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Agri-environment schemes - what have they achieved and where do we go from here?

Drivers of population increase on an arable farm delivering a comprehensive suite of measures for farmland birds

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Summary

In 1999, the RSPB purchased Hope Farm near Cambridge, a site with a simple arable crop rotation and a typical associated avian fauna. Since acquisition, the number of breeding territories of the Government's "Quality of Life Farmland Bird Indicator" species has more than doubled, and there has been an increase in species richness. This has been achieved alongside increased profitability. In this paper it is shown that, for a range of indicator species present on the site, substantial increases in bird numbers at the farm- and field-scales can be delivered by implementing a suite of measures that deliver food and nest sites. Most of the measures can now be cheaply implemented as part of Entry Level Stewardship. We examine which measures, or combinations of measures, have been the most effective in delivering population increases in individual species or groups of species and the quantities needed to significantly increase territory densities.

Key words: Agri-environment, entry level stewardship, skylark, chick-food

Introduction

Hope Farm is a 181.4 ha predominantly arable farm situated on the Hanslope series calcareous clay loam at Knapwell, Cambridgeshire. Following the well-publicised decline of many farmland bird species since the 1970's (Gibbons & Reid, 1993; Eaton *et al*., 2009) linked to multivariate intensification of farming (Chamberlain *et al*., 2000; Newton, 2004) the Royal Society for the Protection of Birds (RSPB) purchased the site in 1999 in order to "trial, demonstrate and advocate new farmland management techniques that favour farmland birds". This aim is delivered through a range of research trials (some of which have subsequently been adopted as agri-environment options) and, since 2007, through an Entry Level Stewardship (ELS) agreement. The trials and ELS options provide variously summer and winter food and nesting habitat.

Supporting wildlife whilst minimising adverse impacts on the efficiency of farming operations has been a cornerstone of the work at Hope Farm. Currently, trials and ELS options account for approximately 6% of the cropped area taken out of production, with further ELS management occurring on non-cropped areas (mainly enhanced hedgerow and ditch management), or as part of the cropped area (e.g. skylark plots, low-input grassland). Six percent is likely to be greater than the land area managed for wildlife under a typical ELS agreement. However, as most of the trials and options take place on relatively unproductive field edges, the financial loss to the RSPB has been minimal. The latest figures available show a record return of £47,450 in 2008, with profits at or above the 2000 baseline in all subsequent years (Fig. 1).

Whilst maintaining profitability, the Hope Farm Bird Index (HFBI), which represents the number of breeding territories on the farm of the nineteen species that comprise the Government's "Quality of Life Farmland Bird Indicator", has more than doubled during the RSPB's ownership (Fig. 1). The diversity of bird species present on the farm has also increased. The results highlight to policy makers, the farming community, decision makers and the RSPB membership that commercial arable farming can go hand-in-hand with increasing farmland bird numbers. This paper examines which trial measures and ELS options, or combinations of measures, have been the principal drivers of the substantial increase in the HFBI.

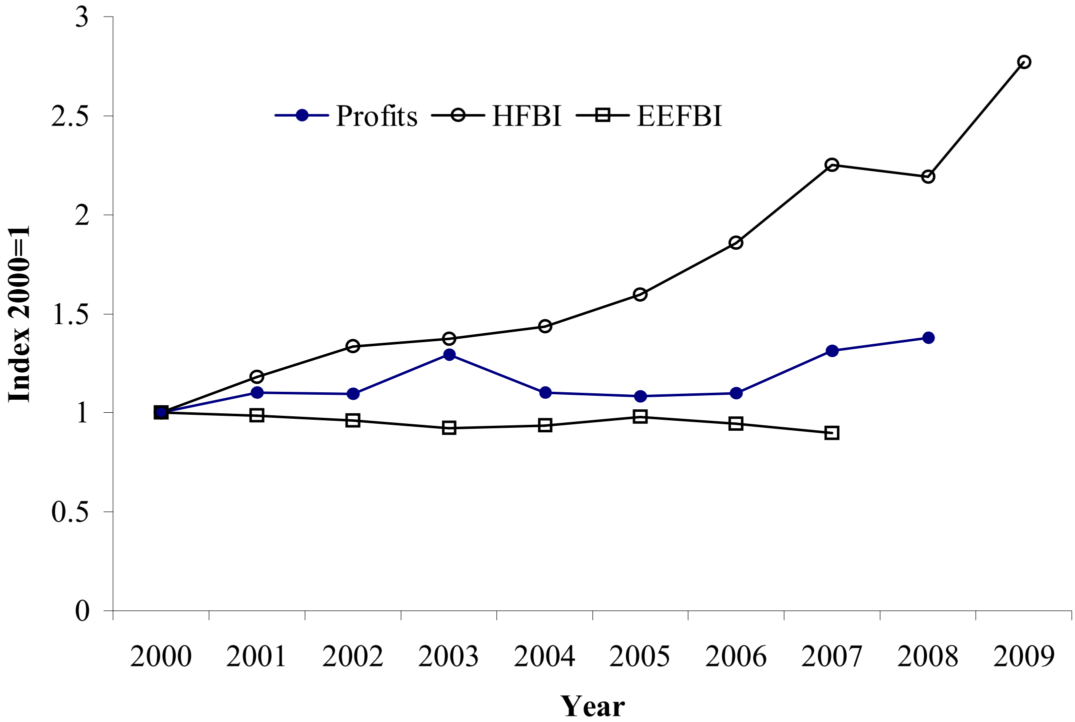

Fig. 1. Trends in HFBI, East of England Farmland Bird Indicator (EEFBI) and Hope Farm Profits.

Materials and Methods

Crops on Hope Farm

Up to the 1970s, Hope Farm was a mixed farm with a beef cattle enterprise grazing about 35 ha of permanent pasture with short-term grass leys integrated into the arable cropping area. Spring sowing occurred on three quarters of the arable land. Spring sowing of arable crops continued into the 1980s with crops including barley and beans but by 1999 all arable crops were autumn-sown. On acquiring the farm, RSPB continued to grow just two arable crops, winter wheat and winter oilseed rape, as part of the overall strategy for land management that included a 2-year period of baseline data collection. Initially arable crops were grown in a three-year rotation (1^{st} wheat, 2^{nd} wheat, oilseed rape). This has now been replaced by a 4-year rotation (wheat, oilseed rape, wheat, spring beans), which includes the reinstatement of spring cropping. A local farmer carries out all farming operations under contract. Since acquisition, the remaining small areas of permanent pasture, grazed by horses and sheep, have remained constant at just over 5 ha. There have been some annual fluctuations in the area cropped but it has averaged 150–160 ha (Fig. 2).

Trials and agri-environment options on Hope Farm

Following an initial period of baseline data collection, experimental trials began in 2001, primarily researching 'Skylark Plots' (Morris 2007), which were conceived and developed at Hope Farm. From 2004, an increasing number of field margin strips (comprising grass buffers, wild bird and pollen and nectar seed mixes) have been introduced (Fig. 2), initially as experimental trials but since 2007 mostly as part of the farm's ELS agreement. Some areas of floristically enhanced

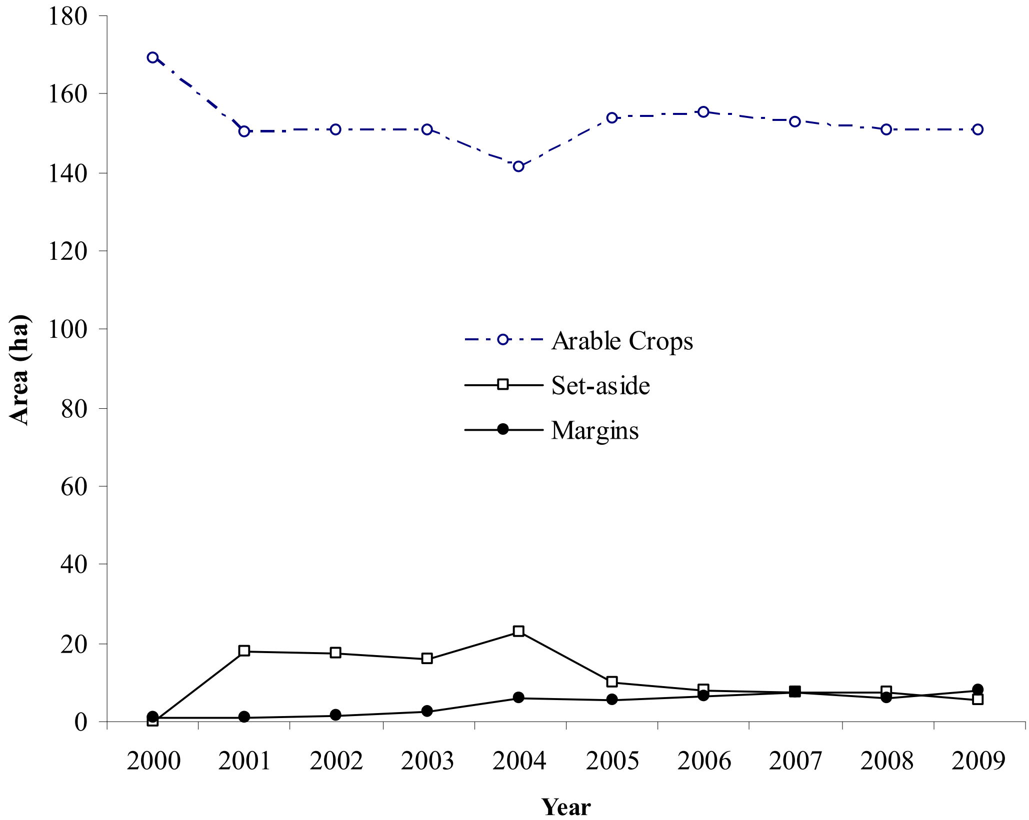

Fig. 2. Areas of arable crops, set-aside and margins at Hope Farm. 'Margins' is a composite measure of grass buffers, floristically enhanced buffers, wild bird and pollen and nectar mixes, beetle banks and strips of unharvested crops. Set-aside area was zero in 2000, as all the area comprised of an industrial oilseed rape crop.

buffers have not been entered into ELS but remain as trial areas, to enable greater flexibility of novel management. Further research trials have included: comparing the bird usage of oilseed rape established by broadcasting and minimum-tillage (Dillon *et al*., 2009*a*), food provision and bird use of two-year rotational set-aside, various unharvested crops and wild bird seed mixes; and monitoring vegetation structure of skylark plots created by spraying with herbicide (Dillon *et al*., 2009*b*).

Up to 2007, a significant proportion of land (approximately 20% of the farmed area in some years) was set-aside on an annual basis to meet EU and trials requirements. The set-aside comprised a mixture of non-rotational field margins and rotational stubbles of one or two year duration. Following the abolition of set-aside at the EU level in 2008, approximately 8% of land was left uncropped in 2008 and 6% in 2009 to accommodate advisory demonstrations and research trials (Fig. 2). This commitment will also allow the farm to support the Campaign for the Farmed Environment, including the target to retain the current area of uncropped land and adopt additional voluntary measures providing habitats such as wild bird seed mixes and grass buffers.

Other non-cropped habitat on Hope Farm

1.2 ha of arboreal habitat is provided by copses. Along with the 8.5 km of hedgerows, these have not changed substantively in area or management since RSPB acquired the farm, although management of the latter now forms part of the ELS agreement. Apart from the research trials above, the only newly created non-cropped habitats are three wet features introduced to provide a dual benefit in terms of reduced diffuse pollution and increased aquatic biodiversity.

Changes in Hope Farm bird population

Common Bird Census (CBC) style monitoring (Marchant *et al*., 1990) provides the basic measure of breeding bird numbers at Hope Farm. Using the same nineteen species that comprise the Government's "Quality of Life Farmland Bird Indicator", a farmland bird index specific to Hope Farm (HFBI) is calculated. The results from the 2009 breeding bird surveys show a continued marked increase with the HFBI now standing 177% higher than in 2000 (Fig. 1). With the exception of 2008, there have been year-on-year increases in the index. Seventeen of the 19 species included within the indicator list have been recorded holding territory in at least one year, with a maximum of 15 in any 1-year. Of particular note are the population increases between 2000 and 2009 of: skylark (*Alauda arvensis*) (10 to 44 pairs), yellowhammer (*Emberiza citrinella*) (14 to 39) and linnet (*Carduelis cannabina*) (6 to 36), all red-listed as Birds of Conservation Concern (Eaton *et al*., 2009). The dramatic rise in the HFBI is in stark contrast with the relatively stable index for the Eastern England region (EEFBI), although caution should be exercised in directly comparing results from the two indices due to differences in calculation that arise from the inclusion of multiple sites (EEFBI) as opposed to a single site (HFBI).

Over the past 5 years, grey partridge (*Perdix perdix*), lapwing (*Vanellus vanellus*) and yellow wagtail (*Motacilla flava*) have become established as regular breeding species. Only tree sparrow and rook out of the 19 Farmland Bird Index species have not recorded at least one territory since 1999. Tree sparrows did breed locally until the 1980's, but are currently absent from the surrounding farmland, and there is little suitable nesting habitat for rook on the farm, although a neighbouring wood does have a large rookery and rooks feed on the farm throughout the year.

Statistical analysis

At the whole-farm scale, correlations between the number of territories of a species (or group of species) and habitat diversity were calculated using Simpson's Reciprocal Index 1/D (Simpson, 1949), so that values closest to one represent the most diverse units:

$$D = \sum \frac{n(n-1)}{N(N-1)}$$

n = total number of parcels of a particular habitat; N = total number of parcels of all habitats.

Three separate simple Generalised Linear Models (GLM) were constructed in SAS (SAS Institute Inc.) to examine whether the annual number of territories varied with: (i) the total amount of habitat (wild bird and pollen & nectar mixes, set-aside stubbles, floristically enhanced and grass buffers, skylark plots, beetle banks) managed to provide chick-food for all HFBI species, (ii) the total amount of field-edge habitat (floristically enhanced buffers, wild bird and pollen & nectar mixes) managed to provide chick-food for field-edge dwelling species with primarily insectivorous diets (grey partridge, common whitethroat, yellowhammer and reed bunting) and (iii) the total amount of in-field habitat (skylark plots, spring beans, beetle banks and set-aside stubbles) managed for crop-dwelling species (lapwing, yellow wagtail and skylark). A further multivariate GLM examined which individual managements (trials, ELS options or changes to cropping) had the largest impacts on the HFBI species.

At the field-scale, Generalised Linear Mixed Models (GLMM) were used to determine: (i) the effect of in-field habitat and management on skylark territory density; and (ii) whether territory density of HFBI species varied with the amount of land managed for birds, in three areas of the farm with different habitat characteristics (see below). 'Field' was included as random factor, 'year' as a repeated measure to account for multiple samples from the same fields and log field area (ha) as an offset. For skylarks, a model was fitted with a three-level fixed term 'crop' (winter wheat; break crops; set-aside stubbles) to determine if territory density varied between the main in-field habitats on the farm. For each of the three main 'crop' types separately, the effect of changes in husbandry on skylarks was then examined by introducing a fixed factor 'management' into the models. This factor contrasted the initial management practice with new management implemented as part of research trials or changes in cropping. For winter wheat, the contrast was between conventional management and the addition of skylark plots. For break crops, winter oilseed rape and spring sown bean crops were compared. For set-aside, comparison was made between standard one-year rotational set-aside and set-aside of two-years duration. Other field-scale models were fitted with a fixed factor 'management'. For HFBI and insectivorous field-edge dwelling species, this was a four-level factor representing the proportion of the field area managed to provide chick-food (0 = no management; 1 = 0.1–1.99%; 2 = 2.0–3.99%; 3 = ≥4%). For crop-dwelling species, 'management' was a three-level factor indicating the presence of set-aside stubbles (0 = no stubble; 1 = rotational stubble; 2 = 2-year set-aside). All models included a fixed factor 'block' (representing areas of the farm characterised by (i) flat, open terrain, with large fields and low boundaries; (ii) more undulating terrain with generally taller hedgerows; (iii) more wooded river valley, in the past managed predominantly as pasture) and an interaction term 'block*management'.

In all models, habitats such as hedgerows and wooded areas were not included, as they remained constant in area and management between years. Overdispersion in the datasets was automatically corrected by SAS. *P*-values presented are from the minimum adequate models (MAM), which were produced by the stepwise removal of non-significant ($P > 0.05$) variables.

Results

Farm scale

With the exception of skylark, all species or groups assessed had significant positive relationships with the diversity of habitats present in the farmed area (Table 1).

Table 1. *Correlations at whole-farm scale between number of territories of a species (or group of species) and the diversity of the farmed area (arable, grass and margins).*

Group or species	r^2	*P*-value
HFBI species	0.87	0.001
Skylark	0.52	0.126
Common whitethroat	0.69	0.026
Yellowhammer	0.86	0.001
Linnet	0.66	0.036
Hedge nesters (common whitethroat, linnet, yellowhammer)	0.67	0.036
In-field nesters (lapwing, yellow wagtail, skylark)	0.64	0.046
Chick diet - invertebrates	0.81	0.005
Chick diet - grain	0.70	0.025

Diversity calculated using Simpson's Reciprocal Index.

Table 2. *Results from three separate simple Generalised Linear Models (GLM) examining whether the annual number of territories varied with the amount of habitat managed for birds*

	No. of territories: all HFBI species	No. of territories: insectivorous field-edge dwelling species	No. of territories: crop-dwelling species
All chick-food habitat	ns	ns	ns
Field-edge chick-food habitat		df 1; F 56.62; $P < 0.0001$; +	ns
In-field habitat		ns	df 1; F 6.04; $P < 0.0395$; +

Table 3. *Results from a multivariate GLM examining which individual management measures had the largest impacts on the total annual number of territories of HFBI species*

	No. of territories of HFBI species
Set-aside stubbles	ns
Wild bird mixes	df 1; F 75.83; $P < 0.0001$; +
Pollen & nectar mixes	ns
Grass buffers	df 1; F 6.62; $P = 0.0368$; +
Skylark plots	ns

The HFBI did not vary significantly in relation to the total amount of chick-food habitat present in the same year (Table 2). However in a multivariate model containing individual management measures as predictor variables, the HFBI did have significant positive relationships with two measures: wild bird mixes and grass buffers (Table 3). Field-edge species with primarily insectivorous diets and crop-dwelling species also showed no significant relationship with the total amount of chick-food habitat available. However, territories of field-edge species had a significant positive relationship with the amount of chick-food habitat present in strips around the field edges, and territories of crop-dwelling species were positively correlated with the amount of field-centre habitat management (Table 2).

Field scale

Skylark territory density did not vary significantly with 'crop' at the $P = 0.05$ level (df 2; F 3.37; $P = 0.0691$). In factor level contrasts however, densities were significantly higher in set-aside than in wheat or break crops. In wheat fields, territory densities were significantly higher in crops with skylark plots than in conventional wheat (df 1; F 9.15; $P < 0.001$), but territory density did not differ significantly between initial and new managements for either break crops or set-aside, although it should be noted that the sample size for 2-year set-aside was only four fields.

There was a trend for HFBI species territory density to be positively correlated with the proportion of field area managed as chick-food habitat, although this was not significant at $P = 0.05$ (df 3; F 2.78; $P = 0.0749$). Factor level contrasts showed that territory densities were significantly higher where there was ≥4% of land managed as chick-food habitat than where <2% was in management (Fig. 3). There was no significant effect of 'block'.

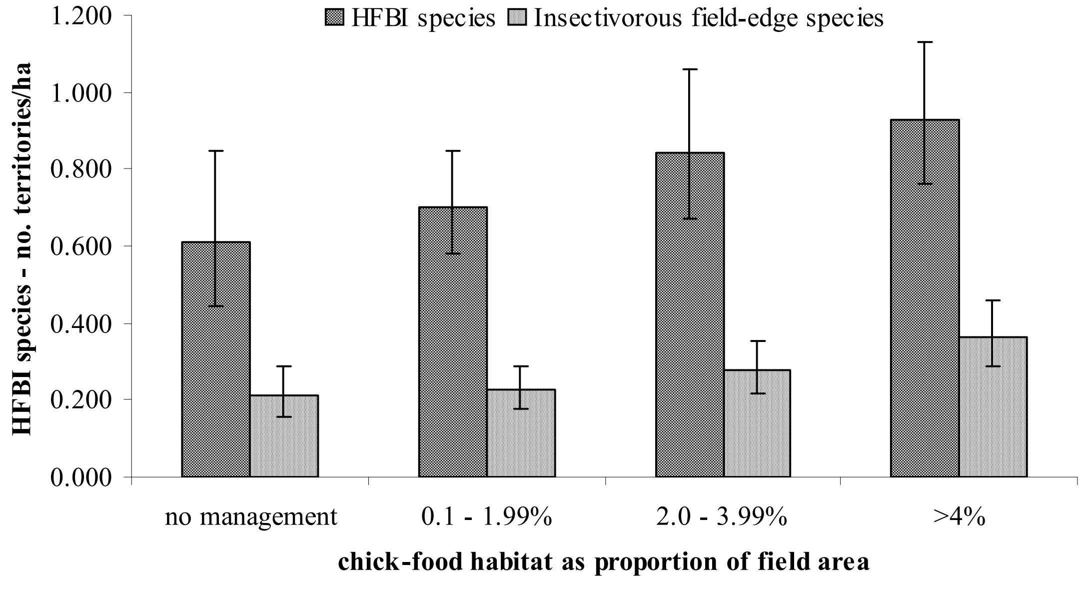

Fig. 3. Effect of proportion of field-area managed to deliver chick-food on the territory density of HFBI and insectivorous field-edge dwelling species. Error bars are 95% confidence intervals.

Territory density of insectivorous field-edge dwelling species showed a highly significant positive relationship with the proportion of field-area under field-edge chick-food habitat (df 3; F 6.12; $P = 0.0043$). Densities in fields with ≥4% field-edge management were significantly greater compared to fields with no field-edge management (Fig. 3). Territory densities of crop-dwelling species showed a significant relationship with stubbles (df 2; F 6.05; $P = 0.0104$). Densities were significantly greater in 1-year set-aside than in fields with no set-aside ($P = 0.0385$), highly significantly greater in 2-year set-aside than in fields with no set-aside ($P = 0.0051$) and. borderline significantly greater in 2-year than in 1-year set-aside ($P = 0.0504$). Territory density of insectivorous field-edge and crop dwelling species also varied significantly with 'block'; densities were significantly higher in the more open landscape than in the other two blocks, which showed no significant variation.

Discussion

At Hope Farm, territories of various individual species and species groups (including the HFBI) have increased since 2000. It is uncertain whether this increase arises from enhanced reproductive success within the farm, immigration of birds from surrounding farmland onto the site, or a combination of both. This paper shows the increase in birds varies positively with the increased provision of habitats that provide food or nest sites; although the results presented here are correlative and therefore causation may be inferred but is not demonstrated. However, the increase in individual species and species groups seems likely to be driven by a number of different factors.

Since the purchase of the farm, the diversity of habitats has increased because of research trials, changes in crops and set-aside and the introduction of an ELS agreement. In 2000, the arable farmland was simply composed of fields of winter wheat and winter oilseed rape, hedgerows, ditches and a few narrow grass margins. By 2009, spring beans and over-wintered stubbles had been added to the rotation and the following habitat features had been added: a comprehensive network of grass margins, skylark plots in the winter cereals, pollen and nectar flower mixtures (a mix of legumes and phacelia), floristically-enhanced grass margins, wild bird seed mixtures, a beetle bank and three wet features. Over the 10 years, other habitat features came and went as a result of research trials and changes in stubble management and unharvested crops. In most cases, the increase in habitat diversity correlates with increases in territory numbers of the individual species or species groups examined. It is arguable how important habitat diversity per se is in driving the increase in bird populations on the farm. For skylark, there is no evidence that the increase in population is linked to a greater diversity of habitat. This is expected for a species that will thrive in large blocks of homogeneous open habitat (e.g. winter wheat, which has been present on the farm before and throughout the RSPB ownership), as long as there is sufficient forage and nest sites (Donald, 2004). For the other species analysed, although there appears to be a positive relationship with habitat diversity, it is entirely possible that the more important driver is the introduction of a few important forage and nest site habitats that were previously scarce or absent on the farm.

All of the measures listed in the previous paragraph variously contributed to the provision of seed food, insect food and/or nesting habitat. The analyses show that some of these trials and agri-environment options are likely to be important in driving bird population increase on the farm. At the farm-scale, the abundance of species which nest in the field margins and boundaries was correlated with the amount of habitat created in the field margins, whilst the abundance of in-field species was correlated to the amount of in-field habitat. This provides evidence that breeding birds respond to the availability of chick-rearing habitat on the farm. In the case of the in-field species, both foraging and nest site provision are likely to have been improved. For boundary-dwelling species, the main benefit is likely to have been increased chick-food provision, although, in conjunction with hedgerow management, nest sites quality may also have been enhanced. The number of territories of HFBI species was significantly related to the areas of wild bird seed mixes and grass buffer strips on the farm. The primary bird benefits of these measures are seed food through the winter and insect food (and possibly nest sites) in the summer, respectively. However, seed mixtures are effectively low-input crops that may also provide insect food in the breeding season as well as winter cover and seed. Buffer strips may also provide some seed food, but are often regarded as too dense to enable effective foraging by farmland birds (Henderson *et al*., 2007). However, many of the grass buffers on Hope Farm have been established within the past three years as part of the farm ELS agreement and therefore swards currently remain quite open for foraging birds. In some cases, trial techniques such as scarification with a power harrow have further suppressed dense tussocky vegetation.

At the field scale, relatively modest levels (about 4% of the field area) of chick-food habitat provision appear to have been sufficient to significantly increase populations of HFBI and insectivorous field-edge dwelling species. Such quantitative information on the scale of habitat provision needed to deliver population increase is scarce and provides a useful insight when designing and implementing packages of measures to benefit farmland birds (Winspear *et al*., 2010). The highest skylark densities were associated with set-aside. This agrees with the results of other studies reported in Donald (2004), although in some studies breeding success in this habitat is low. The highest densities of skylark and a suite of crop-dwelling species that also included lapwing and yellow wagtail were found in 2-year set-aside. Two-year set-aside was left unsprayed for the whole of the first and part of the second summer, thus providing enhanced levels of vegetation cover for nests, seed food from weed and volunteer plants and invertebrate chick-food. Although this management is beneficial to skylarks, there are considerable costs involved with leaving land out of agricultural production for this length of time and restoring the land to good agricultural condition after the second summer, which means that it is unlikely to be widely adopted (C Bailey, pers. comm.). Skylark numbers did vary positively with the provision of skylark plots in winter wheat. The main benefit of skylark plots is believed to be the creation of habitat with a low, patchy vegetation structure required for foraging and nesting, which is otherwise largely absent from winter cereal crops in late summer (Morris *et al*., 2004). For fuller discussion of skylark populations on Hope Farm, see Gruar *et al*. (2010). It should be noted that on Hope Farm, as elsewhere (Chamberlain *et al*., 2009), provision of in-field habitat for crop-dwelling species is most successful on open land with few and/or low boundaries.

Factors other than those tested in this paper may sometimes influence bird populations on the farm. For example, it is possible that the high HFBI for 2009 may have been due in part to the fields on the farm most suitable to skylarks being in winter wheat with skylark plots, while most of the fields adjacent to Hope Farm were in oilseed rape. This may partly explain the very high counts of skylark and linnet (the chicks of which are fed on partially-ripe rape seed), respectively. However, the underlying trend in the HFBI is strongly positive against a background of stability in Eastern England, suggesting that the management measures introduced over the past ten years have driven the observed increases on the farm. This increase in farmland birds has been achieved without taking large amounts of land out of production, without undertaking any form of predator control and during a period when yields and profits on the farm have increased, and thus should be achievable on arable farmland elsewhere.

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