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Densities and population estimates of breeding Skylarks *Alauda arvensis* in Britain in 1997

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We present the results of a national survey of breeding Skylarks Alauda arvensis *in Britain in 1997 carried out by the British Trust for Ornithology (BTO). Numbers of Skylarks and land-use types were recorded by volunteers in 608 1-km squares, selected using random stratification based on the Institute of Terrestrial Ecology's (ITE) Landscape Classification to avoid over- or under-sampling particular habitat types. The results suggest a maximum national population of around 1000 000 pairs. This agrees extremely well with the national population estimate of around 1046 000 pairs derived from the Breeding Bird Survey (BBS) of the BTO/Joint Nature Conservation Committee/Royal Society for the Protection of Birds, and provides further evidence for the robustness of the BBS as a national monitoring scheme for common and widespread species. The figure is approximately half that of the most recent published estimate of 2000 000 in 1988–91. However, the scale of this discrepancy is likely to reflect a bias in Atlas field methodology and site selection since there has been a real decline of approximately 9% since 1990. Arable squares supported the highest densities of Skylarks; 4.6–6.0 pairs per km², and 46–49% of the British breeding population was associated with arable areas. Marginal upland and upland areas supported lower densities but still accounted for approximately 34% of the estimated national breeding population. Differences in density at broad habitat scales were reflected in geographical differences across Britain, with southern and eastern arable regions supporting much higher densities than western and northern ones. At a finer scale, Skylarks occurred at highest densities on, and showed highest habitat preferences for, set-aside and various types of ungrazed grassland. Winter cereal, improved grassland and set-aside held the highest proportion of the Skylark population on farmland in England and Wales; grazed pasture, winter cereals and spring cereals held the highest proportion in Scotland.*

The decline in the numbers of Skylarks *Alauda arvensis* in Britain, particularly within agricultural habitats, has been well documented.[1–3] Between 1975 and 1994, the species underwent a national decline of around 55%.[2] Within farmland alone this equates to a loss of approximately three million breeding birds.[4] There is increasing evidence that the decline in Skylarks has been caused by widespread changes in agricultural practices in Britain since the mid-1970s. Such changes include the simplification of crop rotations, the increased use of pesticides, more intensive grassland management and a shift from spring- to autumn-sown cereals.[1,5,6] Similar declines have been recorded for a range of farmland birds, many of which have also undergone marked range contractions (e.g. Grey Partridge *Perdix perdix*, Tree Sparrow *Passer montanus*[1] and Corn Bunting *Miliaria calandra*[7]). In contrast, the decline in Skylark numbers has been accompanied by a relatively small (< 5%[1,8])

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reduction in range, and the species remain widespread in most open country habitats throughout Britain and Ireland. However, most research to date has focussed on farmland populations,[4,9,10] and comparatively little is known about habitat selection or trends in numbers or densities elsewhere in Britain, particularly within the large upland populations of this species.[11,12]

We present the results of the first national survey of breeding Skylarks in Britain, organized by the British Trust for Ornithology (BTO). Fieldwork was undertaken by volunteers during the breeding season of 1997. The aims were to produce a reliable population estimate against which future estimates could be compared, and to investigate regional and habitat related patterns in distribution and abundance. To date, most single species surveys in the UK have used either (a) random site selection throughout Britain (e.g. used for Rooks *Corvus frugilegus*[13]), (b) semi-random site selection throughout Britain (e.g. one random tetrad within each 10-km square of the National Grid used for Lapwings *Vanellus vanellus*[14]) or (c) semi-random site selection throughout the species range (e.g. one random tetrad within each 10-km square in which the species was recorded breeding in one or both of the breeding atlases used for Corn Buntings[7]). The Skylark survey presented here is the first single species survey to be completed in which survey sites were randomly selected throughout Britain but stratified by landscape type. We outline the rationale and site selection methodology for this approach and present national, regional, landscape type and crop-specific estimates for the mean and maximum Skylark populations and densities. We compare these figures with national estimates derived from two other BTO surveys, the Breeding Atlas[8] and the BTO/ Joint Nature Conservation Committee/ Royal Society for the Protection of Birds, Breeding Bird Survey (BBS),[15–17] that use alternative sample site selection processes and field methodologies. We use data from the intensive 1997 Skylark survey to assess the reasons for observed differences between these figures and consider the strengths and weaknesses of this new survey methodology. Finally we discuss the implications of the results for the conservation of the Skylark in Britain.

METHODS

Fieldwork for the 1997 survey was carried out by over 600 volunteers across Britain. The sampling units used for the survey were 1-km grid squares. A total of 1000 1-km squares was selected and assigned to volunteer fieldworkers who undertook to survey one or more in the summer of 1997.

Selection of 1-km squares

Skylarks are found in most open habitats throughout the UK.[8] The practicalities and costs of surveying one tetrad in every 10-km square, of which there are approximately 2700 in Britain, make this scale of coverage impossible (the survey of Lapwings covered only England and Wales, a total of 1713 10-km squares[14]). Similarly, because the species is so widespread, limiting the squares to those located only within the species range as documented in the Breeding Atlas[8] also results in a prohibitively large number of survey sites. A total of 1000 1-km grid squares was considered a reasonable number for volunteers to cover and these were selected using randomized stratified sampling from the National Grid.

Although Skylarks are present throughout Britain, the distribution documented in the Breeding Atlas[8] suggests densities vary markedly with landscape type. For this reason, squares selected were stratified using the Institute of Terrestrial Ecology's (ITE) Landscape Classification[17,18] such that each of four broad landscape types was represented in the final sample of squares in the same proportion as they are found at the national level. Landscape types are defined by a number of factors, including predominant vegetation types, geology, topography, soil type and climate.[17,18] The landscape types are arable, pastoral, marginal upland and upland, the distributions of which are shown in Fig. 1. The most important advantage of this approach is that it avoids over- or underestimating the population of a species by sampling a disproportionately high number of squares from one particular habitat type. This also overcomes difficulties of a common bias in coverage by volunteers towards the more densely inhabited regions of the south and east of Britain.[19,20] Thus

Figure 1. The broad distribution of (a) arable, (b) pastoral, (c) marginal upland and (d) upland ITE Landscape Types in Britain from Barr *et al.*[18]

fieldwork effort is targeted more effectively and national population sizes can be estimated more accurately.

Habitat data collection

Detailed habitat information was collected for each square, usually prior to the Skylark survey itself. Squares were divided into distinct habitat patches, defined as areas greater than 20 m × 20 m within which the habitat or land-use was relatively uniform. These patches were allocated a habitat code to describe the vegetation and land-use, using a standardized habitat coding system devised for a range of BTO surveys.[21] Habitats were divided into nine major habitat types within which they were classified into two increasingly fine levels (equivalent to levels two and three in Crick[21]). The system developed by Crick[21] was modified slightly to include more detail on farmland habitats (Appendix). In cases where the habitat type was not known, the most general code was used, e.g. farmland, grassland etc. followed by a code for unknown. Grazing pressure, whether by rabbits, deer or livestock, was also recorded, in all open habitats, as either heavy or light. Light grazing was defined as producing an even sward with an average height of greater than 10 cm. Heavy grazing was defined as producing a much shorter sward with an average height of less than 10 cm.

Bird data collection

Observers were asked to visit each square four times, with visits evenly spread between mid-April and mid-June. The locations of all singing Skylarks were mapped onto the recording form. Observers were not required to walk across areas of suitable habitat in order to 'flush' birds, but were asked to use access roads and tracks (or tractor tramlines if no access routes were available) to ensure that the entire square was surveyed for singing birds only. Volunteers were requested to carry out the surveys early in the morning, where possible within two hours after sunrise, but not before. Volunteers were also advised to take approximately two hours to survey a square and to vary the starting point of the route between visits to avoid bias due to time of day and to avoid surveying in poor weather (wet or windy days) when birds are often less active and/or less detectable.

Figure 2. Distribution of 1-km squares that were covered as part of the 1997 national Skylark survey.

Population estimates and data analysis

Population estimates were calculated assuming that a singing Skylark represented a Skylark territory and that the birds are not polygynous.[22,23] National population estimates derived from single species surveys are usually based on the mean number for a survey square/tetrad. However, for species that establish territories and breed late in the season (e.g. Corn Bunting), maximum counts have been shown to be more appropriate.[7] Skylarks have multiple broods and breed from mid-April to

mid-July[21], but the survey methodology, based upon observations of territorial activity (usually male song flights), may have resulted in marked variation in detectability through the season. Since territoriality varies with the stage of breeding, we present both mean and maximum population estimates.

The national population of Skylarks and the confidence limits for this figure were estimated from calculations of the population size in each of the four strata defined by ITE landscape types following Greenwood.[24] The national population estimate, S_{np}, was derived by combining density estimates from each of the four strata using the formula:

$$S_{np} = (S_a \times N_a) + (S_p \times N_p) + (S_m \times N_m) + (S_u \times N_u)$$

where S equals the mean or maximum number of Skylarks per 1-km square on arable (a), pastoral (p), marginal upland (m) or upland (u) and N equals the number of 1-km squares on arable (a), pastoral (p), marginal upland (m) or upland (u) in Britain. Ninety-five percent confidence limits for the national population estimate were derived using a boot-strapping method with 999 repeated simulations.[25] On each run of the boot-strap simulation, the survey data set was randomly resampled with replacement such that the frequency of squares from each stratum was the same as in the 608 squares covered. Hence 999 new values of S_a, S_p, S_m, and S_u were produced to give 999 new estimates of S_{np} in addition to the actual estimate. The 25th highest and lowest values were taken as the upper and lower 95% confidence limits. This estimate was then compared with a national population estimate derived from summing regional population estimates calculated from the sample squares within each of ten regions of Britain. Level one NUTS (Nomenclature of Terrestrial Units for Statistics[26]) regions of the EC were used to divide Britain into ten regions. The population estimate derived for each NUTS region was calculated in the same way as it was for each ITE landscape type. The mean and maximum Skylark population for a given region was estimated from sample squares and multiplied by the number of squares in that region to arrive at a regional population estimate. Analyses were carried out using the SAS statistical package.[27]

Density was also calculated for 27 habitat types defined at the patch level. As very small patches can artificially inflate densities, all patches less than 1 ha in area were omitted. A preference index was calculated for each habitat type based on observed and expected counts. Observed values were taken as the maximum counts only. The expected count per patch was determined by multiplying the observed total per square by (patch area/total area). Observed and expected values were summed for each habitat and the preference index was expressed as observed/expected. Use of a preference index enables a measure of habitat use relative to the general abundance of Skylarks in a square and thus controls for regional differences in abundance at the 1-km level. Statistical analysis of this data set was not possible as the large number of low expected counts would have invalidated χ^2 tests or G-tests.[28] These data have also been used to examine seasonal patterns of territory occupancy in detail and the results of these analyses are presented elsewhere.[29] Habitat and crop-specific population estimates were calculated for individual crop types using derived Skylark density estimates at the national level and the national area of crops taken from June 1997 census summaries undertaken annually by MAFF (England and Wales) and The Scottish Office (Scotland). The agricultural data sometimes differed in definition between the two June census data sets, so estimates were derived for England and Wales separately from Scotland.

RESULTS

Skylark population estimates

A total of 608 1-km squares was surveyed for Skylarks which represented a wide geographic spread across Britain (Fig. 2). Within these squares, 47% were visited four times in the breeding season and 64% were visited at least three times. A small number of arable and pastoral squares were only visited once (17% and 13% respectively), while quite a large proportion of marginal upland and upland squares received single visits only (37% and 49% respectively). Overall, more marginal upland and fewer upland squares were covered than had originally been selected (Table 1), resulting in a significant difference

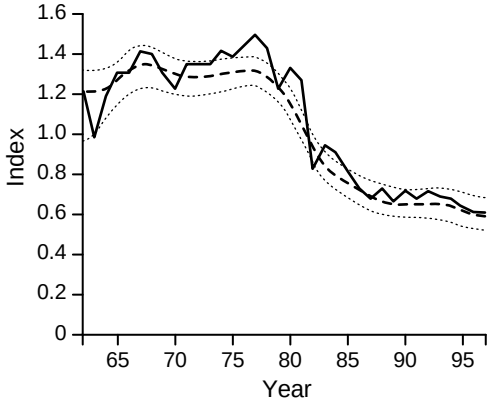

Figure 3. Common Birds Census (CBC) Index for Breeding Skylarks from 1962–97. (—) Chain index; (---) smoothed Mountford Index, (···) 95% confidence intervals of the Mountford Index.

between the proportion of different habitat types covered and the proportion initially selected (Table 1, $\chi^2 = 16.51$, df = 3, $P < 0.01$); thus marginal upland habitats were over- represented and upland habitats were under-represented in the sample as a whole. Estimating national population size from individual landscape types (rather than simply extrapolating to the total number of 1-km squares in Britain) must therefore be used to avoid a bias in the estimate. Within the squares surveyed, there was no bias in the distribution of unsuitable squares, defined as squares with >50% of woodland, urban habitat or water ($\chi^2 = 7.35$, df = 3, $P < 0.10$).

Mean and maximum estimates for the population size of breeding Skylarks in each of the four ITE landscape types are given in Table 2. The greatest proportion of the national Skylark population was associated with arable landscapes which accounted for around 40% of the squares surveyed but supported c. 45% and c. 49% of the mean and maximum national population respectively. This equates to a mean population density of 4.55 pairs per 1-km square and a maximum of 5.97 pairs per 1-km square in arable areas. Lowest densities were recorded in the uplands: a mean and maximum of 2.46 and 2.69 pairs per 1-km square. The fact that a large number of upland and marginal upland squares were only visited once may have resulted in an underestimate of the upland densities and population size. There was a significant difference between the mean density of Skylarks recorded on upland and marginal upland squares visited once (2.92 ± 0.56, n = 86) compared to squares visited more than once (3.13 ± 0.39, $n = 118$, $t_{85,117} = 1.51$, $P < 0.05$), which may indicate later nesting activity at higher altitudes given that single visits tended to occur early in the season. Upland populations may be underestimated due to this bias, although the error according to the ratio of the above densities is fairly small (6.7%). Summing the population estimates for the four landscape types results in a mean national Skylark population of 800 541 pairs (95% confidence intervals 737 783 and 861 321) and a maximum of 1002 651 (95% confidence intervals 925 130 and 1077 675).

The numbers of 1-km squares surveyed in each NUTS region are given in Table 3. The resulting national population estimates derived from summing population estimates for the different NUTS regions (Table 3) were not

Table 1. The number and percentage of 1-km squares in each of the four ITE Landscape Types that were initially selected as Skylark survey squares and the number and percentage that were actually surveyed for Skylarks in 1997.

	Squares selected		Squares surveyed		
ITE Landscape Type	Number	%	Number	%	Expected
Arable	349	34.9	207	34.0	213
Pastoral	280	28.0	197	32.4	170
Marginal upland	147	14.7	104	17.2	89
Upland	224	22.4	100	16.4	136
Total	1000	100	608	100	608

Expected, the number of survey squares that would have been surveyed if the proportions surveyed in the four Landscape Types were exactly as in the initial selection.

Table 2. The mean and maximum (plus 95% confidence intervals) population size and density (pairs per 1-km square) of Skylarks in four ITE Landscape Types and the resulting national population size derived from these four estimates. The number of squares in each Landscape Type are: arable = 81 488; pastoral = 70 593; marginal upland = 70 593; upland = 49 829; one singing male is assumed to represent one territory, i.e. one breeding pair.

	Mean population and density				Maximum population and density			
		Confidence limits		Density		Confidence limits		Density
ITE Landscape Type	Population estimate	Lower	Upper	pairs/1-km square	Population estimate	Lower	Upper	pairs/1-km square
Arable	370 731	349 572	390 283	4.55	486 959	458 616	514 516	5.97
Pastoral	169 734	169 525	183 261	2.40	228 262	211 062	245 821	3.21
Marginal upland	137 456	126 607	148 671	3.60	154 385	139 350	166 854	4.03
Upland	122 621	106 593	139 106	2.46	133 043	116 101	150 483	2.69
National total	800 541	737 783	861 321		1002 651	925 130	1077 675	

Table 3. The maximum and mean (plus 95% confidence intervals) population size and density of Skylarks (pairs per 1-km square) and in the ten NUTs regions in Britain and the resulting national population size derived from these estimates.

	Mean					Maximum			
				95% Confidence limits				95% Confidence limits	
NUTS region	Number surveyed	Population estimate	Density	Lower	Upper	Population estimate	Density	Lower	Upper
Scotland	183	283 130	3.33	261 034	305 947	330 743	3.89	302 927	357 287
North England	37	42 169	2.66	34 527	48 130	50 095	3.16	42 845	57 414
Yorkshire/Humberside	33	41 132	2.71	35 914	46 070	50 439	3.31	44 154	56 113
East Midlands	36	120 034	7.45	102 453	133 558	157 414	9.77	135 609	176 784
East Anglia	29	63 622	4.86	54 508	72 940	80 378	6.14	69 969	91 637
Southeast England	104	96 844	3.42	88 332	103 647	133 373	4.71	121 709	144 852
Southwest England	66	70 539	2.89	62 222	76 799	92 262	3.78	80 990	100 960
West Midlands	38	38 656	3.02	34 751	43 228	52 096	4.07	46 147	57 600
Northwest England	23	15 076	1.97	11 424	18 744	19 285	2.52	14 973	23 292
Wales	59	45 263	2.09	39 827	50 411	52 193	2.40	46 618	57 997
National total	608	816 467		724 991	899 476	1018 081		905 943	1123 935

significantly different from the population estimates derived from ITE landscape types; NUTS regions: mean of 816 467 (95% confidence intervals 724 991 and 899 476) and maximum of 1018 081 (95% confidence intervals 905 943 and 1123 935). This similarity in figures, despite the fact that the sample was not stratified by region, may reflect the fact that a large proportion of squares in a number of individual NUTS regions fall into the same ITE landscape type. For example the east Midlands, East Anglia and southeast England are all >75% arable; southwest England and northwest England are both >80% pastoral and west Midlands, Wales and Scotland are 60% pastoral, 56% marginal upland and 50% upland respectively. Thus NUTS regions may in fact be a reasonable approximation to the ITE Landscape Classification.

Population estimates, density and preference in different habitats

Mean densities were determined for 27 habitat types defined at the level of the individual habitat patch (Table 4). The lowest densities

Table 4. Habitat preferences and densities (pairs per km^2) of Skylarks based on the total number of counts per square and the proportion of the square occupied by a given habitat. Indices are calculated as sum observed/sum expected using maximum counts per visit over a given period. Sample sizes (number of squares) are given in parentheses and include zero counts for density estimates, but exclude cases where both observed and expected values were zero for the preference index.

Habitat	Density ± sd	Preference index
Bog	3.43 ± 6.92 (21)	0.54 (16)
Brassicas (including oilseed rape)	8.97 ± 13.80 (87)	0.94 (77)
Cattle pasture, lightly grazed	4.71 ± 11.52 (98)	0.74 (69)
Cattle pasture, heavily grazed	4.64 ± 10.48 (142)	0.88 (107)
Coastal (e.g. sand dunes, saltmarsh)	14.05 ± 24.63 (12)	0.80(9)
Chalk downland and other dry semi-natural grassland	16.33 ± 36.21 (36)	1.55 (29)
Dry heathland	7.86 ± 19.90 (93)	1.17 (54)
Improved ungrazed pasture	8.42 ± 21.08 (244)	1.24 (170)
Improved grazed pasture	2.99 ± 7.56 (93)	0.59 (76)
Legumes	12.51 ± 19.00 (56)	1.35 (51)
Mixed heathland	6.99 ± 17.68 (62)	0.96 (32)
Moorland	12.95 ± 23.08 (64)	1.53 (46)
Miscellaneous natural grassland	6.22 ± 22.83 (19)	0.67 (15)
Miscellaneous cereals (e.g. triticale, rye etc.)	9.87 ± 15.68 (106)	1.14 (89)
Other/unspecified habitats	5.16 ± 13.10 (69)	0.97 (57)
Root crops	10.82 ± 24.37 (66)	1.09 (57)
Spring cereals	12.22 ± 17.91 (99)	1.30 (93)
Scrub	4.75 ± 16.20 (134)	0.86 (99)
Set-aside	30.61 ± 35.68 (55)	2.15 (52)
Sheep pasture (lightly grazed)	5.00 ± 10.72 (79)	0.94 (44)
Sheep pasture (heavily grazed)	3.75 ± 10.00 (157)	0.52 (92)
Suburban	1.48 ± 7.24 (233)	0.36 (153)
Unimproved ungrazed grassland	7.02 ± 21.11 (95)	1.41 (78)
Unimproved grazed grassland	0.62 ± 2.93 (44)	0.98 (95)
Winter cereals	10.73 ± 13.37 (209)	1.05 (182)
Wet heathland	3.94 ± 7.81 (43)	0.86 (20)
Woodland	1.99 ± 20.85 (309)	0.29 (215)

occurred in suburban land, woodland and all types of grazed pasture and winter cereals. Amongst the highest densities were set-aside, chalk downland, coastal and moorland habitats. Habitat preference indices were determined by comparing expected and observed maximum frequencies per patch (Table 4). Set-aside and chalk downland had the highest preference indices, a result that concurred with the density estimate. Legumes and spring cereals had the highest preference indices of the crop types considered. Winter cereals, one of the more common nesting habitats for Skylarks,[4] had a preference index close to 1, indicating this habitat is neither preferred nor avoided. The least preferred habitats were suburban land, woodland, bog, grazed improved pasture and heavily grazed sheep pasture.

Crop-specific densities were used to calculate population estimates for specific agricultural habitats by multiplying density estimates by national crop and grass areas derived from June census data. Density estimates and crop areas were derived separately for England and Wales and for Scotland, as crop types were defined differently in the different countries. Densities were calculated as the total (maximum) number of Skylarks counted in a habitat divided by the total area of that habitat surveyed (we do not consider between-patch variation as was done in Table 4). Population estimates for specific crop types are shown in Table 5. In England and Wales, winter cereal held the largest proportion of the population. Improved grassland held the second largest population, despite occupying by far the largest area, indicating the relative

Table 5. Crop-specific population estimates for Skylark in England and Wales and in Scotland. Population sizes were estimated by multiplying mean density (birds/ha) for a given crop and the total area (ha) occupied by that crop within each region. Crops are presented in order of population size. Crop areas were derived from MAFF June census summaries for England and Wales and by The Scottish Office June census summaries for Scotland.

Crop type	Crop area (%)	Mean density	Population estimate (%)
England and Wales			
Winter cereals	2670 167 (27)	0.103	275 027 (34)
Improved grassland	4622 877 (47)	0.054	249 635 (31)
Set-aside	263 906 (3)	0.296	78 116 (10)
Rough grazing	983 503 (10)	0.059	58 027 (7)
Root crops	336 975 (3)	0.119	40 100 (5)
Brassicas	396 626 (4)	0.095	37 679 (4)
Spring cereals	223 965 (2)	0.129	28 891 (4)
Legumes	194 644 (2)	0.129	25 109 (3)
Other cereals	93 209 (1)	0.196	18 269 (2)
Scotland			
Grazed pasture	781 660 (45)	0.084	65 480 (39)
Winter cereal	195 143 (11)	0.141	27 488 (17)
Spring cereal	278 801 (16)	0.096	26 829 (16)
Grass for mowing	323 000 (19)	0.076	24 571 (15)
Set-aside	40 175 (2)	0.360	14 458 (9)
Brassicas	670 78 (4)	0.051	3409 (2)
Root crops	43 459 (2)	0.054	2366 (1)
Other cereals	8806 (1)	0.142	1254 (1)

unsuitability of this habitat. Set-aside covered only 3% of farmland area, but held almost 10% of the population, indicating how important this highly preferred crop is in terms of the national farmland population. Crop-specific population estimates for Scotland are shown in Table 5. Grazed pasture held by far the largest proportion of the population, and also occupied by far the largest area. Winter cereals and spring cereals held similar numbers, the latter crop being relatively more common in Scotland than in England and Wales. Set-aside occupied only 2% of the farmland area, but held an estimated 9% of the farmland population. The combined crop-specific population estimates, particularly for England and Wales (Table 5), are high relative to the overall estimates (Table 3) and are likely to have been over-estimated due to differences in habitat definition used between the habitat survey used here and the MAFF June census. They are likely to give reasonable relative estimates for crops where definitions were constant between the two data sets, particularly cereals and set-aside, but estimates will be less reliable for habitat categories where the MAFF definition included a large number of habitat types which differ in their suitability to Skylarks, especially grassland.

DISCUSSION

The results of the 1997 Skylark survey suggest a mean national population of approximately 800 550 breeding pairs and a maximum of approximately 1002 650. The confidence intervals of this estimate are relatively small, differing from the population estimate by only 5–7%, and comparable with those of surveys of Lapwing[14] and Wood Warblers *Phylloscopus sibilatrix*.[30] At the regional and landscape type scale the highest densities of Skylarks were associated with southern and eastern Britain, particularly East Anglia and the east Midlands while the lowest densities were associated with northern and western Britain particularly northwest England, Yorkshire/Humberside and the west Midlands. These regional patterns reflect differences in landscape type within these regions, highest densities being associated, in general, with arable areas. At a finer spatial scale, Skylarks were recorded at highest

densities on semi-natural and natural grassland and set-aside, and exhibited the strongest preferences for these habitats, as well as moorland, spring cereals and legumes. Within farmland, winter cereals, improved grassland and set-aside held the highest numbers of Skylarks in England and Wales, and grazed pasture, winter cereals and spring cereals held the highest numbers in Scotland.

Comparison of Skylark population estimates with estimates derived from the BBS

Results for both the national and arable population size can be compared with the Breeding Birds Survey (BBS). This is a UK-wide, extensive, volunteer-based, annual survey in which survey squares are selected as a random sample stratified by observer density from within large sampling regions in the UK.[15,16] The survey methods use sampling transects visited twice in a breeding season from which densities are estimated. The national population estimate derived from BBS for 1995, following the approach of Gregory & Baillie,[20] was 2200 000 birds (95% confidence intervals 2000 000 and 2400 000, R Gregory pers. comm.) which equates to approximately 1100 000 pairs. Recent BBS results suggest a decline of c. 5% in Skylark numbers since 1995[15,16] resulting in an estimate of c. 1046 000 pairs in 1997, a figure that agrees extremely well with the maximum of 1002 651 derived from the national Skylark population. The results of the BBS[20] (for 1995) found 58% of Skylarks were associated with farmland where the highest densities were on tillage: 19 birds per km^2 (c. 9–10 pairs). For farmland as a whole (means for improved and unimproved grassland, grass-till and till weighted by area[19]) the mean density was c. 15 birds per km^2 or 7.5 pairs per km^2. This compares with an estimated 46–49% of Skylarks found to be associated with arable landscapes from the 1997 Skylark survey at slightly lower densities of 4.55–5.97 pairs per km^2. The close agreement between population estimates for Skylarks derived from the BBS and from the more intensive and targeted survey presented here suggests that the BBS provides good estimates of population sizes and densities of relatively common and widespread birds in Britain. This provides further evidence for the robustness of the BBS as a national monitoring scheme for common and widespread species.

Comparison of Skylark population estimates with estimates derived from the 1988–91 Breeding Atlas

The most recent published figure for Skylark population in Britain is the 1988–91 Breeding Atlas[8] when the population was estimated as around 2000 000 breeding pairs, of which 1348 888 were found on farmland at densities of 11.6 territories per km^2. This is almost double the estimated population size derived from the 1997 Skylark survey (maximum national population 1002 651; maximum arable population 486 959) despite the fact that the CBC Index (Fig. 3) indicates a decline of only c. 9% during this time period (1989–97). This large discrepancy is likely to result from differences in survey square selection and survey methodology.

CBC methods are likely to suggest a higher population for a number of reasons. First, on any one visit it is extremely unlikely that all males present will be recorded, particularly in the case of the 1997 survey in which only singing males were recorded. Thus even using maximum counts from two (BBS) or four (national survey) visits may underestimate the national population size. An indication of the extent to which this may underestimate numbers can be assessed using data from CBC sites. The survey method for these sites involves a greater number of visits (10–12) and uses a mapping technique which uses the location of all birds registered (i.e. not just singing birds) to delineate territories.[22] Comparing the number of territories on all (n = 59) lowland farmland CBC sites in southeast England with the maximum count of singing males recorded on a single visit between mid-April and mid-June, suggests that approximately 16% of territories present will not be recorded; the maximum count of singing males recorded on any one visit (selected at random from all the visits to the square between mid-April and mid-June) to CBC sites (n = 59) was 10.28 ± 14.21 (mean ± sd), compared with an estimated territory number (calculated using observations from all visits to CBC sites) of 11.92 ± 17.81 (mean ± sd) territories km^2 (the difference is not significant z = 0.556 ns). Second, the standard method by which data are extracted from CBC maps[22] may result in a bias towards higher densities of birds since edge/peripheral territories are often included in the total

number of breeding pairs in a given site. Thus a bird with a territory of which 50% lies outside the CBC plot boundary will still be recorded as one territory, not 0.5 (i.e. in relation to the proportion of the sightings within the plot).

Differences in survey square selection may also account for much of the discrepancy. The Breeding Atlas estimate was calculated from CBC data that were collected mainly on farmland plots in the south and east of England (69 farmland plots and four woodland plots[31]). Skylark densities are known to be higher in arable areas[20] and the results in Table 2 provide further support for this, density in arable areas being 4.55 pairs per km^2 compared with the next highest density, on marginal upland, of 3.60 pairs per km^2. Furthermore the CBC plots on which the Breeding Atlas estimate was based were concentrated in the southeast of England, where densities are higher than on farmland elsewhere in Britain. For example, the mean density of territories from 118 arable squares surveyed in the 1997 national survey in the south and east of Britain (survey squares in NUTS regions 74 and 75 plus Lincolnshire) was 4.72 ± 0.44 territories/100 ha (mean ± se). This is significantly higher than the mean in arable squares outside the south and east (n = 89 arable squares); 4.32 ± 0.64 ($t_{88,117}$ = 1.60 $P <$ 0.02). A similar degree of overestimation was evident as a result of the 1993 Corn Bunting survey[7] and this was also attributed to regional bias in the data used in the Breeding Atlas towards regions subsequently shown to support the highest densities of birds. Furthermore, these differences agree with the findings comparing the densities derived from CBC and BBS for seven widespread bird species in British farmland and woodland.[20] In the latter study, different species achieved roughly similar density rankings by both methods but CBC estimates were consistently higher than those derived from the BBS.

Lowland farmland population

The Skylark CBC Index indicates a continuing decline in lowland farmland.[2] The continued decline of Skylarks in areas supporting the highest densities of this species is a cause for concern, particularly since set-aside, which has been shown to be widely beneficial for Skylarks,[4,10,32–34] has now been in place for several years. It is possible that there has been a masked population change and that set-aside has helped to slow a decline that, in its absence, would have been much more rapid. We estimate that set-aside holds approximately 10% of the lowland farmland population, despite covering only 2–3% of farmland area. Densities on set-aside were approaching three times that on other crops. If set-aside was replaced by a crop such as winter wheat, these figures suggest that the Skylark population would decrease by approximately 7%. Close monitoring of numbers of Skylarks and other farmland birds will be important with set-aside set to be phased out by 2000,[36,37] and the results of this survey demonstrate the suitability of the BBS for such monitoring.

Populations in grassland and upland habitats

Although most attention has focussed on arable areas, the survey also highlights the importance of upland and grassland habitats. The 1997 survey showed marginal upland and upland combined supported around 34% of the total breeding population of Skylarks. Within the BBS, semi-natural grassland and heath (which approximate to marginal upland and upland) supported around 33% of the breeding population.[20] High densities of Skylarks were recorded on natural ungrazed grasslands and habitat preferences were apparent for these and moorland habitats. There is very little published information on Skylark population change associated with grassland or upland habitats. However, management of lowland grassland has been transformed during the last 50 years and an increasingly large proportion of natural grasslands has become intensively managed, often including reseeding and drainage operations and high fertilizer input.[37] Evidence from CBC data suggests that, since 1975, Skylark populations in pastoral areas have declined almost as rapidly as those associated with arable areas.[2] The results of this survey highlight the importance of grassland habitats for Skylarks and support suggestions that intensification of grassland management may also have played a role in the recent declines of this and other farmland bird species, although the mechanisms remain poorly understood.[1]

Upland habitats remain under-studied relative to lowland arable areas, but two recent studies both suggest Skylark populations in the uplands may also be declining. Analyses of CBC data between 1975 and 1994 suggest that the Skylark population decline in the uplands started later than on arable land: c. 1980 compared with c. 1975. Although Skylarks have declined at a significantly faster rate in arable than upland areas since 1975, the rate of decline in these two habitats does not differ from 1980 onwards.[2] In addition, recent studies in Sutherland and Caithness suggest an average decline of 12% per year between 1988 and 1995.[12] This represents an overall decline of 81% on unafforested and apparently unchanged peatland sites. It has been suggested that it may be linked to declines in the lowlands as many birds that breed in the uplands winter further south, but the possible causes of such a decline remain poorly understood[12] and require further investigation.

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APPENDIX

Habitat codes and definitions for farmland and set-aside land modified from Crick.[21] The codes, levels and definitions for the remaining eight Habitat Types (woodland, scrubland, semi-natural grassland, dry heath and bog, farmland, human sites, water bodies, coastal and inland rock) are as detailed in ref. 21. (Sugar beet, for example, would be represented by the code E, 4,31 where E = farmland, 4 = tilled land, 31 = sugarbeet.)

Habitat type	Level 1	Level 2	
E Farmland	1 Improved grassland	1 Ungrazed	22 Winter rape
	2 Unimproved grassland	2 Cattle	23 Spring rape
	4 Tilled land	3 Sheep	24 Other brassica
	5 Orchard	4 Horses	25 Winter beans
	6 Other farmland	5 Other stock	26 Spring beans
		6 Bare earth	27 Winter peas
		11 Winter wheat	28 Spring peas
		12 Spring wheat	29 Clover
		13 Unknown wheat	30 Other legume
		14 Winter barley	31 Sugarbeet
		15 Spring barley	32 Potatoes
		16 Unknown barley	33 Carrots
		17 Winter beans	34 Onions
		18 Spring oats	35 Other root crop
		19 Unknown oats	36 Linseed
		20 Rye	37 Maize
		21 Triticale	38 Mixed arable strip
			39 Other non cereal
Z Set-aside	1 Rotational	1 Natural regeneration only	
	2 Non- rotational	2 Natural regeneration and sown grass cover	
	3 Unknown	3 Natural regeneration and sown crop cover	
		99 Unknown	