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Twenty years of local farmland bird conservation: the effects of management on avian abundance at two UK demonstration sites

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Capsule At two demonstration farms, Game & Wildlife Conservation Trust's Loddington Farm in Leicestershire and Royal Society for the Protection of Birds's Hope Farm in Cambridgeshire, targeted management led to much faster increases in avian abundance than in the surrounding regions.

Aims To compare changes in avian abundance at Loddington Farm since 1992 and Hope Farm since 2000, and relate these to regional trends in bird abundance and to the habitat and predator management conducted at the two sites.

Methods Loddington Farm is a mixed arable 292-ha farm in a partially wooded landscape in Leicestershire. It was managed as a shoot from 1993 to 2002, combining habitat management with predator control (stopped in 2002) and winter grain provision (ceased in 2006). Hope Farm comprises a 181-ha mainly arable farm in an open landscape in Cambridgeshire, where habitat management for farmland birds has taken place since 2002. At both sites, breeding bird abundance has been monitored annually. Information on farm management was translated into three variables measuring annual provision of nesting cover, summer food and winter food. The number of Carrion Crow and Magpie territories was used as an index of predator abundance.

Results Avian abundance increased at both farms much faster than within their respective regions. Recovery of priority species was positively correlated with the provision of summer foraging habitats and negatively correlated with the provision of supplementary grain during winter. The latter finding was counterintuitive and may reflect an increase in hedgerow provision that coincided with the cessation of grain provision at both farms. The increase in bird abundance was not sustained at Loddington Farm in the absence of predator control, although it was at Hope Farm where predator densities were markedly lower.

Conclusion The data from Hope Farm suggest that where predator densities are relatively low (<3 Crow + Magpie pairs/km^2 locally, <0.2 Foxes/km^2 in spring regionally), recovery of farmland birds can be achieved through habitat management alone. Where predator densities are high (>5 corvid pairs/km^2 and >1.1 foxes/km^2), as at Loddington Farm, species recovery, particularly of open-cup nesting species, may require predator control as well as habitat management. Further study is needed to confirm this tentative conclusion from only two sites.

Population declines across a wide range of UK bird species associated with farmland have been noted since the mid-1980s (O'Connor & Shrubb 1986, Marchant *et al.* 1990, Gibbons *et al.* 1993, Fuller *et al.* 1995). Many of these species were given priority status under the UK Biodiversity Action Plan (BAP) (Anon. 1995), resulting in targeted research that led to a greater understanding of their ecological requirements and the causes of their decline (summarized in Grice *et al.* 2004, Newton 2004). This research showed that the main factors limiting the numbers of each priority species fall into one or more of the following

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categories: a place to nest, summer invertebrate food for chicks, and overwinter food and shelter (the 'Big Three'). With the right habitats deployed together at sufficient scale, it is possible to provide the critical resources that farmland birds need to survive, breed successfully and rebuild their numbers (Winspear *et al.* 2010). Nevertheless, the UK Government's Farmland Birds Indicator DE5 (Boatman *et al.* 2006), based on changes in the abundance of 19 farmland bird species, continues to decline (Defra 2014). Furthermore, out of 12 species considered to be farmland specialists (Gregory *et al.* 1999), 9 remain red-listed as Birds of Conservation Concern (BoCC) (Eaton *et al.* 2009).

Many of these population declines began during the mid-1970s, at a time of rapid agricultural change when arable agriculture intensified at the expense of mixed farming: spring-sown cereals were largely replaced by autumn-sown crops, rotational grass leys disappeared, fields were enlarged by boundary removal, and chemical inputs of fertilizers, pesticides and growth regulators increased (Jenkins 1984, Ewald & Aebischer 2000, Robinson & Sutherland 2002). Major changes also took place in UK agricultural policy, driven mainly by the Common Agricultural Policy of the European Union. These included the introduction (1992) then withdrawal (2008) of mandatory set-aside, the start of agri-environment schemes (1987) and the decoupling of subsidies from production with the Single Farm Payment (2005). Set-aside, together with agri-environment options, offered an opportunity for land managers to be compensated financially for the creation and maintenance of wildlife habitats on agricultural land (Aebischer 1997, Buckingham *et al.* 1999, Smallshire *et al.* 2004). From 2005, this scope was extended with a new agri-environmental scheme, Environmental Stewardship (Defra 2005), which provided management options capable of fulfilling the Big Three habitat and food requirements of declining farmland birds and was available to all farmers in England (Phillips *et al.* 2010, Winspear *et al.* 2010). Other schemes have been introduced in Scotland, Wales and Northern Ireland (Anon. 2007, DARDNI 2007, Rose 2011).

The Game & Wildlife Conservation Trust (GWCT) and the Royal Society for the Protection of Birds (RSPB) have a long history of research into the causes of UK farmland bird declines and hence considerable understanding of species requirements for recovery (Aebischer *et al.* 2000a, Vickery *et al.* 2004, Wilson *et al.* 2009). Both organizations have sought to share their knowledge with policy-makers and land managers through practical demonstrations on the ground, the GWCT since 1992 at Loddington Farm (Stoate & Leake 2002, Stoate *et al.* 2012), and the RSPB since 2000 at Hope Farm (Morris *et al.* 2010, RSPB 2012). At both sites, the abundance of breeding birds has been monitored annually and detailed information collected on farm and wildlife management. This paper brings together these two data sets in order to compare the sites and review the changes in bird abundance that have taken place in relation to 'Big Three' habitat provision and other forms of management. We seek to distinguish management interventions that have consistent associations with changes in avian abundance at both sites from interventions whose effects may be site-specific. In doing so, we aim to identify management interventions that may have wider general utility in facilitating the recovery of depleted lowland farmland bird populations.

MATERIALS AND METHODS

Loddington Farm (Allerton Project, GWCT)

Loddington Farm was bequeathed to GWCT by Lord and Lady Allerton in 1991 and encompassed 292 ha of land at Loddington, Leicestershire (52°36′48″N 0°50′10″W). The soils comprise mainly Hanslope and Denchworth clays, with 212 ha of arable (73% of area), 42 ha of pasture (14%) and 22 ha of woodland (8%). The holding was extended to 333 ha in 1993–94, but the additional land was not included in the bird monitoring so is excluded from further consideration. The undulating mixed agricultural landscape surrounding Loddington Farm is made up of 46% arable, 40% grassland and 11% woodland (quantified from Land Cover Map 2000 (Fuller *et al.* 2002) within a 10 × 10-km square aligned on the Ordnance Survey grid and centred on the farm). Within the same area, there were two family syndicate shoots based on released Common Pheasants *Phasianus colchicus*, involving hopper-fed grain in winter, some (mainly maize-based) game crops and very little predator control.

The project began in 1992, a baseline year in which farm management remained unchanged to allow initial wildlife monitoring. From 1993, the farming system was adapted to meet the year-round ecological requirements of wild game birds and by 1994 a system of land management was established and maintained until 2011 (Appendix Table A1). The cropping was mainly winter wheat, beans (winter and spring) and winter oilseed rape, with barley, linseed and oats also grown in some years. It was managed by GWCT farm staff in collaboration with a neighbouring farm. Non-inversion tillage was adopted in an increasing proportion of fields from 2001. The permanent pasture supported a flock of 280 ewes, with beef cattle during 2007–09.

From 1993 until its disappearance in 2008, set-aside was used for habitat creation: strips 20 m wide along field edges and through field centres provided wildlife habitats such as beetle banks and wild bird cover, and split up large fields; wild bird cover in the form of annual cereal-based game-bird brood-rearing crops and biennial kale-based crops provided seed food and cover during winter. Conservation headlands (marginal crop strips selectively treated with pesticides to promote weed and invertebrate abundance – Sotherton 1991) were placed on half the cereal fields and moved to different fields each year to prevent weed build-up. Set-aside was also used to create a riparian buffer strip along the Eye Brook, with small pools being created in the largest of these in the late 1990s. Perennial grass margins 2 m wide were introduced in all other arable field margins; some were widened to 6 m in 2004. A Countryside Stewardship agri-environment agreement in 1993 and subsequent Entry Level and Higher Level Stewardship agreements compensated for some of the income foregone.

Woodland management comprised rotational thinning and coppicing, to improve the internal structure of the woods present in 1992 (18 ha). Woodland too tall to thin was clear-felled and replanted in 1993 with mixed native deciduous and coniferous trees. Another 4 ha of similar new woodlands were planted in 1994. Gaps in hedgerows were filled with native fruit-bearing shrubs, and hedge trimming was conducted every 2 years to keep hedges at heights of 2–3 m. From 2005, small field boundary and field corner wetlands were introduced across the farm.

From 1993 to 2001 inclusive, a full-time gamekeeper controlled nest predators (primarily Carrion Crow *Corvus corone*, Eurasian Magpie *Pica pica*, Brown Rat *Rattus norvegicus*, Grey Squirrel *Sciurus carolinensis*, Fox *Vulpes vulpes*, Stoat *Mustela erminea* and Weasel *Mustela nivalis*), mainly between March and July, although Brown Rat control and some Fox control were conducted outside this period. The keeper also provided grain in hoppers for game birds during winter to early May, with some hand feeding along hedges. Predator control was deliberately stopped after 2001, while habitat management and winter grain provision continued. In winter 2005/06, grain provision was reduced from about 140 feed hoppers to just 10, then ceased completely in subsequent winters, leaving only habitat management. In 1999, four nest boxes were erected for Barn Owls *Tyto alba* and 49 boxes for Tree Sparrows *Passer montanus*.

Two methods were used to monitor breeding bird abundance at Loddington since 1992. Territory mapping was carried out over the original (292 ha) area in 1992, 1998, 2001, 2006 and 2010, and transect counts were conducted annually. The territory mapping was based on standard British Trust for Ornithology (BTO) Common Birds Census (CBC) methods (Marchant *et al.* 1990, Bibby *et al.* 2000). The farm was divided into five sections, each visited ten times during April–July, eight times before 9:00 GMT and two in the last three hours of daylight. In 1992, 1998 and 2001, territory mapping fieldwork was carried out by one of the authors (CS), with additional support in 2006 and 2010. All analysis of maps was carried out by CS Wood Pigeons *Columba palumbus* were not recorded because they were so abundant. Barn Swallows *Hirundo rustica*, Western Jackdaws *Corvus monedula*, Common Starlings *Sturnus vulgaris* and House Sparrows *Passer domesticus* were not recorded because an unknown number bred on private houses and buildings.

For transect counts (Bibby *et al.* 2000), the same approach was used in all years and involved the same observer (CS) throughout. The transect was approximately 11.5 km in total length, incorporated arable, grassland, woodland and wetland habitats, and followed tracks and field edges. It was surveyed four times each year between late April and early June, each occasion being divided between two early mornings. In woodland, all birds seen or heard within the boundary of the wood were recorded. In farmland, all birds seen or heard were recorded in the field boundary on one side of the transect route, and all birds in the adjacent field on the other side. Detectability was assumed not to vary between years. Average counts across the four visits (residents) or the last three (summer visitors) were used to provide an annual measure of relative abundance for each species.

Both survey methods were intended to monitor passerines, although data for other groups were also collected. Nest counts in April and May were used to monitor the annual number of territorial pairs of Eurasian Sparrowhawks *Accipiter nisus*, Common Buzzards *Buteo buteo*, Barn Owls, Magpies and Carrion

Crows. Spring game-bird breeding density was monitored annually using a four-wheel-drive vehicle as a mobile hide for two hours after dawn and before dusk in March to survey field margins, woodland boundaries and open fields with binoculars, plotting the location and sex of observed game birds on a map (Coles & Blank 1975, Gilbert *et al.* 1998).

Where data were adequate, the annual indices of abundance provided by the Loddington Farm transect counts were positively and linearly related to the five annual territory counts, explaining over 50% of the variation in three-quarters of cases. The remaining cases corresponded to species whose numbers were relatively stable, giving little scope for strong correlations. Hence we consider that the abundance indices from transects offer a reasonable measure of annual species abundance at Loddington Farm.

Hope Farm (RSPB)

The RSPB purchased Hope Farm in 1999. It is a 181-ha predominantly arable farm situated on Hanslope-series calcareous clay loam at Knapwell, Cambridgeshire (0° 3′17″W, 52°14′49″N), 67 km south-east of Loddington Farm. It comprises 170 ha of arable (93% of area), 5 ha of permanent pasture (3%) grazed by horses and sheep, small woodland copses totalling 1 ha (<1%) and 8.5 km of hedgerow. The landscape around Hope Farm is flat, open and largely unwooded, composed of 78% arable, 15% grassland and 3% woodland (Land Cover Map 2000, within a 10 × 10-km square aligned on the Ordnance Survey grid and centred on the farm). Within the same area, three farmers operate small family shoots based on released Pheasants and Red-legged Partridges *Alectoris rufa*, with some game strips and hopper-fed grain and limited predator control (occasional corvid removal).

Farming operations were carried out by a local farmer under contract. Initially arable crops were grown in three-year rotation (autumn-sown first wheat, second wheat and oilseed rape), which was maintained for two years of baseline wildlife monitoring in 2000 and 2001. Set-aside was industrial oilseed rape in 2000, which was converted to a mixture of non-rotational field margins and rotational stubbles lasting one or two years as part of experimental trials. Trials of a method to boost Eurasian Skylark *Alauda arvensis* numbers (bare patches in cereal crops) began in 2001 (Gruar *et al.* 2010), and pollen-and-nectar strips were sown in 2002. Other wildlife-friendly measures introduced in 2003 and 2004 were wild bird cover (mixtures with biennials, annuals and cereals), unharvested cereals, a beetle bank and floristic margins. In 2004 the cropping was changed to a four-year rotation incorporating spring cropping (winter wheat, winter oilseed rape, winter wheat and spring beans). Apart from occasional ploughing to control Black Grass *Alopecurus myosuroides*, minimum tillage was used when establishing wheat and beans, with oilseed rape seed mostly broadcast without cultivation. Further agri-environment measures were adopted in subsequent years under Entry Level Stewardship and experimental trials of field margins, late-season nesting habitat and sheep grazing took place in 2009–10 (Appendix Table A1). Apart from the research trials, the only newly created non-cropped habitats were some laid and in-filled hedges, and three wet features introduced to reduce diffuse pollution and increase aquatic biodiversity.

There has been no gamekeeper or predator control on Hope Farm or the neighbouring landholdings, with the exception of one adjacent farm, where small numbers of corvids have been removed to protect a small family game-bird shoot since 2007. Some supplementary grain was provided as a single heap in winter/early spring pending habitat development, but none since winter 2004/05. Two Barn Owl boxes and 15 House Sparrow boxes have been in place since 2001/02, 50 Common Starling boxes since 2002/03 and 2 Common Kestrel *Falco tinnunculus* boxes since 2006.

Breeding birds were monitored annually since 2000 using the same territory mapping techniques as at Loddington Farm (Marchant *et al.* 1990, Bibby *et al.* 2000), with 10–12 visits each year. All visits started at least one hour after sunrise and were completed before 11:00 GMT. During 2000–04, two surveyors conducted visits in one day, splitting the farm into two blocks and swapping the survey blocks between visits to minimize observer bias. Since 2005, each year an experienced single surveyor (not necessarily the same individual each year) undertook all bird counts on both blocks over a two-day period, swapping the order of the surveyed blocks between visits. A small team lead by AJM have been responsible for the analysis of field maps since 2002.

Farm management variables

To reduce the risks of detecting spurious relationships between changes in bird populations and a wide variety of management interventions, information describing the latter were condensed into five management variables. We scored habitats as having a major, minor or no role in the provision of nesting cover, summer food and winter food for birds (Appendix Table A1), then summed the areas having a major role, added half the areas having a minor role, and divided by total farm area to provide a weighted proportion for each of the Big Three. The annual density of Carrion Crow plus Magpie territorial pairs was used as an index of generalist predator levels. If these variables affected avian abundance, it was expected that summer food and predator levels would have their greatest influence on breeding success, so would affect the number of breeding pairs with a one-year lag. Likewise, winter food habitats established in one year could influence abundance only in the following breeding season, whereas nest cover was deemed to influence breeding abundance in the same season. These four variables were coded temporally to reflect these expected timings. The provision of grain over winter (supplementary feed) was coded as 0 (no) or 1 (yes) depending on its presence in January–March of the year in which breeding abundance was measured. Interrelationships between the five variables were examined using Pearson correlations.

Bird species groupings, densities and indices of abundance

Bird species were classified into species groupings (Appendix Table A2), first according to their conservation status, as either a UK BAP priority species (Anon. 1995) or as a Red-listed BoCC (Eaton *et al.* 2009), then according to their dependence on farmland, as a member of the Farmland Bird Index (FBI), one of the UK government's former headline indicators of Quality of Life (DETR 1999), or as a subset of the latter comprising farmland specialists that are highly dependent on farmland habitats (Gregory *et al.* 1999). The farmland bird species were also classified into functional groups based on diet (Wilson *et al.* 1996, Holland *et al.* 2006): non-passerine herbivores, passerine granivores (many of which, during the breeding season, may eat invertebrates or feed invertebrates to their young) and passerine insectivores. A final category comprised open-cup nesters, which were potentially vulnerable to nest predation. The percentage overlap in species among the eight groupings (Appendix Table A3) exceeded 50% for BAP and BoCC species (89%), and for FBI and farmland specialist species (63%).

For each bird species, territory densities on Loddington Farm and Hope Farm were calculated by dividing the number of territories by area, in each year for which data were available. We divided by total farm area except in the case of farmland bird species (as defined in Gibbons *et al.* 1993), where we divided by the area of arable and grass to take into account the proportional difference in farmland area between the two farms. These absolute values of abundance were used for a direct comparison of territory density between farms for the species common to both, considering the number of species in each species grouping where starting, minimum and maximum densities were higher at one farm than at the other.

To relate temporal changes in bird abundance to variables representing the different forms of management, we needed annual measures so we used the Loddington Farm transect counts and the Hope Farm territory counts. Pooling data across different survey methodologies is already done by BTO's joint CBC/Breeding Bird Survey (BBS) index (Freeman *et al.* 2007) and by the Pan-European Survey (Gregory *et al.* 2005). The time series for each species was standardized by adding 0.5 to each value (to ensure that zeros would not compromise subsequent calculations), then dividing the Loddington Farm series by its 1992 value and the Hope Farm series by its 2000 value so that both series began with a value of 1. We generated composite abundance indices for each of the species groupings as the geometric mean of the standardized index values across the relevant species (Gregory *et al.* 2005).

To provide information on background trends in avian abundance, we used regional indices of species abundance for the period 1994–2010 derived from BBS data for the Office of National Statistics Regions of England (Risely *et al.* 2012). For Loddington Farm, we used trends for East Midlands (Derbyshire, Northamptonshire, Leicestershire & Rutland, Lincolnshire and Nottinghamshire), while for Hope Farm we used trends for East of England (Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk and Suffolk). The BBS began in 1994, so for each species its 1994 value was also used for 1992 and 1993 on the assumption that any trend over two years would be minimal. The regional time series for each species were standardized in the same way as the farm series before generating regional trends for the species groupings.

Local bird population growth rates

For conservation policy, it is useful to know how quickly a species or group of species can recover if conditions are suitable. To gauge potential rates of local population growth at the two farms, we could not calculate average annual rates of change over the full data series from each farm because of major changes in management, for example, the cessation of predator control at Loddington Farm. Instead, we focused on the maximum average rate of change in abundance over five years. For each species grouping, we took every possible consecutive five-year sub-series of annual abundance and calculated the average annual rate of change. The maximum of these rates across all sub-series provided a measure of the maximum practically achievable local population growth rate for the management described earlier. The five-year length was a compromise between the needs to smooth inter-annual variation and to avoid underestimation from the onset of density dependence. For comparison, maximum average rates of change over five years were also calculated for the regional indices of abundance. Although average rates of change across many BBS squares are likely to be less variable than those recorded at individual farm sites (as stochastic variation across BBS squares will be dampened in the regional average), the former provides a useful comparison of bird population changes in the same region and during the same time period.

Relating bird abundance to management

Relationships between the abundance indices of species groupings and the five explanatory management variables were examined by general linear regression. To take into account any underlying temporal variation in regional abundance, the annual index value for each species grouping at each farm was expressed as a ratio of the corresponding annual BBS regional index value, then log-transformed to improve normality and stabilize the variance. The resulting data series was used as the response variable in the regression. Complicating factors were the differing nature of the Loddington Farm and Hope Farm series, the possible presence of density dependence and that of serial correlation. All regression models included farm as a structural factor to allow different intercepts for the Loddington Farm and Hope Farm series. Any density dependence was taken into account by including the original abundance series, log-transformed and lagged by one year, as an obligate explanatory variable (Langton *et al.* 2002). The presence of serial correlation among the residuals was tested using a lagged residual test (Wooldridge 2002) after fitting a model with all main effects. If the test was positive for a particular species, all further modelling for that species was carried out using Restricted Maximum Likelihood with a common AR(1) error parameter across the Loddington and Hope Farm series.

The different types of management at Loddington and Hope Farms meant that any relationship involving a management variable could differ between farms, so we needed to check for statistical interactions between management variables and farm. With just 28 data points, there was a strong risk of over-fitting models to the data if all variables and interactions were taken together. We therefore proceeded in two steps, initially testing farm interactions one at a time against a model containing all five management variables as main effects, then including all five main effects and all interactions found to be significant in the initial step, and removing interactions that were no longer significant. Tests of interactions and main effects were carried out using F-statistics if there was no autocorrelation, and Wald tests if there was. Statistical analyses were carried out in Genstat 16th edition (VSNi 2013).

RESULTS

Temporal changes in management

At Loddington Farm, the amounts of habitat providing summer food, nesting cover and winter food increased over the first two years of management, fell back slightly as land was transferred out of natural regeneration set-aside, then remained relatively stable for the next ten years (Fig. 1a). From 2003 onwards, the greater use of two-year stubble, grass buffers, pollen & nectar mixes and increased hedgerow management led to an increase in the amounts of all three habitat types, although winter food habitats fell back slightly after the abolition of set-aside in 2008. Predator levels remained low until 2002, when keepering stopped, then returned to their 1992 level and increased thereafter, to levels roughly four times higher than at Hope Farm (Fig. 1). Grain was provided over the winters of 1993/94 to 2004/05.

At Hope Farm, large increases in the amounts of habitat providing summer food, nesting cover and

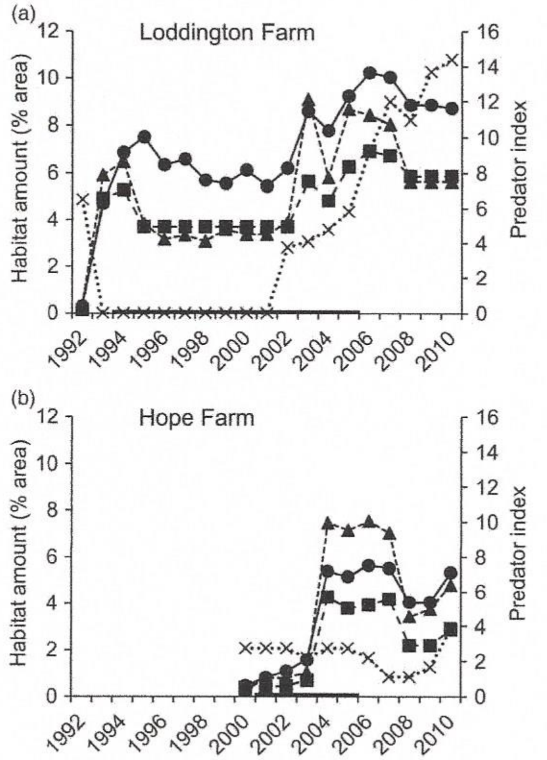

Figure 1. Temporal changes in the five variables describing the management at Loddington Farm (1992–2010) and at Hope Farm (2000–10). The three habitat variables (–●– summer food, –■– nesting cover and --▲-- winter habitat) are expressed as annual percentages of farm area, and the predator index (--×--) is obtained from the density of breeding Carrion Crows and Magpies. Periods in which winter grain was provided are marked by a solid horizontal line (—).

winter food in 2004 reflected the onset of management (Fig. 1b). The amounts of all three habitat types remained relatively constant until 2008, when stubble and fallow under set-aside were returned to cultivation. Predator levels dipped slightly in 2007–09, but remained above the levels recorded at Loddington Farm during the keepered phase and below those recorded during the non-keepered phase. Grain was provided during the winters 2000/01 to 2004/05.

Because the timing of different types of habitat provision tended to be synchronized within each farm, and their amounts fluctuated following broadly similar patterns over time, there were strong positive correlations between the three habitat variables, particularly between summer food and the other two variables (Table 1; 54–64% of variation explained). The summer habitat variables were both correlated with the predator index, explaining 18–29% of variation. Winter food and the predator index were negatively correlated with grain provision, accounting for 16–34% of variation.

Bird species at the two farms

Over all years, 75 bird species were recorded during the breeding season at Loddington Farm and Hope Farm (Appendix Table A2). Of these, 59 were recorded during territory mapping at Loddington Farm, 65 during transect counts there (for a total of 72 when territory and transect counts were combined) and 55 at Hope Farm. There were 45 species in common between the Loddington territory counts and Hope Farm, and 47 in common between the Loddington transect counts and Hope Farm.

Overall, the numbers of territorial species recorded each year increased at both farms, from 50 to 54 at Loddington Farm (43 to 48 when based on transects) and 43 to 48 at Hope Farm. The three most abundant species were the same at both sites, namely Wood Pigeon, Chaffinch *Fringilla coelebs* and Blackbird *Turdus merula* (although Wood Pigeon territories were not censused at Loddington Farm, the transects yielded abundance indices 2–3 times higher than those of Chaffinch or Blackbird). Both farms held the same suite of breeding raptors, at roughly similar densities. Eurasian Sparrowhawk was present in all years, with one pair increasing to two from 2006 at Loddington Farm and one pair on Hope Farm. Common Buzzard was absent from both farms initially, increasing to 2–3 pairs on Loddington Farm from 2002 and to 1 pair on Hope Farm from 2009. Common Kestrel fluctuated in number from 0 to 3 pairs on Loddington Farm and from 0 to 2 pairs on Hope Farm.

Table 1. Pearson correlation matrix for the five variables describing the management at Loddington Farm and Hope Farm ($n = 28$).

Variable	Nesting cover	Winter food	Predator index	Grain provision
Summer food	0.736***	0.799***	0.423*	−0.252
Nesting cover		0.606***	0.542**	−0.308
Winter food			0.328	−0.393*
Predator index				−0.582**

*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

Changes in bird abundance at the two farms

Direct comparisons of starting, minimum and maximum territory densities between the two farms (Table 2) showed that starting densities were higher at Loddington Farm than at Hope Farm for 78% of the 40 species in common and present at the start of each project. Most of these were among the BAP species, BoCC species, passerine insectivores and open-cup nesters rather than among the farmland (FBI and specialist) species groupings. Minimum densities were consistently higher at Loddington Farm than at Hope Farm across all species groupings. This was the case, for instance, for 82% of the 34 species in common and present in all years. The situation for maximum densities varied according to species grouping. For FBI, farmland specialist, BAP and BoCC groupings, between 67% and 89% of species achieved higher maximum densities at Hope Farm than at Loddington Farm, most markedly so for farmland specialists (eight out of nine). Conversely, maximum densities of open-cup nesters and especially passerine insectivores (eight out of ten) were higher at Loddington Farm than at Hope Farm.

The trends in abundance of the eight species groupings, together with the corresponding regional trends, are shown in Fig. 2. Over the 19 Loddington years, the general pattern was for an initial increase in abundance, followed by a decline. The increase persisted longest for passerine granivores, passerine insectivores and open-cup nesters, where it broadly coincided with the keepered period 1993–2001. Over the 11 Hope Farm years the general pattern was for a nearly linear increase in abundance, most marked for the FBI index, farmland specialists, BAP and BoCC species. These patterns translated into generally higher average annual rates of increase within the first half of the time series than in the second half at Loddington Farm, whereas this was not the case for Hope Farm.

Comparing the two sites, the maximum annual rates of increase over five years were similar at around 12% for the FBI index and farmland specialists, but they were about 50% higher at Loddington Farm than at Hope Farm for BAP and BoCC species, and nearly twice as high for non-passerine herbivores, passerine granivores and open-cup nesters (Table 2). Relative to background regional changes in avian abundance, maximum annual rates of increase over five years were much higher at both Loddington Farm and Hope Farm than in their respective regions across all groupings, averaging 15% at Loddington Farm versus 2% in the East Midlands, and 10% at Hope Farm versus 0% in East of England (Table 2).

Relationships between abundance and management

Relationships between abundance and the five management variables were examined for the eight species groupings (Table 3). The open-cup nester grouping was the only one to require an autoregressive component during model-fitting.

For nesting cover, there were significant interactions with farm for the FBI species, farmland specialists and non-passerine herbivores. At Loddington Farm the relationship was significantly negative for FBI species; at Hope Farm the relationship involving non-passerine herbivores was significantly positive. For summer food, significant interactions with farm were detected for BAP, BoCC and passerine insectivore species; relationships were positive at both sites (significantly so in five out of six cases), with stronger relationships at Hope Farm than at Loddington Farm (Table 3). The only other significant relationship involved open-cup nesters, and was also positive. Relationships involving winter food were consistent across farms (no significant farm interactions) and significantly negative for BAP and BoCC species, non-passerine herbivores and open-cup nesters. Relationships involving predator abundance were also consistent across farms and significantly negative for passerine granivores, passerine insectivores and open-cup nesters. For grain provision, interactions with farm were significant for farmland specialists and open-cup nesters (significant negative relationships at Hope Farm but not Loddington Farm). There were also significant negative relationships for FBI, BAP and BoCC species.

The strongest correlations among habitat variables involved summer food provision (Table 1). If the summer food variable was excluded, the pattern of relationships in Table 3 remained broadly similar except for winter food provision, where non-passerine herbivores was the only one of four groups to retain a previously significant negative relationship.

DISCUSSION

At both demonstration farms, the bird monitoring revealed how effective the management had been: for all species groupings, the maximum rates of increase in breeding abundance over five years far exceeded those recorded across the corresponding regions (Table 2),

Table 2. Comparative frequency of bird species abundance at Loddington farm and Hope farm (species in common only) based on starting, minimum and maximum territory densities, and maximum average annual rate of increase in abundance (*r*) across all periods of five consecutive years at the two farms and in their respective regions, for the species groupings in Appendix 1.

		Starting densities			Minimum densities			Maximum densities		Rate of increase			
		No. of species with higher densities at			No. of species with higher densities at			No. of species with higher densities at		Maximum *r* (%)			
Species grouping	Total species	Loddington Farm	Hope Farm	Both zero	Loddington Farm	Hope Farm	Both zero	Loddington Farm	Hope Farm	Loddington Farm	East Midlands	Hope Farm	East of England
Species in common	45	31	9	5	28	6	11	27	18	–	–	–	–
FBI	13	8	4	1	6	3	4	3	10	12.9	1.8	12.3	0.3
Farmland specialists	9	6	2	1	5	1	3	1	8	12.3	2.2	11.8	0.2
BAP species	11	9	1	1	7	1	3	3	8	11.0	1.4	7.2	−0.7
BoCC Red List	9	8	0	1	6	0	3	3	6	11.9	1.4	7.9	−0.5
Non-passerine herbivores	6	4	2	0	3	1	2	2	4	20.2	1.0	13.7	0.1
Passerine granivores	8	5	3	0	6	2	0	3	5	20.5	4.5	10.1	−0.4
Passerine insectivores	10	9	0	1	8	1	1	8	2	13.3	3.6	7.4	0.0
Open-cup nesters	20	16	4	0	17	3	0	12	8	19.0	4.0	10.5	0.7

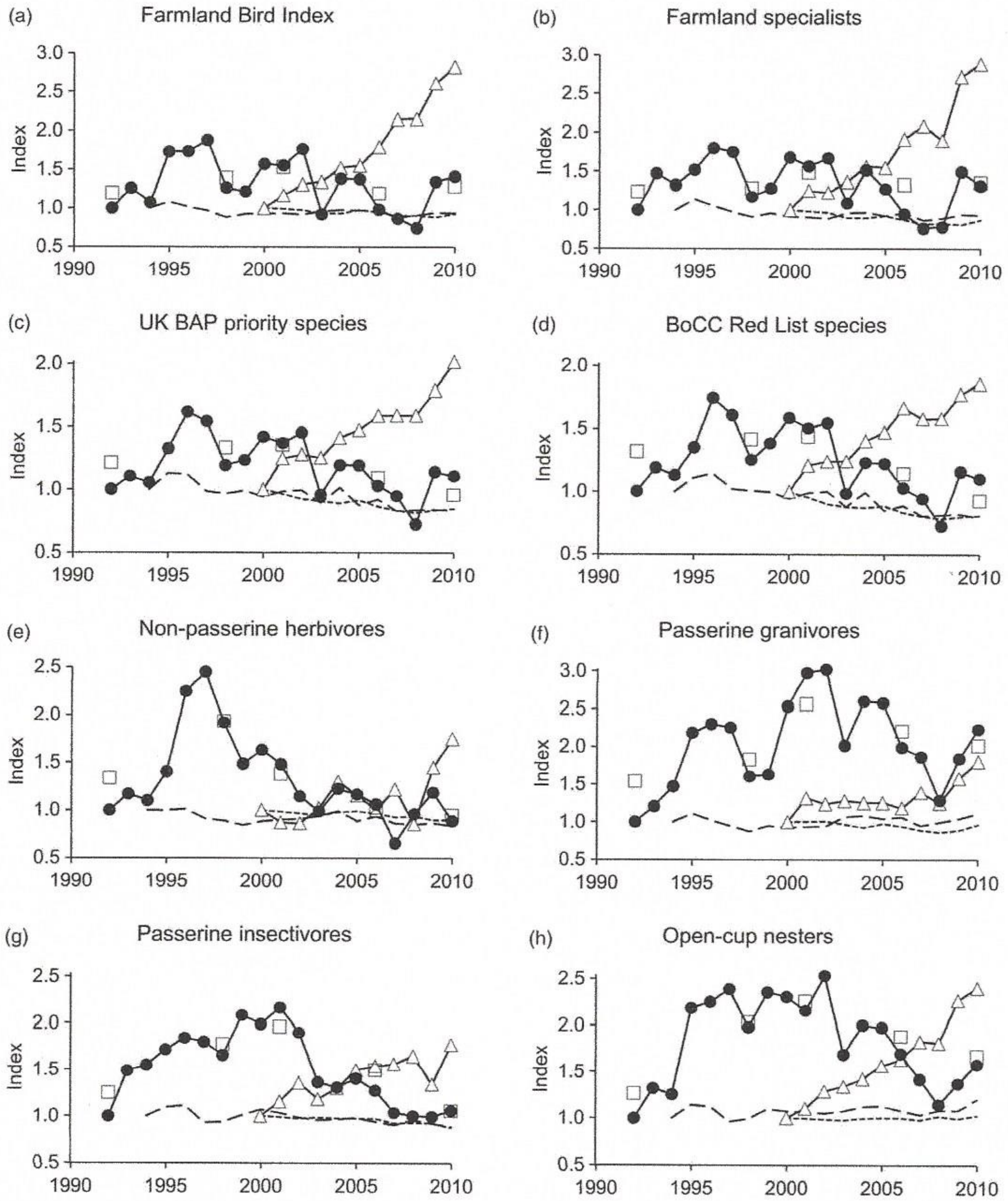

Figure 2. Temporal trends in abundance of eight species groupings at Loddington Farm (-●- annual transect count surveys 1992–2010, □ territory mapping surveys in 1992, 1998, 2001, 2006 and 2010) and Hope Farm (-△- annual territory mapping surveys 2000–10). For comparison, the East Midlands regional BBS trend (---, 1994–2010) is given for Loddington, and the East of England one (------ , 2000–10) for Hope Farm. For ease of reference, the scales of the Loddington Farm territory survey and of the regional BBS trends have been adjusted so that the territory survey mean is the same as the Loddington Farm transect survey mean, the East Midlands series starts at the 1994 Loddington Farm transect survey value and the East of England series starts at the Hope Farm 2000 territory survey value.

although the comparison with BBS data probably overstates the magnitude of the difference (see Methods). The targeted management at both farms delivered local rates of population growth greater than 10% per annum, and up to 20% per annum, for a wide suite of species. By comparison, the regional BBS trends rule out any strong background growth in bird populations in the wider countryside.

Table 3. Regression coefficients for the relationships between the abundance index of eight species groupings and each of five variables describing the management at Loddington Farm and Hope Farm. Each variable and its interaction with farm were assessed in the presence of the other management variables, in a regression model that took into account site effects, density dependence and, where necessary, autocorrelation. If an interaction was significant, two regression coefficients are presented, the upper one for Loddington Farm and the lower one for Hope Farm.

	Nesting cover		Summer food		Winter food		Predator index		Grain provision	
Species	Interaction with farm	Coefficient	Interaction with farm	Coefficient	Interaction with farm	Coefficient	Interaction with farm	Coefficient	Interaction with farm	Coefficient
FBI species	**	−0.127* 0.021		0.027		−0.015		−0.009		−0.213*
Farmland specialists	*	−0.081 0.047		0.003		−0.023		0.008	*	0.035 −0.504***
BAP species		0.011	*	0.048* 0.117**		−0.058**		−0.019		−0.126*
BoCC red list		0.013	**	0.043* 0.128***		−0.057**		−0.019		−0.120*
Non-passerine herbivores	**	−0.089 0.101*		0.067		−0.088**		−0.029		−0.192
Passerine granivores		−0.018		0.050		−0.030		−0.031*		−0.067
Passerine insectivores		−0.002	**	0.020 0.086*		−0.028		−0.030**		−0.051
Open-cup nesters[a]		0.023		0.047**		−0.047**		−0.031***	**	0.033 −0.228***

[a]Species grouping where autocorrelation was detected.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

Whilst we can be confident that our management has increased the carrying capacity of the farmland for a wide range of breeding birds, we cannot be sure about the relative importance of improved on-farm demography (breeding success and survival) and immigration from surrounding areas as drivers of the observed increases in breeding numbers. Species-specific studies of breeding success have confirmed that the periods of greatest population growth were associated with high productivity (Stoate & Szczur 2001, White *et al.* 2008, 2014, Gruar *et al.* 2010), and the quality of the managed land may also have lowered the mortality and emigration rate of fledged birds or attracted immigrants from surrounding land. No data exist to quantify directly the balance of emigration versus immigration on the two farms, but monitoring of farmland birds on conventionally farmed areas within 5 km of Loddington and Hope Farms (Stoate & Szczur 2001, Stoate 2002, RSPB unpubl.) showed that local trends matched regional ones, with no evidence of redistribution.

The question is then whether local population growth rates of up to 20% per annum can plausibly be driven entirely by local reproductive success. The management at Loddington and Hope Farms increased productivity by 50% on average across 7 passerine species (Stoate & Szczur 2001, Donald & Morris 2005, White *et al.* 2014). Factoring this increase into the demographic models for the 11 non-corvid farmland passerine species in Aebischer *et al.* (2003), while keeping survival rates the same, yielded an average increase of 24% per annum. In real life, Cirl Bunting *Emberiza cirlus* in Devon is an example of a closed population of a farmland bird, and its average growth rate over the five-year period 1989–94 was 28% per annum (Peach *et al.* 2001). Another example is the Grey Partridge *Perdix perdix* on the Sussex Downs, where intensive management led to an average 25% per annum increase over the six-year period 2004–10 (Ewald *et al.* 2012). Population growth rates of up to 20% per annum are therefore theoretically and practically plausible without recourse to immigration.

For the non-passerine herbivores, passerine granivores, passerine insectivores and open-cup nesters, the maximum rates of increase at Loddington Farm (average 18.3%) were almost twice those at Hope Farm (average 10.4%). The difference is unlikely to be caused by climatic effects, given that the two farms are separated by only 67 km. One possible explanation is that the scope for population increase, given the resources available, differs between the two farms for these bird groups. At both sites the hedgerow, boundary and in-field management successfully targeted farmland birds (see previous paragraph), but the four groupings discussed here include many woodland species. Woodland is scarce at Hope Farm and in the surrounding landscape (≤3% of area), whereas it occupies around a tenth of the Loddington Farm landscape, which may therefore offer greater potential for bird population growth. A second possibility is that initial densities of birds were lower at Loddington Farm, giving scope for a faster initial recovery as density-dependent constraints were relaxed. Table 2, however, reveals that this was not the case because, for instance, 9 out of 10 passerine insectivores and 16 out of 20 open-cup nesters had higher starting densities at Loddington Farm than at Hope Farm. A third possibility is that reduced predator levels through keepering in the early years at Loddington Farm boosted population growth beyond that achieved through habitat provision alone. Further information on the role of predator levels is available from the regression analysis of abundance against management variables (Table 3). This identified significant negative relationships for three of these four groupings, and a coefficient of similar magnitude for the fourth. Although consistent across the two farms, the results are probably driven by data from Loddington Farm, where changes in keepering produced large changes in predator levels across years. As noted above, we cannot rule out the possibility that immigration is at least partly responsible for the increases, as birds settling to breed may cue in to sites with high-quality nesting habitat and low perceived predation pressure. However, the groupings included species where previous studies at Loddington Farm had found that breeding success was depressed when predator numbers were high (e.g. Blackbird, Song Thrush *Turdus philomelos*, Dunnock *Prunella modularis*, Spotted Flycatcher *Muscicapa striata*, Chaffinch; Stoate & Szczur 2001, 2006, White *et al.* 2008, 2014), and also included open-cup nesters, comprising the species a priori most likely to be vulnerable to predation losses. After predation control ceased at Loddington, the abundances of passerine insectivores and open-cup nesters especially declined to levels close to those measured at the start of the monitoring (Fig. 2). The implication, albeit from a single site, is that in the presence of high levels of common predators habitat management is not sufficient in itself to generate local population growth for bird species that are vulnerable to nest predation.

Why then did these same suites of birds show increases in abundance at Hope Farm, where predators were not controlled? The most likely explanation is the difference in predator densities at the two sites, with the predator index at Hope Farm being consistently lower than that at Loddington Farm in any of the non-keepered years (Fig. 1). At Loddington Farm, the increases in bird numbers were reversed after predator control ceased, despite a similar proportion of land devoted to favourable habitats (10–15%) as at Hope Farm (9–11%). At the same time, corvid territories at Loddington Farm increased to levels roughly four times higher than at Hope Farm. Because predator control at Loddington Farm was targeted as much at Foxes, small mustelids and Brown Rats as at corvids, the corvid-based measure of predator levels provided a good proxy for mammalian predator levels at that site. The same was not necessarily true of Hope Farm, but Heydon *et al.* (2000) found that the regional spring Fox density was 7 times lower in East Anglia than in the East Midlands (0.16 versus 1.17 foxes per km^2). This suggests that Fox density at Hope Farm was also low, in line with corvid density, and that overall the situation at Hope Farm was closer to that at Loddington Farm during the keepered phase than during the non-keepered phase. In terms of species recovery, it is possible that at Loddington Farm there is a risk of a predation trap, whereby the regulating influence of predators maintains prey density at a low level (Newton 1993). In such a situation, predator control becomes not only useful as an accelerator of local population growth but a requirement to kick-start recovery.

Regional density maps based on BBS data (http://www.bto.org/volunteer-surveys/bbs/latest-results/maps-population-density-and-trends) confirm that, like Foxes, background densities of Carrion Crows and Magpies in Leicestershire were higher than in Cambridgeshire. The reason is probably the difference in landscape: Crow density on farmland appears to be limited by nest-site availability (Charles 1972), and is higher in landscapes with mixed agriculture and forest than in agriculture-dominated ones (Andrén 1992), while Gooch *et al.* (1991) measured higher densities of Magpies in woodland than on arable land. It seems likely that the wooded terrain at Loddington Farm was attractive to these corvids, with trees providing shelter, vantage points and breeding areas, unlike the open landscape at Hope Farm. It is also possible that game-bird releasing and associated management was more intensive, and provided more resources (particularly live prey and carrion) for predators on the two family syndicate shoots in the landscape surrounding Loddington Farm than on the three small-scale family shoots around Hope Farm, although data are inadequate to confirm or refute this. Based on the predator densities and landscape characteristics of the two farms and their regions, a tentative numerical assessment for low predation pressure is: combined Crow and Magpie density less than 3 pairs/km^2, Fox density less than 0.2 animals/km^2 in spring and a woodland area less than 3% of landscape. High predation pressure at Loddington was characterized by: combined Crow and Magpie density greater than 5 pairs/km^2, Fox density greater than 1.1 animals/km^2 in spring, and woodland occupying at least 8% of landscape. Work is clearly needed to determine more precisely the densities and conditions under which predators may limit the effectiveness of conservation interventions, and the influence of game management and habitat structure on predator abundance and impacts.

The importance of predation at Loddington Farm appears to be at variance with a recent UK-wide analysis of temporal changes in declining passerine species (Newson *et al.* 2010), which was unable to detect an inverse relationship with changes in corvid abundance. It is possible that predation effects or the effects of breeding success on population size are scale-dependent, so that effects that are apparent locally disappear at the national level. It is also possible that the detection of predation effects requires changes in predator abundance greater than those that occur naturally; if so, intervention such as the predation control at Loddington Farm may be needed to produce the variation in predator densities over time that allows predation effects to impact prey densities (Stoate & Szczur 2006). A third possibility is that detecting the effect of individual predatory species, as in Newson *et al.* (2010), is considerably more difficult than detecting the aggregate effect of a guild of common generalist predators whose changes in density are synchronized (Tapper *et al.* 1996, Fletcher *et al.* 2010), as at Loddington Farm during the keepering phase. This possibility is supported by Madden *et al.* (2015), who found that experimental studies that removed only corvid species were less likely to show a positive impact on productivity than ones removing corvids alongside other predators (16% versus 60%).

Of the relationships between changes in habitat provision and changes in breeding bird abundance, those involving summer food habitats were consistently positive across species groupings and farms. Even for BAP and BoCC species, where interactions were detected, the difference between farms was in the magnitude of the positive slope rather than in the direction of the relationship, and the coefficients were significantly greater than zero at both sites. In terms of the conservation of declining species, therefore, the data from both farms support the need for the creation and maintenance of habitats providing summer food, particularly invertebrates. These included mainly conservation headlands, pollen & nectar mixes, beetle banks and ponds at Loddington Farm, and Skylark plots, floristic margins, pollen & nectar mixes and ponds at Hope Farm. All these elements are options within the English Environmental Stewardship scheme. Direct evidence of their use by foraging birds has been collected at the two farms for Skylark, Song Thrush and Yellowhammer *Emberiza citrinella* (Murray *et al.* 2002, Murray 2004, Gruar *et al.* 2010).

For nesting cover, the analysis highlighted inconsistent relationships between the two farms for FBI species, farmland specialists and non-passerine herbivores (Table 3), with significant negative relationships at Loddington Farm and non-significant positive ones at Hope Farm. Loddington Farm relied mainly on hedges, grass buffer strips and beetle banks for nesting habitat, whereas Hope Farm had relatively more fallow plots, floristic margins and Skylark plots. It seems likely that the suite of nesting habitats deployed at Hope Farm was more attractive to target farmland birds than those put in place at Loddington Farm, where the emphasis was more on nesting cover suitable for game birds.

For winter food, the significant negative relationships involving four species groupings are counterintuitive, given that several other farm- and landscape-scale studies suggest that winter food provision, particularly via stubbles and wild bird cover, is associated with farmland bird population growth (Gillings *et al.* 2005, Baker *et al.* 2012). In a separate analysis of the Hope Farm data, annual variation in the abundance of breeding FBI species was positively correlated with the extent of wild bird cover on the farm during the previous winter (Morris *et al.* 2010). At both farms, winter food habitats were created using mainly wild bird cover, set-aside and grass buffer strips. All of these have primary or secondary roles as summer food or nesting habitat, so will be included to some extent in the corresponding variables. The winter and summer food variables were particularly highly correlated (r = 0.80, Table 1). When summer food was excluded from the analyses in Table 3, only one of four groups still showed a significant negative relationship with winter food provision. The relationships involving winter food provision may therefore be largely artefacts of underlying correlations between variables. They may also have been influenced by the wide variety of habitats and measures included in the winter food category, with variable amounts of food being provided during different months and years (Boatman *et al.* 2003, Gillings *et al.* 2005, Vickery *et al.* 2005).

The final variable in the analysis was grain provision. The relationship with bird abundance was negative in all five instances where it was significant. The scale of our study may have been too small to investigate feeding effects on breeding density properly because many winter-fed birds are likely to breed off-farm. Moreover, the simple scoring approach took no account of the effective supplementation of resources (amounts of grain provided and consumed by birds), neither of which we were able to quantify reliably. In East Anglia, Siriwardena *et al.* (2007) found that positive effects of feeding on local population growth depended on the extent to which target birds consumed the seed, and it may be that too few species (other than game species at Loddington Farm) consumed our grain. At Hope Farm, grain feeding was at a low level (one location) and coincided with a period of minimal habitat provision, especially of winter food resources, so possibly the patterns might reflect generally inadequate provision of winter food. An alternative or complementary explanation is that the provision of grain may be directly or indirectly boosting numbers of generalist predators such as Brown Rats, which may subsequently have a deleterious impact on some breeding species in subsequent years in the absence of predator control. A possible management option perhaps worth exploring is whether substituting smaller seed such as rape or millet might reduce consumption by the larger non-target species without affecting that by farmland birds. The positive effects detected by Siriwardena *et al.* (2007) on the abundance of breeding birds suggest, however, that such predator interactions are not a general feature of supplementary feeding. Complicating the interpretation further is the fact that at both farms the cessation of grain provision coincided with a step increase in hedgerow area (Appendix Table A1), suggesting that the negative relationship with grain provision might in fact reflect a positive relationship with the amount of hedgerow.

The strong inter-correlations between the Big Three habitat variables (Table 1) limit our ability to distinguish between their respective effects on bird abundance. It seems wise therefore not to attempt to over-interpret the results for the habitat variables. Other factors may also hamper their interpretation, for instance the fact that they are based on extent of habitat rather than quality of that habitat (e.g. in terms of invertebrate prey and seed abundance). As such, we were not able to test variation in habitat quality and possible effects on bird abundance. Furthermore, the variables included a suite of habitat types designed to accommodate a wide range of declining farmland species; because different species have different requirements, our analyses may lack the necessary resolution to detect underlying relationships that may be largely species-specific. For example, the beneficial role of Skylark plots on breeding productivity is well established (Gruar *et al.* 2010); they are primarily considered to offer accessible chick food and secondarily nesting opportunities (Morris *et al.* 2004), so are included in the summer food and nesting habitat variables, yet neither variable is significantly positive for FBI species or farmland specialists. Hence, while the analysis shows that habitat provision and management can have a positive effect on local population growth, it does not, in its current form, explain how this comes about. There is an ongoing role for species-specific studies when trying to identify the factors most likely to bring about recovery of individual declining species (Aebischer *et al.* 2000b).

Conclusions and recommendations

Increases in bird abundance were dramatic at both farms, but were not sustained at Loddington Farm in the absence of predator control, despite similar proportions of land devoted to wildlife-friendly habitat at each site. Habitat creation alone at Hope Farm resulted in substantial increases in farmland bird abundance that matched or exceeded those observed at Loddington Farm. Predator levels at Hope Farm were, however, markedly lower than at Loddington Farm in the absence of predator control, certainly for corvids and probably also for Foxes. The greater extent of woodland at Loddington Farm and in the surrounding landscape may explain why background predator levels were higher there.

Because our study is based on only two demonstration sites, it is unclear how general our results are to the wider farmed landscape. We are unable, for example, to say what proportion of farms in the UK are more like Loddington, and what proportion more like Hope Farm. Bearing in mind these uncertainties, the data from Hope Farm suggest that where predator densities are relatively low, recovery of farmland birds can be achieved through habitat management alone. Where predator densities are high, as at Loddington Farm, recovery of species, particularly those vulnerable to nest predators, may require predator control as well as habitat management.

Both Loddington Farm and Hope Farm demonstrate that appropriate management can generate large local increases in numbers of priority farmland birds over relatively short time periods. These local successes need to be rolled out much more widely for an uplift to appear in the regional or national bird population indices. For this to happen, it is imperative that the economic incentives for land managers are properly aligned. The key is the offsetting of costs, as is currently achieved for farming in England through agri-environment or other means. We consider it crucial that such compensatory mechanisms remain consistently and widely available into the future if farmland bird recovery is to be expanded across the UK.

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SUPPLEMENTAL DATA

Supplemental data for this article can be accessed at 10.1080/00063657.2015.1090391

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APPENDIX

Table A1. Areas (ha) of wildlife habitats created or maintained annually on (a) Loddington Farm (GWCT) and (b) Hope Farm (RSPB). The numbering below each habitat heading indicates whether the habitat type is considered to be of major (bold font) or minor (normal font) importance for the provision of (1) nesting cover, (2) summer food and (3) winter food.

Year	Woods	Wild Bird Cover	Non-harvested cereals	Maize game crops	Stubble, fallow, setaside	Skylark plots	Floristic margins	Grass buffer strips	Pollen & nectar mixes	Beetle banks	Ponds	Hedges	Ditches	Conservation Headlands
		2 **3**	**3**	3	1 2 **3**	1 **2**	1 **2** 3	1 2 3	**2**	1 **2**	1 **2**	**1** 2 3	**1** 2 3	**2**
(a) Loddington Farm (1992–2010, total farm area 292 ha)														
1992	17.83	0	0	0	0	0	0	0	0	0	0.73	0	0	0
1993	17.83	2.30	0	0.66	8.33	0	0	6.20	0.69	0.69	0.73	6.43	0	0
1994	22.47	2.30	0	0	10.32	0	0	6.20	0.69	0.69	0.73	6.43	0	5.30
1995	22.47	4.90	0	0	0	0	0	6.20	0.69	0.69	1.93	6.43	0	9.85
1996	22.47	2.97	0	0	0	0	0	6.20	0.69	0.69	1.93	6.43	0	7.41
1997	22.47	3.47	0	0	0	0	0	6.20	0.69	0.69	1.93	6.43	0	7.85
1998	22.47	2.71	0	0	0	0	0	6.20	0.69	0.69	1.93	6.43	0	5.66
1999	22.47	4.18	0	0	0	0	0	6.20	0.69	0.69	1.93	6.43	0	4.55
2000	22.47	3.56	0	0	0	0	0	6.20	0.69	0.69	1.93	6.43	0	6.49
2001	22.47	3.59	0	0	0	0	0	6.20	0.69	0.69	1.93	6.43	0	4.53
2002	22.47	5.05	0	0	0	0	0	6.20	0.69	0.69	1.94	6.43	0	5.97
2003	22.47	8.87	0	0	11.34	0.02	0	6.20	0.69	0.69	1.94	6.43	0	5.30
2004	22.47	7.39	0	0	0	0.02	0	12.78	2.39	0.69	1.97	6.43	0	4.35
2005	22.47	7.40	0	0	8.33	0.02	0	12.78	2.39	0.69	1.97	6.43	0	4.40
2006	22.47	7.40	0	0	6.18	0.02	0	12.78	4.78	0.89	1.97	9.11	0.20	4.40
2007	22.47	7.40	0	0	5.03	0.02	0	12.78	4.78	0.89	1.98	9.11	0.20	4.40
2008	22.47	5.42	0	0	0	0.02	0	12.78	4.78	0.89	1.99	9.11	0.20	4.40
2009	22.47	5.42	0	0	0	0.02	0	12.78	4.78	0.89	2.00	9.11	0.20	4.40
2010	22.47	5.42	0	0	0	0.02	0	12.78	4.78	0.89	2.00	9.11	0.20	4.00
(b) Hope Farm (2000–2010, total farm area 181 ha)														
2000	1.20	0	0	0	0	0	0	1.00	0	0	0.30	0	0	0
2001	1.20	0.90	0	0	0	0.20	0	1.00	0	0	0.30	0	0	0
2002	1.20	0.90	0	0	0	0.30	0	1.00	0.40	0	0.30	0	0	0
2003	1.20	0.90	0	0	0	0.30	0.90	1.00	0.40	0	0.30	0	0	0
2004	1.20	0.90	0	0	10.20	0.10	1.90	2.95	0.40	0.05	0.30	0	0	0
2005	1.20	1.20	0	0	10.20	0.10	1.90	1.20	0.69	0.05	0.30	0	0	0
2006	1.20	3.55	0	0	7.90	0.30	1.90	1.20	0.69	0.05	0.33	1.18	0.11	0
2007	1.20	2.17	0	0	7.90	0.30	1.90	2.14	0.69	0.05	0.33	1.18	0.11	0
2008	1.20	2.30	0.90	0	0	0.30	3.20	1.50	0.90	0.05	0.33	1.18	0.11	0
2009	1.20	2.30	1.50	0	0	0.30	3.20	1.50	0.90	0.05	0.33	1.18	0.11	0
2010	1.20	2.50	0.70	0	2.50	0.30	3.20	1.50	1.90	0.05	0.33	1.18	0.11	0

Table A2. Bird species recorded at Loddington Farm and Hope Farm during the breeding season, with number of years recorded and categorization into species groupings. Names in italics are UK BAP priority species (Anon. 1995), ones in bold italics are also red-listed as BoCC (Eaton *et al.* 2009). nr: not recorded.

	Years recorded			Species grouping					
Species	Loddington Farm CBC 5 years	Loddington Farm Transect 19 years	Hope Farm CBC 11 years	FBI	Farmland specialists	Non-passerine herbivores	Passerine granivores	Passerine insectivores	Open-cup nesters
Greylag Goose	0	1	0						
Canada Goose	4	5	0						
Gadwall	0	4	0						
Mallard	0	15	6						
Tufted Duck	5	9	0						
Red-legged Partridge	5	19	11			Y			
Grey Partridge	2	13	7	Y	Y	Y			
Common Pheasant	5	19	11			Y			
Little Grebe	4	8	0						
Grey Heron	0	8	0						
Eurasian Sparrowhawk	5	8	10						
Common Buzzard	2	9	2						
Common Kestrel	4	3	8	Y					
Eurasian Hobby	0	1	0						
Common Moorhen	0	18	11						
Common Coot	5	16	0						
Northern Lapwing	1	6	5	Y	Y				
Stock Dove	4	18	11	Y	Y	Y			
Wood Pigeon	nr	19	11	Y		Y			Y
Collared Dove	5	0	11			Y			
Turtle Dove	3	4	4	Y	Y	Y			
Common Cuckoo	0	4	0						
Barn Owl	2	2	1						
Little Owl	5	2	5						
Tawny Owl	0	8	1						
Common Kingfisher	5	6	0						
Green Woodpecker	4	0	10						
Great Spotted Woodpecker	2	0	10						
Eurasian Skylark	5	19	11	Y	Y		Y		Y
Barn Swallow	nr	nr	11					Y	
Meadow Pipit	1	1	2					Y	
Yellow Wagtail	5	17	8	Y				Y	Y
Grey Wagtail	1	0	0						
Pied Wagtail	5	6	11					Y	
Eurasian Wren	5	19	11					Y	
Dunnock	5	19	11					Y	Y
European Robin	5	19	11					Y	
Common Blackbird	5	19	11					Y	Y
Song Thrush	5	19	11					Y	Y
Mistle Thrush	5	0	6					Y	Y
Grasshopper Warbler	2	1	0						
Sedge Warbler	1	3	4						
Reed Warbler	0	0	1						
Eurasian Blackcap	5	19	11						Y
Garden Warbler	5	17	5						Y
Lesser Whitethroat	5	15	9						Y

(*Continued*)

Table A2. Continued

Species	Years recorded			Species grouping					
	Loddington Farm CBC 5 years	Loddington Farm Transect 19 years	Hope Farm CBC 11 years	FBI	Farmland specialists	Non-passerine herbivores	Passerine granivores	Passerine insectivores	Open-cup nesters
Common Whitethroat	5	19	11	Y	Y				Y
Common Chiffchaff	5	18	8						Y
Willow Warbler	5	19	7						Y
Goldcrest	5	19	1						Y
Spotted Flycatcher	5	14	1					Y	
Long-tailed Tit	5	17	9						
Blue Tit	5	19	11						
Great Tit	5	19	11						
Coal Tit	5	17	0						
Willow Tit	5	0	0						
Marsh Tit	4	19	0						
Eurasian Nuthatch	2	1	0						
Eurasian Treecreeper	5	15	0						
Eurasian Jay	0	2	0						
Eurasian Magpie	3	10	9						
Western Jackdaw	nr	19	4	Y					
Rook	5	0	0	Y					
Carrion Crow	3	10	11						
Common Starling	nr	19	11	Y	Y			Y	
House Sparrow	nr	16	11				Y		
Tree Sparrow	4	15	0	Y	Y		Y		
Common Chaffinch	5	19	11				Y		Y
European Greenfinch	5	19	11	Y			Y		Y
European Goldfinch	5	17	11	Y	Y		Y		Y
Common Linnet	5	19	11	Y	Y		Y		Y
Eurasian Bullfinch	5	19	11				Y		Y
Yellowhammer	5	19	11	Y	Y		Y		Y
Reed Bunting	5	19	11	Y			Y		Y
Corn Bunting	0	0	1	Y	Y		Y		

Table A3. Percentage overlap in species between the eight species groupings defined in Table A2.

Species groupings	Farmland specialists	BAP species	BoCC Red List	Non-passerine herbivores	Passerine granivores	Passerine insectivores	Open-cup nesters
FBI	63	41	38	18	36	7	29
Farmland specialists		41	45	19	35	4	18
BAP species			89	8	36	15	21
BoCC Red List				9	27	16	15
Non-passerine herbivores					0	0	4
Passerine granivores						0	33
Passerine insectivores							18