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# Changes in Farmland Bird Abundance at Colworth 2000-2006

**Authors**

**Ian Henderson, Nigel Clark & Stephen Holloway**

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# EXECUTIVE SUMMARY


1. Unilever monitors 10 operational indicators of sustainable management on crops, to identify best practice for ecological, social and agro/economic conditions.

2. Within this framework, the Colworth Farm Project was a Lead Agriculture Programme, where systematic research was used to assess crop management effects on the abundance and distribution of plants and animals – specifically in this report, birds.

3. At Colworth, between 2001 and 2005, herbicide inputs were reduced to almost nil on experimental areas of crops and additional spring crops and set-aside added to a diversifying crop rotation.

4. For birds, a rapid population increase over three years, for a wide range of bird species, was sustained over five years, at 25% above the base line year (2000).

5. Good field boundaries, low pesticide applications, especially on fallows, and crop complexity were each responsible for high bird abundance, and the latter two caused the increase between years.

6. These conditions create habitat options for nesting and foraging and food resources throughout the year.

7. The converse is that larger expanses or parcels of land can extend uniformity (monocultures) beyond the natural foraging range of many bird species, so reducing the numbers that are supported there.

8. The principle of heterogeneity can be applied successfully to any agricultural system and not necessarily at the expense of commercial viability; albeit at scales varying with biogeography.

# A. GENERAL REPORT

## 1 INTRODUCTION

One of the most important conservation issues effecting bird populations in lowland Europe has been the widespread loss of structural diversity on farmland, due to simplified crop rotations and increasing pesticide use. Together they have contributed to well-documented declines in the abundance and variety of many plants and animals. More generally, demands for higher standards in the UK, for the protection of biodiversity, soils and raw materials have driven several government and privately funded research programmes to investigate more sustainable farm practices. In England, a Government commitment to reverse declining bird population trends on farmland by year 2020 (via the Farmland bird index of 'representative' species) will require large areas of land to make basic and fundamental contributions to habitat and food provision. Crop rotations may play their part and must be explored for their environmental value. Merging the combined agronomic and environmental potential of farmland into a workable formula is a challenging task. On this subject, however, we present results showing the response of farmland bird populations to combinations or elements of mixed cropping. Some crops can contribute as legitimate and complementary bird-habitats – particularly for bird species that are otherwise poorly represented among cereals.

Unilever monitors 10 operational indicators as a framework for the sustainable management of key crops around the world, as required for their business. The indicators are used to identify best practice for crop management practice regarding ecological, social and economic conditions. Within this framework, the Colworth Farm Project began in 1999, as a Lead Agriculture Programme within the Unilever Sustainable Agriculture Initiative (SAI). The farm allowed an assessment of agricultural methods and practices on commercial crops, within a relatively risk free environment. The research programme was relevant to farming on a range of European crops grown by or sourced by Unilever from third parties (oil seed rape, linseed, potatoes, cereals, peas, spinach and mustard). For biodiversity, some underlying and fundamental principles, such as the need for 'heterogeneity' (complexity at different and varying scales) can also be applied to all cropping systems anywhere, given suitable knowledge of local or regional ecology.

The Colworth Farm itself comprised 400 ha of arable land on clay, of which 61 ha were dedicated to the long-term rotational experiment outlined in this report (Fig. 1). The aim was to provide representative information on two Unilever crops (peas and oilseed rape) within a typical cereal-dominated rotation, over a sequence of years (Table 1). This would identify, at the whole-farm level, both the practical and impractical measures for the sustainable production of raw materials.

- *Aims and predictions at Colworth were as follows*: the project used systematic plant, invertebrate and bird monitoring programmes to assess the impact of crop and non-cropped habitat management, on the abundance and distribution of plants and animals (Colworth Report 2004). For birds, intensive crop management is widely considered to have been responsible for long-term declines on farmland in Europe with pesticide use and simplified cropping patterns being especially implicated (Curry *et al.* 2002; Donald *et al.* 2006). An experimental plan was therefore carefully replicated to quantify the relative effects of crop diversification and reduced chemical inputs on birds and other taxa. Such measures were expected to support:
- enhanced populations, due to the creation of breeding and forage habitats (which includes varied field types) and easier access to food (e.g. Benton *et al.* 2003).
- The capacity to increase levels of biodiversity on commercially viable crops could also be heralded as a 'win-win' scenario in both practice and in principle. Within a 'climate' of increasing awareness that farming should accept greater environmental responsibility (Curry *et al.* 2002), dual benefits or multi-functional benefits are especially desirable. Such a scenario would protect long-term supplies of raw materials as well as support viable populations of plants and animals.

## 2. PROCEDURE AND KEY RESULTS

For birds, between 2001 and 2006, herbicide inputs were reduced to almost nil on experimental crops and additional spring crops and set-aside introduced to the rotation. The effect of these measures was:

1. a rapid population increase among a wide range of bird species between 2001 and 2003,
2. a sustained population increase, over five years (2002-2006), at 25% above the base line year (2000).

Species of *high conservation concern*, and those monitored as Government '*environmental indicators*' increased by 30% and 20% respectively (Fig. 2). In all, 70% of the total increase in population occurred within three years of the experimental design being implemented – **showing how responsive** some bird species can be to circumstances that change in their favour.

Key factors affecting the distribution of birds at Colworth were:

- High quality boundaries: Extensive, thick hedgerows (around 3m high by 3m wide) with well-vegetated bases were especially significant, along with weed-rich ditch banks.
- Low pesticide applications in summer were responsible for increased use of fields by foraging birds in summer (weeds and attendant invertebrates) and during the following winter by improving weed-seed availability. This was especially evident on set-aside fallows, where delayed pesticide applications were very effective for Skylarks and buntings (Yellowhammer and Reed Bunting).
- Greater crop complexity was very effective in creating new 'habitats' for birds to feed and breed in. Bird densities on oilseed rape and weedy set-aside fallows (delayed spraying) supported up to five times the number of birds recorded on winter wheat, but other crops, spring wheat and peas, also contributed.

Key factors causing **changes** in bird populations at Colworth were:

- Weedy fallows, due to herbicide applications being delayed from April until June.
- A mixed rotation, offering varied and complementary field types as year-round habitat options for birds (supporting breeding conditions and over winter survival).

## 3 INTERPRETATION AND WIDER RELEVANCE

### 3.1 General Principles

The loss of ecological heterogeneity - landscape or field and/or species complexity - at multiple spatial and temporal scales is a universal consequence of multivariate agricultural intensification. In temperate agricultural systems, large-scale developments in pest control technology and machinery have created large-scale changes in agricultural landscapes (O'Connor & Shrubb 1986, Chamberlain *et al.* 1998), by typically creating larger expanses or 'units' of crops. These units, as single fields or multiple field areas, frequently extend uniformity beyond the foraging range of many breeding bird species, so that parents must travel further and breed further apart in order to procure resources, enough to raise successful broods. Modern agriculture also extends the period during which land is used, so creating greater uniformity over time as well as space, all in one stroke. Policy frameworks and management solutions need to recreate complexity as the key to restoring and sustaining biodiversity (e.g. Benton *et al*. 2003). With thought, this can often be achieved without impinging significantly on agronomy, although not without some investment in time and management.

### 3.2 Crops

Larger areas of single crop types support a characteristic but generally impoverished fauna compared to the same area given to varied field types and their connecting boundary features. Even crops that attract seemingly high bird faunas, such as oilseed rape in the UK, only fulfil a component role that not all species will benefit from. For example, birds of conservation concern in the UK, such as Yellowhammer and Reed Bunting exploit oilseed rape for invertebrates and caterpillars in summer, for seeds in later summer and even as nest sites for Reed Bunting too. However, two further species of conservation concern in the UK, Lapwing and Skylark rarely use oilseed rape because the crop is generally too tall and dense. Instead these species thrive in low growing spring crops or fallows that provide easy access to bare ground. Mixed crops therefore increase species richness and provided options to adapt with the differential development of crops. This allows birds to move between adjacent crops if some become unsuitable with crop development. Skylarks do this when they move from cereals into spring crops such as peas, in June, allowing them to extend their breeding season to include crucial second broods. Lapwings also require combination habitats – laying in open bare ground but requiring insects and vegetation cover for their chicks later. Spring crops and fallows or wide grass margins fulfil this combination.

For farmers, the economics of field management and technology suggest that in-field complexity is unlikely to be practical for modern farms, except by adopting special agri-environment scheme prescriptions (e.g. Skylark or Lapwing scrapes or wide field margins). Their flexibility to choose the content of mixed rotations may also be limited by market constraints but mixed rotations have a historical basis for aiding pest control, that may mean some agronomic justification is reclaimed through longer-term planning. In terms of pollution control and resource protection, via for example the Water Frameworks Directive, mixed cropping, including fallows, offers a third important function and potentially as necessity in future years in regions considered susceptible to diffuse sources of agricultural run-off. Landscape diversification using crops should also be valued as a practical option for farmers who are frequently 'submerged' in policy measures that require them to become accustomed to new or unfamiliar skills for landscape management (e.g. for wildlife). Instead, with crop rotations, they can use their knowledge of crop management to 'hit the ground running' and apply their practical skills to wider application. For most farmers, crop and landscape management is also a conceptually easier 'tool' to management than manipulating in-crop pesticide regimes, and without impinging directly on crop quality *per se*.

### 3.3 Non-Cropped Areas

In any farming context, high quality boundaries or divisions between harvestable areas of land add an extremely valuable and additional layer of habitat complexity. Their value can be relatively easily quantified and appropriate conditions created with minimum effect on agronomics of the working crops. If so applied, these habitats will be the single most important factors in determining bird distributions around agricultural land. Boundaries act as dispersal corridors, nest sites, places of shelter and a larder, and all edge habitats fulfil a critical and fundamental function for the ecological dynamics of a system. At Colworth, for example, *almost all* of the bird species living there were dependent on field boundaries for at least one key element of their life cycle, for example, nesting or foraging or sheltering from predators between foraging bouts. Optimal hedgerow density could even be quantified, at around 100m hedgerow per ha field. Above this, relatively few extra breeding territories were added (diminishing returns) and below this breeding density declined. Such values could be calculated for farmed landscape.

### 3.4 Controlling Pesticides

From Colworth, data have shown that some bird species forage extensively within crops, but that the effective management of pesticides in crops, for retaining both yield and biodiversity was difficult to achieve in practice. For most farmers, crop and landscape management is a conceptually easier 'tool' than manipulating in-crop pesticide regimes, and does not impinge directly on crop quality *per se*. However, every opportunity to reduce pesticide-use in crops should be taken, as this will always improve the food value of crops for birds. Careful management of non-cropped areas to avoid contamination is generally easier and very effective and should be considered *a given* for any serious pretensions towards sustainable farming. In this way, pesticide control offer the most functional way of optimising the agronomic and biodiversity values of farmland.

### 3.5 Integrated Landscapes, Integrated Ecology and Scale

By combining crops and non-cropped areas in strategic fashion, the management of farmland would be both flexibility and effective. Such combinations would procure an 'integrated ecology', to provide year-round benefits to wildlife. Their life-cycle requirements, including breeding demands, shelter and survival (meaning food and winter conditions in the UK) would all be catered for. The overall value of connecting all components of structural complexity would *always be greater than the sum of the parts* – for example, by allowing birds to exploit open areas they would not otherwise have ready access to.

Scale, however, is an important issue that operates in parallel at different levels. In the UK, the majority of smaller bird species in Britain operate typically within a 300 m radius of their nest site, such that a range of habitats needs to be provided roughly within the area of a 1-km$^2$ or less. Even the large species such as Lapwing and Grey Partridge can be remarkably sedentary when conditions are favourable. Crop monocultures or block cropping that extends across 1-km$^2$ or greater are likely to be sub-optimal at least in terms of the breeding densities of birds that could be supported. Expansive units of single crop types beyond this scale, would also be less effective at providing adequate and a varied foraging and breeding habitats, for the widest range of bird species possible – reducing biodiversity. Although, the scale at which mosaics can be applied will vary according to the regional ecology (food availability with soil and climate), generally, scale effects would be similar for similar bio-geographic regions of climate, regional landscape and topography. In cold-temperate or perhaps all temperate, lowland world regions, the scale at which farming mosaics can be applied will probably not vary beyond one order of magnitude (e.g. from the 1-km$^2$ scale to the 10-km$^2$scale) but in any circumstance could be relatively easily quantified though studies of local bird assemblages.

### 3.6 Wider Application

Unilever's responsibilities extend to many countries in the world, typically through sourcing agricultural raw materials. This is reflected in a large number of agricultural programmes on a range of crops, which benchmark operations against principals or indicators of sustainability. The importance of this is that general principles (green corridors, buffer zones, food and habitat provision) partly tested for their effectiveness at Colworth, could have broad relevance to other agriculturally based business interests. Ultimately the goal would be to advance good agricultural practice over a wider geographic area in the world, which has immense responsibility for multi-national corporations such as Unilever. The alternative would simply be to shift environmental ‘problems’ from one part of the world to another.

In any agricultural circumstances, careful adjustments of crop and landscape mosaics (to suit regional conditions and needs) should be entertained as an option for improving the sustainable provenance of agricultural land. The current climate in Europe, is for adding multifunctional value to farmland, with latitude for greater aesthetic and leisure needs, as well as biodiversity. The fundamental process of managing landscape mosaics will therefore re-surface many times over.

Finally, two important results from Colworth demonstrate that species recovery is not a lost cause. The speed of recovery can be surprisingly rapid. This is probably, mainly true for generalist species that typically associate with intensive farmland in the first place as these species are able to adapt to change more readily. Nevertheless, with sufficient knowledge of ecology and with suitable planning, many bird species (and probably other taxa) will be *surprisingly responsive* to the newly available ‘habitats’ or restored habitats and sympathetic farming.

## B. TECHNICAL REPORT

## 4. METHODS

### 4.1 Site Description

The Sustainable Agriculture Project began in winter 1999/2000 as the first year of a six-year rotation. Year 2000 was the baseline year, and experiment began in 2001. The experimental area comprised 61 ha of commercial farmland, situated within the River Great Ouse catchment area. The soil is of a 50:50 clay/silt composition and the site is susceptible to blackgrass *Alopecurus myosuroides* resistance in areas of high fertility. The site has deciduous woodland on two boundaries sides. The eight fields, averaging, 7.5 ha per field, are a mixture of open and enclosed fields, comprising 123 m $ha^{-1}$ of boundaries (hedges, ditches and tracks) of which 83 m $ha^{-1}$ was wooded (hedgerows and woodland edge). Mean hedgerow height and width (including basal herbage but not margins) was 2.77 m and 3.1 m respectively. Hedgerow composition was estimated to comprise at least 68% hawthorn *Cratagus monogyna*, 44% blackthorn *Prunus spinosa,* and 30% elder *Sambucus nigra* among the shrub species. Approximately 27% of hedge boundaries contained mature trees (>5m) of Oak *Quercus robur* or Ash *Fraxinus excelsior*, which were generally thinly distributed. All field boundaries were subdivided and labelled according to similarities in vegetation height, width and/or shrub or tree composition. An adjacent control area was slightly more open, comprising 76.5 ha of arable land, with 71.9 m $ha^{-1}$ of boundaries and 58.8 m $ha^{-1}$ of wooded boundaries.

### 4.2 Crop Rotation (Table 1)

All farm procedures and crop applications were recorded within an annual log. Diversification meant that by summer 2000 six fields were sown to winter wheat (now 42.5 ha) and one field each was sown to winter sown oilseed rape (9.5 ha) and vining peas (“Harrier”; 9.0 ha). From spring 2001, areas of winter wheat were replaced on average by 8.5 ha of natural regeneration set-aside and 9.25 ha of spring-sown wheat. Also, 50% of the oilseed rape was spring-sown from year 3 (i.e., 2002). The site entered a six-year rotation, adopting conventional principles, where all fields were subject to deep ploughing and pre-emergent, non-residual herbicides (“glyphosate”) to create a “stale” seedbed. Post-emergent herbicides, insecticides and fungicides were applied in response to emerging problems or according to experimental requirements rather than as pre-emptive measures.

### 4.3 Experimental Treatments

In year 2 (2001), within-field fertiliser and pesticide treatments were superimposed on the cereals and pea fields. In a replicated design, treatments on half-field sections were assigned as follows:

1. Minimum (on half a field) versus Normal (on half a field) pesticide rates in one direction on, and
2. Minimum (on half a field) versus Normal (on half a field) fertilizer inputs lying perpendicular to ‘1’ on the same crop.

On average, 26 ha, 25 ha, 14.8 ha and 16.6 ha of Normal fertiliser (NF), Normal pesticide (NP), Low fertiliser (LF) and Low pesticide (LP) treatments, respectively, were available in each year of the study. The design allowed the following areas of fertilisers and pesticides to be analysed:

- NF with NP applications (Mean ha $year^{-1}$ =17.6);
- NF with minimum pesticide (MP) applications (Mean ha $year^{-1}$ = 9.0);
- Minimum fertiliser (MF) with NP applications (Mean ha $year^{-1}$ =7.53),
- MF with MP applications (Mean ha $year^{-1}$ =7.31).

Minimum treatments were extreme measures, designed to elicit a maximum response from organisms, usually set at zero, unless remedial action was needed to prevent total crop loss.

### 4.4 Bird Counts

In all years of the study, eight morning visits were made to the site over summer and four to six visits made during winter to map the precise location of all birds seen or heard on the experimental area. This method was consistent, standardised and used well established methods (cf., Common Birds Census: Marchant *et al.*1990). It used the same observer throughout, who walked every field boundary, and a 200 m 'winding' path through every accessible field. Activities of birds, 'singing/displaying', 'foraging', 'flying', carrying food or carrying nest material were identified along with sex and age where possible. In years 2000 and 2005 only (not the intervening years), identical observations were carried out on an adjacent 'control' area farmland. Detailed observations were made of buntings (*Emberiza* spp) provisioning their chicks. This involved repeated 1-hour watches of nest territories, between late May and late July of summers 2002, 2004 and 2005 and observational details of foraging locations.

## 5. RESULTS: FACTORS AFFECTING THE DISTRIBUTION OF BIRDS

### 5.1 Changes in Breeding Abundance and Territory Density

Between 2001 and 2005, there was a significant increase in the number of breeding 'territories' of FBI species on the experimental site (Paired *t*-test (on log+1 value): $t = 2.3$, $P < 0.05$, n = 10 & $t = 2.7$, $P < 0.006$, n = 17 respectively; Fig. 2a). The difference between the baseline year and the five-year average during the experimental period was 31% for 10 farmland BAP species, 19.7% for 17 FBI species and 23% for Skylarks. Around 70% of this increase for BAP species was reached within three years.

There was a significant increase, over five years, in the abundance of BAP species (73%), FBI species (58%) and Skylarks (46%); as well as insectivorous (52%) and granivorous (78%) species groups. With Year*Species-group interactions there were significant differences between the slopes of: (a) FBI species compared to the local regional trend for the same species ($\chi^2_5 = 20.4$, $P < 0.003$), and (b) both the FBI and BAP species groups compared to the Woodland-species group at Colworth ($\chi^2_5 = 18.4$, $P < 0.003$; $\chi^2_5 = 16.6$, $P < 0.01$ respectively; Fig. 2). Increases in the abundance, per visit, of FBI species (6.3%), BAP species (9.4%) and Skylarks (6.3%) on the adjacent control area were not statistically significant. On the experimental area, there was a significant increase in Grey Partridge (LR: $\chi^2_4 = 10.8$, $P < 0.05$, scale = 1.3), a non-significant increase in corvids ($\chi^2_4 = 6.7$, $P < 0.24$, scale = 1.2) and birds of prey ($\chi^2_4 = 6.2$, $P < 0.18$, scale = 1.3) and no change in 'pigeons' ($\chi^2_4 = 8.2$, $P < 0.14$, dispersion = 11.2). Significant increases occurred for insectivorous species and for seed-eating species ($\chi^2_5 = 47.3$, $P < 0.001$, scale = 0.5; $\chi^2_5 = 123.4$, $P < 0.001$, scale = 0.49 respectively) but the overall rate of increase was significantly higher for the latter group ($\chi^2_5 = 32.1$, $P < 0.001$, scale = 0.42). This sequence of results show that changes in abundance and populations for many species, were site-specific to Colworth and a consequence of the experimentation.

### 5.2 Changes in Winter Bird Abundance

Since 1999/2000, mean bird abundance per visit increased on the experimental area by 500% in winter for all FBI species, which was significant across winters ($\chi^2_5 = 16.1$, $P < 0.01$, scale = 1.3). Also, there were significant Year*Species-group interactions between the slopes of both the BAP and FBI species compared to the Woodland group ($\chi^2_5 = 12.3$, $P < 0.05$, scale = 1.2; $\chi^2_5 = 11.1$, $P < 0.05$, scale = 1.5), and the slopes of BAP species and the Woodland group ($\chi^2_5 = 13.2$, $P < 0.03$, scale = 1.2. The overall increase between 1999/2000 and 2004/2005 was significantly greater on the experimental area than on the control area ($\chi^2_1 = 3.9$, $P < 0.05$, scale = 1.3). Note that the FBI group excluded wood pigeons, whose peaks of numerical dominance tended to 'mask' effects or trend relating to other species.

Among species groups in winter on the experimental site, there was a significant increase in abundance of granivorous species ($\chi^2_5 = 17.4$, $P < 0.005$, scale = 0.96; including with the removal of linnet as the numerically dominant species ($\chi^2_5 = 16.7$, $P < 0.006$, scale = 0.7). There was no significant increase in the overall abundance of Skylarks ($\chi^2_5 = 7.4$, $P < 0.19$, scale = 24.0) or insectivorous species ($\chi^2_5 = 8.3$, $P < 0.14$, scale = 0.92), but a significant increase in the abundance of Grey Partridge ($\chi^2_5 = 12.2$, $P < 0.03$, scale = 1.17). There was a non-significant increase in corvids ($\chi^2_5 = 2.2$, $P < 0.82$, scale = 1.7) and birds of prey ($\chi^2_5 = 9.7$, $P < 0.08$, scale = 1.13) and shallow decline in 'pigeons' ($\chi^2_5 = 5.9$, $P < 0.31$, scale = 1.23).

### 5.3 Year-Round Effects on Birds Densities and Field Use

The effects of variables: Year, boundary length-to-field area ratio (the strongest boundary effect and here abbreviated to 'BAR'), field location, field content and pesticide treatment are summarised in Table 3. BAR, field location and field content each accounted for significant differences in the spatial distribution of birds on the site in summer. Field location was a weaker explanatory factor in winter. BAR, varied across the 24 field sub-sections, with the highest density on fields (0.46 bird ha$^{-1}$) at 90 m of hedgerow per ha of field for all hedgerow-based species combined and a negative relationship for Skylarks. BAR was included as a control for boundary affects in subsequent analyses of bird using fields.

## 5.4 Field Content

There were significantly higher densities of birds that used late-sprayed fallows and oilseed rape than winter wheat or early-sprayed fallows. Early-sprayed fallows supported the lowest densities of birds and the lowest richness of species among all field types (Table 3, Fig. 3a), controlling for field location and BAR. Peak densities of birds in crops occurred in the rotation years of high coincidence between 'preferred' field types (i.e. weedy fallows, oilseed rape and vining peas) preferred field locations (that is, years 2002 and 2004). The interaction between field content and field location explains part of the year-to-year variation in population change or abundance on the site.

In winter, variation in the densities of birds across the site and between years was most strongly associated with field content, but there were also treatment effect. With respect to field content, there were significant differences between field types for insectivores and granivorous species in general, as well as for species, Grey Partridge and Skylark.

## 5.5 Field Treatments

In summer, there were significant effects of zero pesticide treatments on the densities, within crops (excluding rape) for Skylarks, Yellow Wagtails, and Linnets, and also for all BAP species combined ($\chi^2_1 = 5.1$, $P < 0.02$). There were no significant effects detected for other species, and although there was a positive effect of low-pesticide treatments in summer for 10 out of 14 species this was not statistically significant (Wilcoxon $T_{19} = 68$, $P < 0.10$). For fertilizers and equal number of species showed positive and negative responses to treatments.

In winter, mean densities of both insectivorous and granivorous species were significantly higher on field sectors subject to zero pesticide inputs during the previous summer. More individual species occurred at higher density on zero pesticide field sectors than normal field sectors (16 of 19 species; Wilcoxon $T_{19} = 165$, $P < 0.01$)) although the effect for most individual species themselves was non-significant. For fertilisers, although there were significant effects for some individual species there was no consistent direction of effect across species (seven of 18 species; Wilcoxon $T_{19} = 45$, ns).

## 5.6 Supporting Information on Provisioning Adults Foraging Activity

Data from 14 nests of buntings, over the three years provided the following information. At least 40% of provisioning flights were into crops or set-aside, the rest into tracks and margins or woodland edge. In all, 84.1% of all provisioning trips (n=346) were to less than 100 m, 26.3% between 100 m and 300 m, 9.7% trips exceeding 300 m and 6.5% exceeding 400 m. In 2001, 2004 and 2005 combined, in crops, there was a significantly higher use of oilseed rape than winter wheat or spring wheat or peas ($\chi^2_3 = 68.3$, $P < 0.0001$).

## 6. SUMMARY AND DISCUSSION

Between 2001 and 2006, there was a significant increase in both the breeding population of BAP species and Farmland Bird Indicator (FBI) species on the experimental site. The difference between the baseline year (2000) and the six-year average during the experimental period was 31% for BAP species and 19.7% for FBI species. There was no concurrent increase for FBI species in the eastern England region indicating that the population changes at Colworth were specific to the site. Significant differences between FBI and BAP species compared to the woodland species indicated that changes to the site were related to farmland management. In winter, the bird abundance increased on the experimental area by 13% since 1999/2000. In 2005, winter densities were higher on the experimental area than on the control area. Observations of parent Yellowhammers showed that **tracks and ditches** were used most frequently for feeding trips, alongside **oilseed rape.** Rape was especially valuable amongst crops. Crop margins were infrequently used for foraging trips but probably afforded greater protection from nest-predators.

Key factors affecting the distribution of birds at Colworth were: (a) Extensive, thick hedgerows (around 3 m high by 3 m wide) with well-vegetated bases, along with weed-rich ditch banks. (b) Low pesticide applications in summer leading to increased use of fields by foraging birds (weeds and attendant invertebrates) and also improving winter weed-seed availability. This was especially evident on set-aside fallows with delayed pesticide applications in spring, and (c) greater crop complexity, creating new ‘habitats’ for birds to feed and breed in. Bird densities on oilseed rape and weedy set-aside fallows (delayed spraying) supported up to five times the number of birds recorded on winter wheat, with spring wheat and peas, also contributing. Key factors causing *changes* in bird populations at Colworth were: weedy fallows and introduced field types, offering varied and complementary options for breeding and over winter food provision.

Over six years, the data have showed that some bird species forage extensively within crops, but that the effective management of pesticides in crops, for both yield and biodiversity is difficult in practice. Instead, greater landscape complexity, which in this case used different crops as habitats, next to margins and hedgerows, provide more options for birds to breed and forage. For most farmers, crop and landscape management is a conceptually easier ‘tool’ to management than manipulating in-crop pesticide regimes, and does not impinge directly on crop quality *per se*. Crops such as peas or rape, as part of a rotation, can rarely be viewed in isolation. Their positioning alongside neighbouring habitats or crops increases the value of pea crops or oilseed rape for biodiversity. Both crops contributed their own species, by supporting complimentary bird faunas, but the species that used peas, for example, are field nesters (Lapwing, Skylark and Yellow Wagtail) for which optimal benefits are derived from their proximity to adjacent fallow fields or wide field margins within the crop-field itself, into which young birds can escape at harvest.

Winter resources are critical too. Weed seeds emerged after the previous crop within stubbles or cultivated land. Ground following oilseed rape was particularly effective in providing seeds, but the availability of any untilled ground in winter, was also valuable. Late winter weedy stubbles (late-sprayed in summer) and natural weed/volunteer re-growths provided the best options for foraging birds. There are still many unanswered questions as to the most effective ways of managing winter conditions for birds, especially regarding oilseed rape or potential cover crops used for nutrient control, such as mustard.

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**Table 1**. Details of the crop rotation installed at Colworth between 1999 and 2006.

| | Field identification number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **37-40** | **39** | **41** | **43** | **45** | **42** | **44-46** | **47** |
| **1999/2000** | WOSR | 1st WW | 2nd WW | 2nd WW | V. Peas | 1st WW | 1st WW | 2nd WW |
| **2000/2001** | 1st WW<br>1st SW | 2nd WW | 3rd WW | V. Peas | 1st WW<br>1st SW | 2nd WW | SAS | WOSR |
| **2001/2002** | SAS | V. Peas | V. Peas | 1st WW | 2nd WW<br>2nd SW | WOSR<br>SOSR | 1st WW | 1st WW |
| **2002/2003** | 1st WW<br>1st SW | 1st WW | 1st WW | 2nd WW | WOSR<br>SOSR | 1st WW | V. Peas | SAS |
| **2003/2004** | V. Peas | 2nd WW | 2nd WW | WOSR | 1st WW<br>1st SW | SAS | 1st WW | 1st WW |
| **2004/2005** | 1st WW<br>1st SW | WOSR | WOSR | 1st WW | SAS | 1st WW | 2nd WW | V. Peas |
| **2005/2006** | 2nd WW<br>2nd SW | 1st WW | 1st WW | SAS | 1st WW<br>1st SW | V. Peas | WOSR | 1st WW |

Key: V. Peas = Vining peas, SW = Spring Wheat, WW = Winter wheat, WOSR = Winter oilseed rape, SOSR = Spring oilseed rape, SAS = Set-aside fallows.

**Table 2.** Showing the bird species that were monitored at Colworth and which contributed to the analysis. The analytical groups into which each species were placed are also presented.

| | | | | Analytical species groups | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | | | **2000-2006 trend** | **Farmland** | **Insectivores** | **Granivores** | **Woodland** | **FBI** | **BAP** |
| Buzzard | *Buteo buteo* | L. | + | * | | | | | |
| Sparrowhawk | *Accipiter nisus* | L. | = | * | | | | | |
| Hobby | *Falco subbuteo* | L. | + | * | | | | | |
| Kestrel(I) | *Falco tinnunculus* | L. | + | * | | | | * | |
| Grey Partridge(BAP, I) | *Perdix perdix* | L. | + | * | | | | * | * |
| Lapwing(BAP, I) | *Vanellus vanellus* | L. | + | * | | | | * | * |
| Woodpigeon(I) | *Columba palumbus* | L. | + | * | | | | * | |
| Stock Dove(I) | *Columba oenas* | L. | = | * | | | | * | |
| Turtle Dove(BAP, I) | *Steptopelia turtur* | L. | = | * | | | | * | * |
| Little Owl | *Athene noctus* | L. | + | | | | | | |
| GS Woodpecker (W) | *Dendrocopus major* | L. | + | | | | * | | |
| Green Woodpecker | *Picus viridus* | L. | + | | * | | | | |
| Skylark(BAP, I) | *Alauda arvensis* | L. | + | * | | * | | * | * |
| Swallow | *Hirundo rustica* | L. | = | * | | | | | |
| Pied Wagtail | *Motacilla alba* | L. | = | * | | | | | |
| Yellow Wagtail(BAP, I) | *Motacilla flava* | L. | + | * | * | | | * | * |
| Dunnock | *Prunella modularis* | L. | + | * | * | | | | |
| Wren(W) | *Trogolodytes trogolodytes* | L. | = | | | | * | | |
| Robin | *Erithacus rubecula* | L. | + | * | * | | | | |
| Blackbird | *Turdus merula* | L. | + | * | * | | | | |
| Song Thrush(BAP) | *Turdus philomelos* | | = | * | * | | | | * |
| Lesser Whitethroat(W) | *Sylvia curruca* | L. | = | | | | * | | |
| Whitethroat(I) | *Sylvia communis* | L. | + | * | * | | | * | |
| Garden Warbler(W) | *Sylvia borin* | L. | + | | | | * | | |
| Blackcap(W) | *Sylvia atricapilla* | L. | - | | | | * | | |
| Willow Warbler(W) | *Phylloscopus trochilus* | L. | + | | | | * | | |
| Chiffchaff(W) | *Phylloscopus collybita* | L. | = | | | | * | | |
| Nuthatch(W) | *Sitta europaca* | L. | = | | | | * | | |
| Treecreeper(W) | *Certhia familiaris* | L. | + | | | | * | | |
| Blue Tit(W) | *Parus caerulus* | L. | = | | | | * | | |
| Great Tit(W) | *Parus major* | L. | = | | | | * | | |
| Marsh Tit(W) | *Parus palustris* | L. | + | | | | * | | |
| Long-tailed Tit(W) | *Aegiathos caudatus* | L. | + | | | | * | | |
| Carrion Crow | *Corvus corone* | L. | - | * | | | | | |
| Jackdaw(I) | *Corvus monedula* | L. | + | * | | | | * | |
| Rook(I) | *Corvus frugilegus* | L. | + | * | | | | * | |
| Jay(W) | *Garulus glandarius* | L. | + | | | | * | | |
| Magpie | *Pica pica* | L. | - | * | | | | | |
| Starling | *Sturna vulgaris* | L. | = | * | * | | | | |
| House Sparrow | *Passer domesticus* | L. | = | * | | * | | | |
| Tree Sparrow(BAP, I) | *Passer montanus* | L. | + | * | | * | | * | * |
| Bullfinch(BAP, I) | *Pyrrhula pyrrhula* | L. | + | * | | * | | * | * |
| Goldfinch(I) | *Caruelis carduelis* | L. | = | * | | * | | * | |
| Greenfinch(I) | *Carduelis chloris* | L. | = | * | | * | | * | |
| Linnet(BAP, I) | *Carduelis cannabina* | L. | - | * | | * | | * | * |
| Chaffinch | *Fringilla coelebs* | L. | - | * | | * | | | |
| Reed Bunting(BAP, I) | *Emberiza schoeniclus* | L. | + | * | | * | | * | * |
| Yellowhammer(BAP, I) | *Emberiza citrinella* | L. | + | * | | * | | * | * |

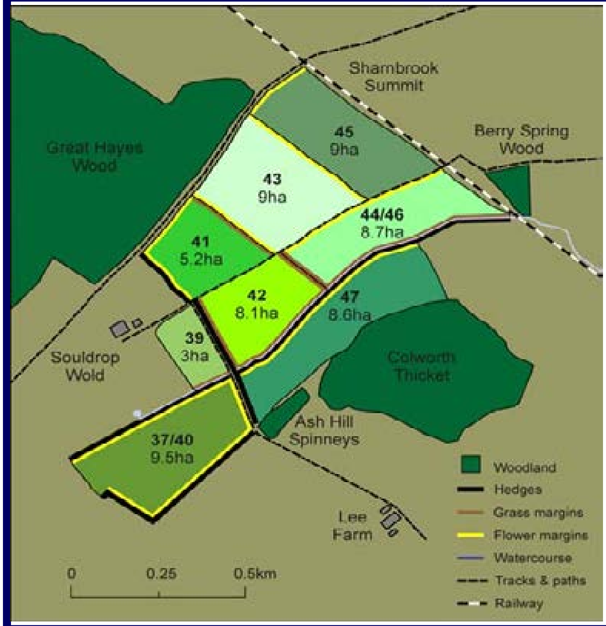
Red-legged Partridge *Aclectoris rufa* L., & Ring-necked Pheasant *Phasianus colchicus* L. status unknown.

**Table 3**. A summary of the results from the regression analysis for birds using crops, treatments and boundary features on the experimental area in summer.

| **Skylark** | | | | | | |
|---|---|---|---|---|---|---|
| **Variables** | **Chi-square** | ***P*** | **d.f.** | **Dispersion** | **Preference summary** | **Highest density (relative to WW)** |
| **Field (crop) type** | 138.5 | 0.001 | 5 | 1.67 | GW, VP, RA, SW, WW, CS | GW=45.8 |
| **Field location** | 67.1 | 0.01 | 7 | 0.99 | 37,43,42,41,45,47,44,39 | |
| **Year** | | | | | 2002, 2004, 2005, 2003, 2001, 2000 | |
| **Fertilisers** (all crops) | 4.18 | 0.04 | 1 | 2.2 | GAP | 2.5 |
| (winter wheat only) | 3.69 | 0.05 | 1 | 1.2 | MIN | 1.45 |
| **Pesticides** (all crops) | 6.68 | 0.02 | 1 | 2.2 | MIN | 0.45 |
| (winter wheat only) | 0.11 | ns | 1 | 1.2 | MIN | 1.16 |
| **Boundary variables** | *Correlation* | | | | | |
| height | -0.1 | 0.001 | | | | |
| **Other Species in Fields** | | | | | | |
| **Field (crop) type** | 144.2 | 0.001 | 5 | 0.4 | RA, GW, SW, VP, WW, CS | RA=6.9 |
| **Field location** | 240.8 | 0.001 | 7 | 0.35 | 37,47,41,39,45,42,44,43 | |
| **Year** | | | | | 2002, 2004, 2005, 2003, 2001, 2000 | |
| **Fertilisers** (all crops) | 4.12 | 0.05 | 1 | 1.04 | GAP | 1.84 |
| (winter wheat only) | 7.6 | 0.005 | 1 | 0.45 | GAP | 7.69 |
| **Pesticides** (all crops) | 8.21 | 0.004 | 1 | 1.04 | MIN | 1.77 |
| (winter wheat only) | 0.45 | ns | 1 | 0.45 | MIN | 1.76 |
| **Boundary variables** | *Correlation* | | | | | |
| height | 0.1 | 0.001 | 23 | | | |

NB. for field location field 37=field 37-40, field 44=field 44-46.
CS=cereal stubbles (early-sprayed set-aside), GW = weedy late-sprayed set-aside fallows,
RA = oilseed rape, SW = spring wheat, WW= winter wheat, VP = vining peas

**Figure 1**. Colworth site field plan and the diversification of field types during the experimental years, 2001 to 2005.




**Diversification:**

**2000**
Wheat 80% cover 2000,
oilseed rape 14%.

**2001-2005**:

| | |
|---|---|
| Wheat | 40-50% |
| Oilseed rape | 14%. |
| Peas | 14% |
| Set-aside (fallow) | 14% |
| Spring wheat | 6% |

**2006**
Reversion to 2000, wheat 60% cover,
oilseed rape 40%.

**Figure 2**. Showing the annual change in breeding birds belonging to the Farmland Bird Indicator, where the rate of increase was faster than for woodland species on the same site.

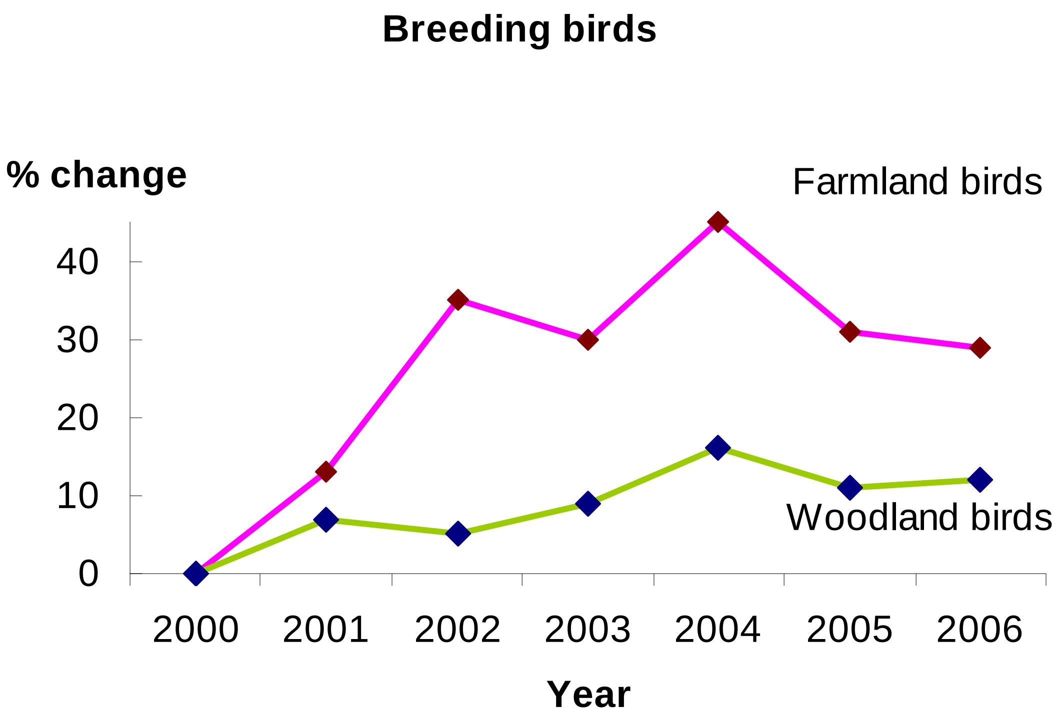


**Figure 3**. Comparing densities of bird recorded on field types during (a) summer (all species combined) and (b) winter (species groups) on the Colworth experimental site.