a positive association between weed seed densities and Skylark distribution.

DISCUSSION

Full interpretation of the results of the research described above will be found in the relevant papers presenting the full results of the two projects. In this section, we concentrate on the practical implications of these results for the conservation of Skylarks.

This work has shown cereals to be the most important habitat for Skylarks in the UK when measured by a number of criteria. More Skylarks were found in cereal crops than in any other habitat, and productivity at the scale of the individual nest was highest in cereals. Cereal stubbles provided the most strongly selected winter habitat for Skylarks. Since the proportion of UK land area given over to cereals is very close to the average of the other Member States, cereals may also be the single most important habitat for Skylarks throughout the EU in terms of numbers supported. However territory densities are generally low compared with set-aside and some non-farmland habitats, and the breeding season is shortened as the crop becomes unsuitable for nesting relatively early in the breeding season. If recent declines have been caused by a decline in productivity, this curtailment of the breeding season in winter cereals is likely to be the main factor involved, since there was no decline in the productivity of individual nests during the period of decline (Chamberlain & Crick 1999). Given their large area and the high productivity of individual nesting attempts in cereals, beneficial changes to the way cereals are managed are likely to prove an effective way of conserving this species. Such changes could be aimed at increasing overall densities of birds in cereals throughout the breeding season and reducing the observed seasonal decline in territory density. Furthermore our results suggest several management changes that could be encouraged to improve conditions for wintering birds.

Compared to autumn-sown cereals, spring-sown cereals support higher breeding territory densities, a higher number of breeding attempts per pair per season and a lower proportion of nests exposed to predation on tramlines, due largely to their later structural development (although lower pesticide usage may have an independent effect; Odderskær *et al*. 1997a). Furthermore, spring tillage allows the possibility of winter stubbles, which are not an option in autumn-sown cereal systems. These results all suggest that spring-sown cereals provide a habitat that is better for Skylarks than autumn-sown cereals in a number of different ways. This finding is consistent with the historical relationship between population trends and area of spring cereals (Fig. 7) and the findings of Chamberlain *et al.* (1999), who found that numbers of several declining farmland species, including the Skylark, declined with decreases in the area of spring barley or increases in the area of winter wheat. Spring-sown cereals have fallen to only around 15% of the total UK cereal area (although there are strong regional variations, with spring-sown cereals making up 60% of the relatively small total cereal area in Scotland).

Odderskær *et al.* (1997b) found that artificially maintained open areas of as small as 7 m^2 within cereal crops led to increased territory density and increased length of the breeding season in such crops. Although nest locations were not described in that study, our results suggest that it is possible that the open areas kept birds in the crop by providing safe nest sites away from tramlines. The possibility of using "Skylark scrapes" in autumn-sown cereal crops to maintain numbers of territories later in the season needs further research, particularly with regard to the optimum size, shape and placement of such areas and their financial and practical aspects. The attractiveness of cereal fields to breeding Skylarks might also be improved by placing suitable foraging habitats nearby (e.g. Weibel 1998).

In winter, cereal stubbles, particularly large weed-rich stubble fields, are extremely important feeding habitats, their attractiveness appearing to stem from the availability of spilt grain which makes up much of Skylarks' diet there. Encouraging a shift from autumn to spring sowing of cereals and a return to mixed farming with undersowing would allow for a period of winter stubble that is impossible under winter tillage systems. Although winter stubbles are the most highly selected habitat, large numbers of wintering Skylarks also use autumn-sown cereals, although it is possible that such crops are used largely in the absence of anything better. Broadleaved weed leaves make up a far higher proportion of the diet in autumn-sown cereals than would be expected from their availability, suggesting that birds are actively seeking these out. Restricting winter herbicide use to increase the availability of such plants is likely to have a positive effect on wintering birds. It is likely that the retention of an arable component within grassland systems is likely to improve conditions for wintering Skylarks (Wakeham-Dawson & Aebischer 1998).

The higher densities of Skylarks found on organic farms (e.g. Wilson *et al.* 1997) are likely to result at least partly from the greater habitat diversity and use of spring-sown cereals compared with conventional ones. The absence of spraying could have an independent effect; for example Odderskær *et al.* (1997a) demonstrated significant effects of pesticide applications in cereal fields on the number of nesting attempts made in a season. However, less than 0.4% of total UK cereal area is currently grown organically (Soil Association pers. comm.). Economic incentives designed to encourage the conversion of conventional farms to organic production are likely to prove effective in the conservation of this species. Outside organic farming, there are currently few agri-environment options to encourage winter stubbles or the sowing of spring- rather than autumn-sown cereals. Conservation options in cereal crops include unsprayed headlands or beetle banks under the Countryside Stewardship Scheme and similar measures in a few Environmentally Sensitive Areas (ESAs). Since Skylarks have been shown by many previous studies to avoid tall field boundaries (e.g. Oelke 1968), headlands placed along such boundaries are unlikely to be of much benefit to breeding birds. A special Countryside Stewardship option, aimed at protecting numbers of the rare Cirl Bunting *Emberiza cirlus* in Devon, includes measures to encourage spring-sown cereals and winter stubbles. Since the introduction of this scheme, numbers of Cirl Buntings have increased greatly (Evans 1997). At present there are no nationwide schemes that encourage the use of spring-sown rather than autumn-sown cereals or the leaving of cereal stubbles over the winter. However the Arable Stewardship Scheme, currently being piloted in the West Midlands and East Anglia, offers both cereal stubble and spring-sown cereal options. The results of this paper suggest that the introduction of this or a similar scheme, adequately funded to ensure uptake over large areas of farmland, is likely to be of considerable benefit to the declining Skylark population, and that extensification of cereal management is likely to offer great benefits to Skylarks.

Aside from agri-environment schemes, there are other economic factors that might lead to a return to spring sowing of cereals in the near future. Demographic projections suggest that the demand in Britain for home-produced food in 2015 is likely to be only between 3% and 5% higher than it was in 1987, owing to relatively low rates of population growth, an ageing population and the fact that in affluent societies, increases in prosperity are not correlated with increases in *per capita* food consumption (North 1990). One prediction has estimated that if current trends in productivity continue and predictions of demand hold true, demand in 2015 could be met even if up to 5 million ha of land currently being farmed were taken out of production (North 1990). A likely alternative to the removal of land from production or the subsidising of huge surpluses is a process of extensification, and it seems inevitable that future agricultural policy will increasingly have to encourage less intensive production. Promoting a return to spring tillage is one way this could be achieved to the benefit of Skylarks.

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