Testing the delivery of conservation schemes for farmland birds at the farm-scale during winter, in Southern lowland England

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Abstract: Many farmland bird species across Europe have continued to show population declines since the 1970s, as a result of agricultural intensification. A large number of conservation schemes and initiatives have emerged from Government and the food industry sector to address this problem. Some farmland bird populations are limited by overwintering survival. This paper compares winter farmland bird abundance and species richness from differing conservation schemes, including: Entry Level Stewardship (ELS), Conservation Grade (CG) and Organic farm management scenarios. Winter bird surveys were tailored to the farm-scale, reflecting the proportions of infield habitat arrangements of nine case study farms. Organic farms provided significantly less infield habitat types across all schemes and were dominated by grassland habitat. Entry Level Stewardship and CG schemes had larger proportions of winter bird food provisions and increased habitat heterogeneity. The results show granivorous passerines to be significantly more abundant on CG farms compared to Organic. Moreover, yellowhammers (*Emberiza citronella* L.) are specialist seed-eaters that were significantly less abundant on Organic farms, compared to ELS and CG. There were no significant differences for insectivorous passerines between schemes. A positive relationship between number of infield habitats and species richness on farms was found, with Organic farms scoring the lowest species richness. These results demonstrate a proof-of-concept that farm-scale management can have positive farm-scale effects for birds; with increasing habitat heterogeneity and the presence of winter bird food provisions. Interestingly, Organic farms are shown not to provide significant benefits to overwintering birds. This paper suggests that the CG scheme provides the best framework for farmers to achieve sufficient infield habitat arrangements to better overwintering farmland birds.

Key words: Agri-environment schemes; Farmland birds; Farmland bird index; Organic; Farm conservation schemes.

1. Introduction

1.1 Background

Agricultural landscapes are in excess of 2000 years old and account for 77% of land area in the United Kingdom (UK) (Angus *et al*., 2009). Traditionally, pristine wilderness areas have been the priority for biodiversity conservation; however the value of agricultural land use is now being realised (Tscharntke *et al*., 2005). Many species have had time to adapt to extensively managed landscape changes within farming, resulting in the development of anthropogenic species-rich ecosystems (Busch, 2006; Kleijn *et al*., 2006). Birds are considered as good indicator species for overall farmland biodiversity (Gregory *et al*., 2005). Approximately, 60% of Europe's threatened bird species are associated with lowland agricultural landscapes (Ausden & Hirons, 2002). Since the 1970s, many farmland bird species have shown severe population declines across Europe (Newton, 2004). Agricultural intensification has increased farming productivity, but has had deleterious effects on farmland bird populations. This has been demonstrated with spatial and temporal correlations between agricultural intensification and biodiversity loss (e.g. Chamberlain *et al*., 2000; Donald *et al*., 2001a; Shrubb, 2003; Gregory *et al*., 2005; Donald *et al*., 2006). Green *et al*. (2005) show that farming practices are the greatest extinction threat to birds. Agricultural intensification is a multi-dimensional process, including: increased mechanisation and agro-chemical use, land drainage, changes in crop types and the spread of monocultures, changes to earlier sowing and harvesting dates, reduction in traditional rotations, increased stocking densities and the removal of uncultivated habitats such as ponds and hedgerows (Krebs *et al*., 1999; Newton, 2004; Tscharntke *et al*., 2005; Donald *et al*., 2006).

Rachel Carson's 1963 book, *'The Silent Spring'* created a public awareness and response to the organochlorine insecticides responsible for bird declines in the 1950s and 1960s. Subsequently, persistent organic pollutants have become heavily regulated internationally and replaced by less persistent compounds; thus, preventing disastrous bird poisoning (Werner & Hitzfeld, 2012). Krebs *et al*. (1999) have termed the current farmland bird loss associated with agricultural intensification as the 'The Second Silent Spring', attempting to emulate the grandeur of the 1963 response. However, the current problem is greater, with the causal effects of intensification occurring indirectly across a range of functions, rather than the direct poisoning of wildlife by pesticides (Krebs *et al*., 1999). Therefore, the mechanisms by which farming practices influence bird populations are diverse and complex. The scale of the problem has been recognised in the UK, with successful monitoring and research having a significant influence on government policy (Greenwood, 2003). Birds have become an area of focus for biodiversity conservation, with the government adopting wild bird population indices as one of its fifteen key headline indicators for sustainable development (Gregory *et al*., 2004). This includes the creation of the Farmland Bird Index (FBI), which shows that farmland bird populations have almost halved since 1970. In 2000, the UK government set a Public Service Agreement (PSA) target to reverse the long-term decline in farmland bird populations by 2020. The PSA target is monitored by using the FBI (Butler *et al*., 2007).

1.2 Farm conservation management for birds

There are different farm management approaches towards biodiversity conservation and the reversal of farmland bird loss. A large number of conservation schemes and initiatives have emerged from Government and the food industry sector, including the development of agri-environment schemes (AES) and farm certification schemes. All schemes share a common aim to achieve environmentally friendly farming; but operate through a range of different objectives, from soil fertility and landscape protection, to the creation of new wildlife specific habitat (Battershill & Gilg, 1997).

Agri-environment schemes that compensate farmers for prescribed environmental management have been in place in the UK since 1987 and are now a central policy mechanism towards reversing farmland bird decline. Scientific research into the effectiveness of AES has focussed on farmland bird breeding populations in the UK and the Netherlands, with numerous studies showing limited success (e.g. Kleijn *et al*., 2001; Kleijn & Sutherland, 2003; Kleijn *et al*., 2004; Berendse *et al*., 2004). It is likely that in some cases AES prescription has had a protection effect on the environment even where farmland biodiversity has declined; thus, slowing the rate of decline (Primdahl *et al*., 2003). Kleijn & Sutherland (2003) suggest an inadequacy in research quality and quantity for the evaluation of AES. However, the UK has been credited for implementing the most successful AESs across Europe (Carey, 2001; Kleijn & Sutherland, 2003). For example, the Countryside Stewardship Scheme (CCS) has been a successful conservation mechanism for increasing the regional abundance of the cirl bunting (*Emberiza cirlus* L.) in Devon (Peach *et al*., 2001).

The *Report on the Future of Farming and Food*, Known as the ‘Curry Report’, published by the Policy Commission in 2002 provided recommendations for a broader-based approach to AES implementation (Davey *et al*., 2010). This has led to a new phase in AES policy, with overall objectives shifting beyond the aim to simply reduce agricultural intensification and towards promoting environmental enhancement (Hodge & Reader, 2010). Since 2005, Environmentally Sensitive Areas (ESA) and CCS closed to new applicants and were replaced by the two-tiered scheme, Environmental Stewardship (Natural England, 2009). This has been designed to address five primary objectives: conserve biodiversity; maintain and enhance landscape quality; protect the historic environment; protect natural resources and promote public access (Defra, 2013). It operates at two levels with Entry Level Stewardship (ELS), a ‘broad and shallow’ approach targeted at 70% of farmland and Higher Level Stewardship (HLS), a 'narrow and deep' approach targeted at 10% of farmland. Approximately 70.3% of English agricultural land is under an AES agreement, with 61.6% ELS and 1.2% HLS (Natural England, 2013). Both ELS and HLS options include a range of agreements designed to benefit declining farmland birds (Table 1) (Smallshire *et al*., 2004). There is currently limited evidence showing landscape-specific benefit for birds under ELS management. However, the time lags in bird population responses to environmental change suggest that it is too early to draw conclusions (Davey *et al*., 2010). Recently, Baker et al. (2012) provide the first proof-of-concept for the broad and shallow ELS scheme, with winter management options having positive effects on bird population growth rates at three landscape scales.

Table 1. A summary of the Environmental Stewardship options that are likely to benefit farmland birds (source: adapted from Smallshire *et al*., 2004).

	Strips or blocks					**Whole or part fields**			
Scheme	Arable margins; buffer strips	Conservation headlands	Un-cropped, cultivated margins	Beetle banks	Seed & flower mixtures	Winter stubble	Spring crops	Summer fallows	Others
Entry Level Stewardship & Organic Entry Level Stewardship	✓	✓ ± fertilizer	✓	✓	✓	✓	✓ Including under sown and whole-crop silage	✓	•Skylark patches •Brassica crops •Rush pastures •Mixed stocking
Higher Level Stewardship	✓ Including flower-rich margins	✓ un-harvested, without fertilizer	✓ also in grassland	✓	✓ enhanced bird seed	✓ also reduced herbicide in previous crop	✓ Low-input; also in grassland	✓	•Fodder crops •Wet grassland •Improved, semi-improved and rough grassland

Organic farming systems are often considered as sustainable and are associated with less intensive farming practices (Rigby & Cáceres, 2001). Multiple objectives focus on environmental protection, animal welfare, food quality and health, sustainable resource use; and social justice (Lampkin, 2003). The organic sector in Europe has seen a rapid growth and development since the 1980s with the support of AES subsidy payments and other market and policy initiatives prompted after Council Regulation (EEC) No. 2092/91 (Stolze & Lampkin, 2009). There is an organic strand of ELS; Organic Entry Level Stewardship (OELS), which is tailored for organic farming systems. Organic farm certification schemes, such as the Soil Association have also played a key role in promoting the market value of organic products. The UK organic land area represents 4.2% of farmland, whilst the OELS cover 3.5% of utilisable agricultural area (Soil Association, 2012; Natural England, 2013).

Organic farm management forbids synthetic pesticides, herbicides and fertilisers; thus requiring a greater use of crop rotations, animal manures and composts as well as mechanical weed control.

Several comparison studies between organic and conventional farming have suggested organic farms deliver greater farmland bird diversity and abundance (Bengtsson *et al*., 2005). However, the biodiversity benefit is likely to relate to habitat heterogeneity and lower agricultural intensification, rather than the specific prescriptions and theology of the organic farming (Krebs *et al*., 1999). Enhanced bird numbers on organic farms are generally responding to more developed hedgerows, margins and trees that are present, when compared to conventional farms (Vickery *et al*., 2004). Krebs et al. (1999) suggest that there is limited research comparing the biodiversity benefits between organic and other 'wildlife friendly' farming protocols.

Conservation Grade (CG) is a market-led 'wildlife friendly' farm certification scheme that sets out a protocol to deliver biodiversity benefits and sustainable intensification that rewards farmers with a premium price for their crop. The theology of CG farming is in contrast with the organic movement; in that it maximises the yield of crop output. The CG model was established in 1985 and now has 101 farms participating. As part of the CG protocol, each farm is required to manage 10% of its farmed area as wildlife habitat (Table 2). The CG habitats are designed to work alongside and qualify for ELS and HLS agreements. The CG protocol has also prohibited the use of certain pesticides including organophosphate, methiocarb and restricted the use of synthetic pyrethroid insecticides on cereal crops. The biodiversity benefits of CG farming are aimed at wild flowers, rare arable plants, pollinating insects, small mammals, ground nesting birds and over wintering birds. Furthermore, CG report a 41% increase in bird abundance in a three year experiment comparing CG farms to conventional farming systems (Nevard & Hughes, 2010).

Table 2. The Conservation Grade (CG) habitat requirements. *'Other habitats' can include woodland, hedgerows, water courses, ponds (Conservation Grade, 2013).

Habitat Type	Required % of farmland area
Pollen & nectar mixes	4.0
Wild bird food crops	1.5
Tussocky & fine grass mixtures	2.0
Annually cultivated natural regeneration (ACNR)	0.5
Other habitats*	2.0
	Total 10.0

1.3 The winter hunger gap

The natural resource requirements for farmland birds fall into three categories: breeding season food, nesting habitat and winter food; often referred to as the 'big three' (Vickery *et al*., 2004; RSPB, 2009). These 'big three' resource categories are not independent of each other for enhancing farmland bird abundance; for example, nesting habitat is only suitable if there is sufficient breeding season food available (Vickery *et al*., 2004). Furthermore, winter food abundance has been shown to positively increase the breeding bird populations the following spring, especially for highly sedentary species (Gillings *et al*., 2005; Hinsley *et al*., 2010). Research into the decline of farmland birds has increased rapidly since the 1990s, but has placed a greater emphasis on breeding bird populations rather than overwintering populations (Figure 1) (Atkinson *et al*., 2002). Consequently, there is no standardised, accepted technique for surveying birds in winter (Roberts & Schnell, 2006).

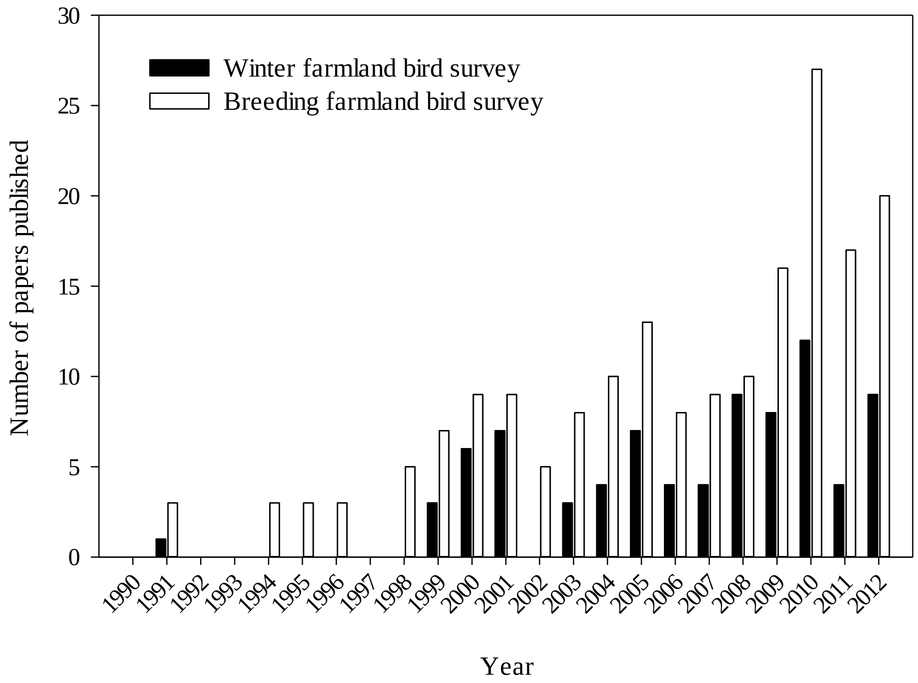

Figure 1. The general increase in journal articles about farmland bird surveys. A greater proportion of studies have focused on breeding bird surveys. These papers were those listed in Web of Science using the terms 'Winter farmland bird survey' and 'Breeding farmland bird survey' in a search carried out on 09/02/2013.

The poor breeding output of farmland birds cannot solely explain the recent population declines for most species; thus, results suggest significant declines are occurring outside the breeding season with poor survival rates (Greenwood, 2003). Bird food provisions help to plug the winter 'hunger gap', where modern agriculture fails to provide for many farmland bird species (Siriwardena *et al*., 2008). The switch from 'spring sown' to more efficient 'autumn sown' cereal and oil seed crops as well as the technological advances in harvesting machinery and increased herbicide use has led to large scale reductions in spilt grain, weed seeds, weedy post-harvest crop stubbles and marginal arable weed species (Robinson & Sutherland, 2002; Wilson *et al*., 2009). Thus, placing limits on the availability and abundance of winter seed foods for granivorous farmland bird species in lowland England. Post-harvest fields left in fallow or stubbles have been shown to support higher wintering densities of many granivorous bird species (Moorcroft *et al*., 2002). Winter food for farmland birds can be enhanced by farm management options that provide crop stubbles and seed-rich 'winter bird crops' (WBCs)

(Henderson *et al*., 2004; Gillings *et al*., 2005; Baker *et al*., 2012). Siriwardena et al. (2007) suggest effective winter farmland bird food has the potential to halt and perhaps reverse population declines.

The research reported in this paper sought to examine the winter infield habitat arrangements of nine case study mixed arable farms from differing conservation schemes including: HLS, ELS, OELS and CG. Furthermore, the present study tests the habitat management prescriptions at the farm-scale in three differing landscapes, to determine which conservation schemes support the highest abundance and species richness of birds across the winter. Here, winter bird count survey data that represents the farm-scale is used from January – March in 2013. The results are used to provide recommendations for maximising the value of conservation schemes with respect to benefiting overwintering farmland bird species. Thus, contributing to one of Sutherland et al. (2006) key ecological research questions of high policy relevance to the UK, by comparing conventional, integrated farm-management and organic farming systems in terms of their effect on biodiversity.

2. Methods

2.1 Study sites

Nine farm study sites were selected in three differing landscapes of lowland England based on Natural England's national character areas (Hampshire Downs; Chilterns; Low Weald/Wealden Greensand) (Natural England, 2013) (Figure2). Triplets of farms comprising the management scenarios: (i) CG; (ii) Organic and (iii) ELS have been matched by production type, soil type and size as far as possible within each National Character Area (Table 3).

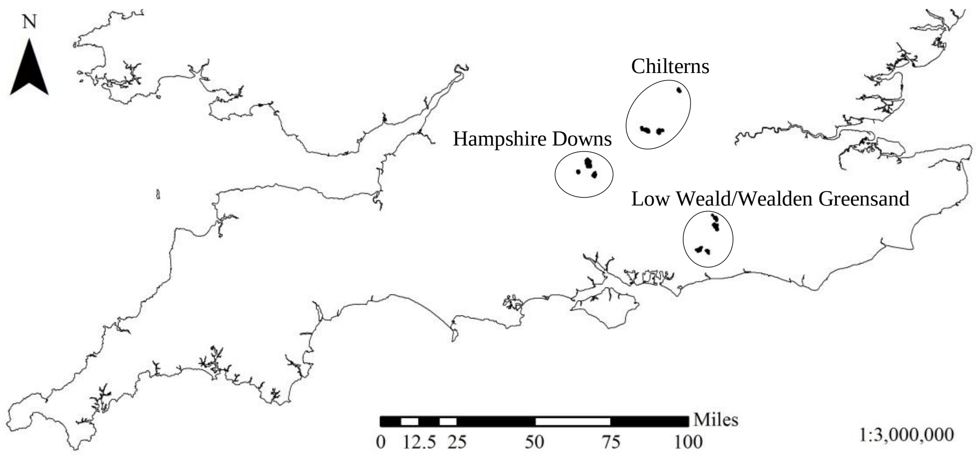

Figure 2. The location of the farm study sites within the three grouped national character areas.

Table 3. The three triplets of farms with differing conservation schemes within each national character area.

National character area	Farm conservation schemes
Chilterns	1. CG + ELS 2. OELS + HLS 3. ELS
Hampshire Downs	1. CG + HLS + ELS 2. OELS + HLS 3. ELS
Low Weald/Wealden Greensand	1. CG + HLS + ELS 2. OELS + HLS 3. ELS

2.2Farm habitat and bird recording

Ordinance survey land cover maps were digitised and infield farm habitat areas and perimeter lengths determined using the Geographical Information Systems (GIS Arc10.1). The infield winter habitat was recorded within categories, during December 2012. For conventional fields these were: (i) bare soil; (ii) cereal stubbles; (iii) other crop stubbles; (iv) grassland: improved, permanent, grazed or un-grazed; (v) winter cereals: wheat, barley or oats and (vi) non – cereal crops: here only oil seed rape, kale and legumes. For wildlife specific habitat these were: (vii) wild bird crops; (viii) game cover crops: here only maize grown for pheasant shoots and (ix) other margins: field edges out of production under AES agreements. Farm habitats outside of the categories above were scoped out of the realms of this study.

A transect methodology, similar to that of the Breeding Bird Survey was adapted for the farm-scale, in order to gain a whole-farm spices richness and density estimates. At each farm, a predetermined survey route of approximately 3000m was selected, using an ordinance survey map. The survey distances were divided up proportional to the infield farm habitat area and then split into100m long, transect sampling units. Field boundary features are important habitats for many farmland birds, providing cover from predators and winter foraging sites (McMahon *et al*., 2005). Therefore, 2/3 of transects were allocated to the perimeter of field boundaries and 1/3 of transects were allocated to the middle of fields. Due to their size, the wild bird crops, game cover crops and other margin habitat areas were only allocated perimeter transects. The start point of each transect was situated so that the habitat was homogenous for its entire length. To avoid double-counting of birds, transects were situated at least 100m away from each other.

Each farm study site was surveyed three times, a month between visits across the winter (January – March 2013). The farms within each triplet were surveyed on consecutive days, so environmental and climatic conditions matched as much as possible for fairest comparison. No visits were made in persistent, heavy precipitation or winds greater than Beaufort scale 4. Bird surveys were carried out by the same observer and began 1 hour after sunrise and were completed at least 1 hour before sunset, to avoid counting birds that were travelling to or from roost sites. The survey routes were reversed between visits to minimise any possible effects that the time of the day has on the presence and detectability of birds. All birds seen or heard along the survey transects were recorded, in three distance categories estimated at right angles to the transect line. The distance categories were: (i) 0-25m; (ii) 25-100m; (iii) 100m or more. Flying birds that were actively hunting or obviously associated with the habitat area (e.g. display flight of skylark *Alauda arvensis* L.) were assigned to the appropriate distance band in which they were first detected (Newson *et al*., 2005). The risk of double-counting birds was minimised by the observer counting birds which were flushed into other areas being surveyed, and ignoring them on subsequent encounters (Bradbury & Allen, 2003).

2.3 Analysis

The statistical analyses were performed using SigmaPlot (Systat Software, San Jose, CA) and in all cases significance was taken at $\alpha = 0.05$ level. The Shapiro-Wilk test was used to check the normality of all data. In some cases data did not conform to normality.

The infield farm habitat categories had their areas totalled and percentage cover determined at the farm-scale. Differences in infield habitat proportions were revealed by one-way Analysis of Variance (ANOVA). Where these were significant, pair-wise comparisons of samples were carried out with the Holm-Sidak test.

There were three problems to overcome when dealing with the winter bird count data: (i) the data include many zero counts for individual species across transects; (ii) individuals in flocks cannot be considered as independent data points; (iii) many bird species were too rare to allow analysis at the species level (Buckingham *et al*., 1999). Therefore, where necessary, species were grouped into ecological or taxonomic guilds for analysis, (similar to: Buckingham *et al*., 1999; Henderson *et al*., 2000; Bradbury & Allen, 2003; Bradbury *et al*., 2004; Cunningham *et al*., 2005; Field *et al*., 2007). This left five guilds and one species group, the skylark which is considered separately to other granivorous passerines because of its varied diet (Wilson *et al*., 1999). The compositions of the guilds are shown in Appendix 1.

Distance sampling software developed by Buckland et al. (2001) (DISTANCE, Version 6.0 Release 2; Thomas *et al*., 2009) was used to produce estimates of bird density over time, between January – March. This technique models the decline in bird detectability with perpendicular distance from the transect line, providing an estimate of individual species that were not detected simply because they were further away. Thus, a detectability function gives an estimate of density for the bird species of interest (Newson *et al*., 2005). Distance sampling with a line transect methodology assumes that: birds directly on the line are always detected, birds are detected at their initial location prior to the observers influence and birds are correctly allocated to the relevant distance category. As recommended by Buckland et al. (2001), birds recorded in the furthest distance category (100m or more) were excluded from analysis because data from unbounded categorisation is difficult to interpret.

To calculate reliable detection functions, 40-60 observations are necessary with sightings from 10-20 replicate transects within a defined study area (Buckland *et al*., 2001; Meadows *et al*., 2012). However, in the present study most species were recorded less often than 40 times per farm per visit. Therefore, farms types with the same conservation management scenario were pooled together (MacLeod *et al*., 2012; Weller, 2012) and similarly detectable species were grouped into guilds (Appendix 1) to achieve sufficient sample sizes to calculate reliable detection functions (Smith *et al*., 2005; Trimble & van Aarde, 2011). This allowed four guilds and one species for distance analysis. For each species or guild, the decline in detectability with distance was modelled for one broad habitat class, with a global detection function for each farm type independently. This was done because there weren't large differences in detectability between open field habitats across farms. Infield right truncation was set to the furthest observed distance. The half-normal key base function, with cosine adjustment was used to model the data. This model produced an estimate for average density of individual guilds per hectare across farm types.

Farmland bird abundance analysis was based on the mean count of species and guilds at each farm. Total bird counts per farm per visit were used for analysis, where farms types with the same conservation management scenario were pooled together to test for differences across the winter period. Differences in winter bird counts among the samples of farms were revealed by either one-way repeated measures ANOVA or Friedman's non-parametric χ^2 test. Where these were significant, pair-wise comparisons of samples were carried out with the Tukey HSD post hoc test.

Species richness (i.e. number of bird species present) at the farm level were determined by the total number of species noted on a farm over all transect sampling units and visits. For this analysis, comparisons between farms were made with analysis of variance, concentrating on the UK overwintering species from two species richness categories: 19 farmland bird species listed by the FBI and 42 farmland bird species listed by Siriwardena et al. (1998) (Appendix 2). Regression analysis was used to determine the relationship between farm species richness and the number of infield habitat types present.

3.0 Results

3.1 Farm structure and winter habitat

The mean numbers of habitat categories recorded across farm types were: CG = 6.0 ± 0.57SE; Organic = 3.3 ± 0.33SE; ELS = 5.6 ± 0.67SE. A one-way ANOVA revealed a significant difference between farm types ($F_{2, 6}$ = 7.125, p=0.026). Post hoc comparisons using the Holm-Sidak test revealed that CG and ELS farms showed significantly ($p=<0.05$) higher numbers of habitat categories than Organic farms, but CG and ELS farms did not differ significantly.

The proportions of habitat abundance differed between farms and conservation schemes (Figure 3). Farms varied between regions in their habitat types they offered. Note all farms from the Low Weald/Wealden Greensand region were unable to sow winter cereal crops during the autumn of 2012 because of wet weather. Organic farms were dominated by grassland, where this habitat category formed the greatest proportion of agricultural land (Figure 3). The mean percentages of grassland habitat recorded across farm types were: CG = 20.3 ± 5.52SE; Organic = 71.3 ± 13.37SE; ELS = 36.4 ± 10.60SE. A one-way ANOVA revealed a significant difference between farm types ($F_{2, 6}$ = 6.339, p=0.033). Post hoc comparisons using the Holm-Sidak test revealed that Organic farms had significantly ($p=<0.05$) higher percentages of grassland than CG farms.

All CG and ELS farms provided some provision of either wild bird crops or game cover crops, whereas only one Organic farm provided wild bird crops. Overall, CG and ELS farms had greater proportions of cereal stubbles than Organic farms. The mean percentages of cereal stubble habitat recorded across farm types were: CG = 21.6 ± 7.94SE; Organic = 9.9 ± 8.35; ELS = 29.3 ± 10.30. However, these means did not differ significantly after one-way ANOVA ($F_{2, 6}$ = 1.198, p=0.365, ns)

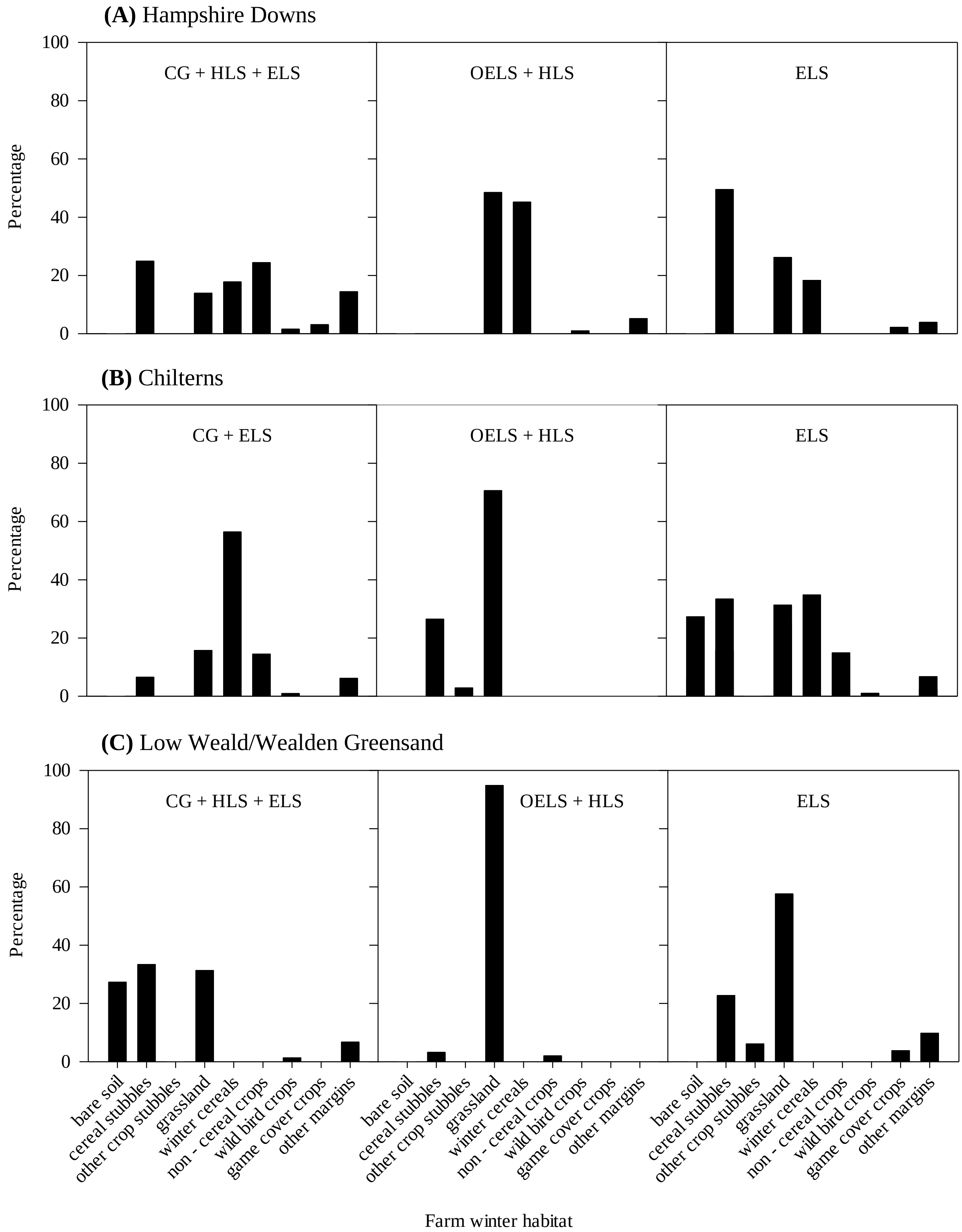

Figure 3. The percentage of winter field habitat across farm types in (A) Hampshire, (B) Chilterns and (C) Low Weald/Wealden Greensand.

3.2 Bird density during the winter

The density per hectare estimate for granivorous passerine guild was highest in January for all farm types. Organic and ELS farms showed a decline in bird density from January to March; whereas, CG farms showed an increase in bird density between February and March (Figure 4A). The skylark wasn't present on any farm during January and there were not enough observations recorded on Organic farms to produce reliable density estimates for any month. Both ELS and CG farms showed increases in Skylark density per hectare estimate between February and March (Figure 4B).

The density per hectare estimate for insectivorous passerine guild remained between 5 and 10 for Organic farms between January and March; whereas, estimates for ELS and CG farms were greater than 10 during March (Figure 4C). All farm types showed a similar pattern for density per hectare estimates for the wren/dunnock/robin guild between January and March. Here, all farm types had a peak density in February (Figure 4D).

Organic and ELS farms showed a similar pattern for density per hectare estimates for tits (*Paridae* L.) between Januarys and March, where density estimates didn't change more than 1.0 between months. However, CG farms showed a 3.5 decrease in density estimates between February and March (Figure 4E).

3.3 Differences in winter bird abundance

The mean winter abundance of bird species and guilds based on three repeated visits (January – March) across nine study farms are shown in Table 4. The two most abundant and frequently observed granivorous passerines in this study were the chaffinch (*Fringilla coelebs* L.) and yellowhammer (*Emberiza citronella* L.). The yellowhammer winter abundance was significantly greater on CG and ELS farms, when compared to Organic (Table 4). The skylark winter abundance was significantly greater on ELS farms when compared to Organic farms (Table 4). Conservation Grade farms had a significantly greater winter abundance of granivorous passerines when compared to Organic farms (Table 4). Organic farms had significantly greater winter abundance of Tits compared to ELS farms (Table 4). There was no significant difference in winter bird abundance between farms for the: chaffinch; starling (*Sturnus vulgaris* L.); blackbird (*Turdus merula* L.); fieldfare (*Turdus pilaris* L.); lapwing (*Vanellus vanellus* L.); woodpigeon (*Columba palumbus* L.); insectivorous passerines; Wren/Dunnock/Robin; Covids (Table 4). The lapwing was not present on Organic farms (Table 4).

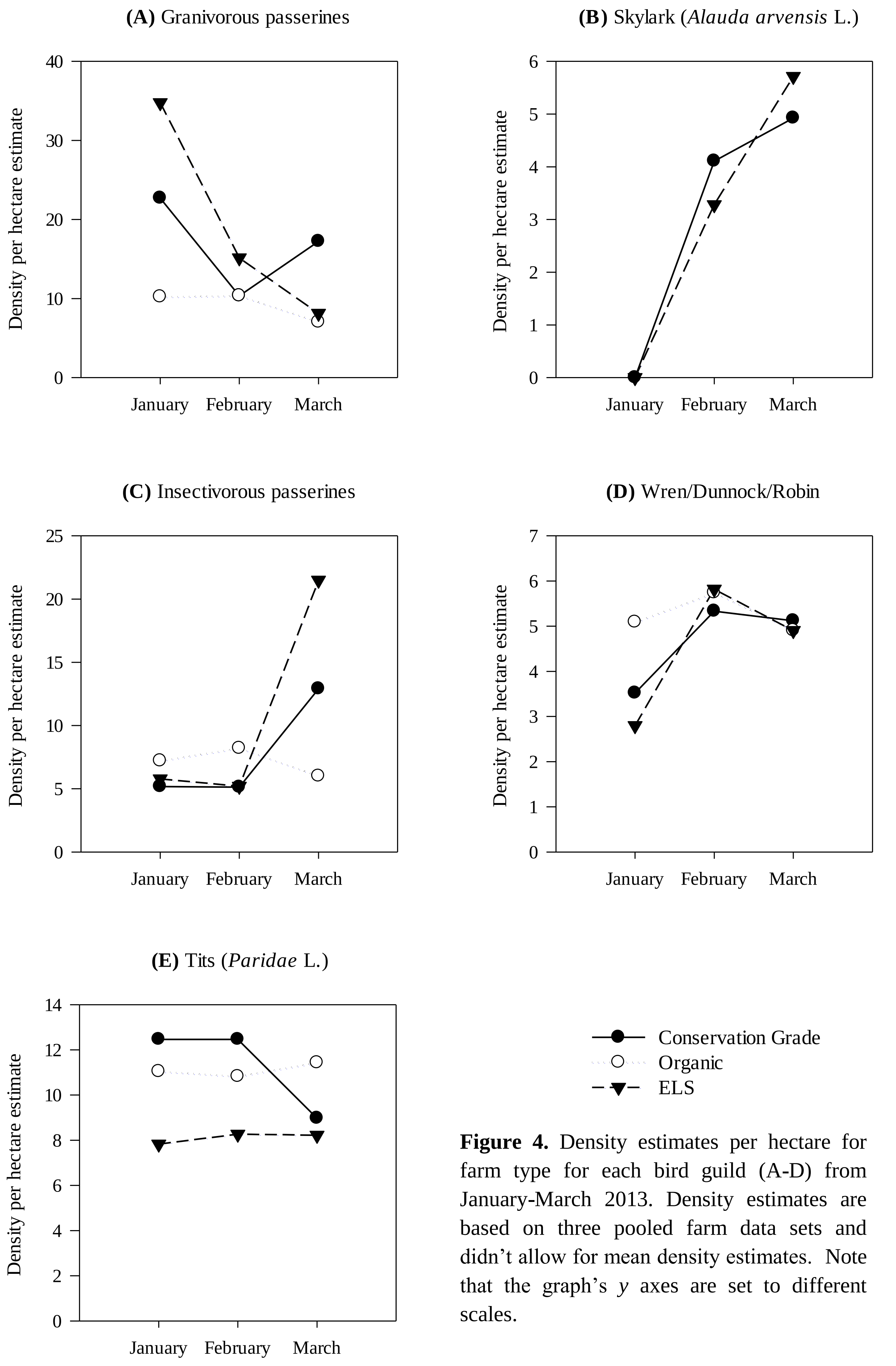

Figure 4. Density estimates per hectare for farm type for each bird guild (A-D) from January-March 2013. Density estimates are based on three pooled farm data sets and didn't allow for mean density estimates. Note that the graph's *y* axes are set to different scales.

Table 4. The differences in winter bird abundance between (A) Conservation Grade; (B) Organic; (C) ELS farms.

		(A) Conservation Grade		(B) Organic		(C) ELS		One-way RM ANOVA†/ Friedman Analysis of Variance‡			
	n	Mean	SE	Mean	SE	Mean	SE	F† / χ^2‡	df	*p*	Tukey HSD post hoc test
Spp.											
Chaffinch *Fringilla coelebs*	9	56.4	16.47	26.7	8.93	51.6	16.50	1.05†	8,2†	*p=0.371*(ns)†	N/A
Yellowhammer *Emberiza citrinella*	9	38.2	13.84	4.4	2.48	14.0	3.91	11.56‡	2‡	***p=0.001***‡	**A>B**; **C>B**; A=C
Skylark *Alauda arvensis*	9	34.4	13.17	2.0	1.01	42.4	19.63	4.14†	8,2†	***p=0.036***†	A=B; A=C; **C>B**
Starling *Sturnus vulgaris*	9	0.3	0.33	1.4	0.98	20.5	8.66	8.087‡	2‡	*p=0.069*(ns)‡	N/A
Blackbird *Turdus merula*	9	18.8	2.48	18.0	2.10	15.4	1.56	0.918†	8,2†	*p=0.419*(ns)†	N/A
Fieldfare *Turdus pilaris*	9	70.5	24.01	72.5	32.27	61.1	26.10	0.045†	8,2†	*p=0.957*†	N/A
Lapwing *Vanellus vanellus*	9	14.2	9.42	0.0	0.0	9.7	4.39	1.27†	8,2†	*p=0.306*(ns)†	N/A
Woodpigeon *Columba palumbus*	9	60.5	16.01	64.7	13.51	60.0	12.63	0.0342†	8,2†	*p=0.966*(ns)†	N/A
Guilds.											
Granivorous passerines	9	115.9	27.12	33.6	10.46	97.4	27.47	3.70†	8,2†	***p=0.048***†	A=C; **A>B**; B=C
Insectivorous passerines	9	111.7	28.24	120.0	51.84	107.2	27.21	0.0259†	8,2†	*p=0.974*(ns)†	N/A
Wren/Dunnock/Robin	9	13.4	1.61	11.0	0.85	10.6	0.67	1.553†	8,2†	*p=0.242*(ns)†	N/A
Tits (*Paridae* L.)	9	29.6	4.51	34.2	5.33	20.3	2.82	4.507†	8,2†	***p=0.028***†	A=B; A=C; **B>C**
Covids	9	22.3	8.09	26.4	7.76	29.8	11.23	0.230†	8,2†	*p=0.797*†	N/A

Overall abundance was first compared between all three farm types by either: † One-way Repeated Measures (RM) ANOVA or ‡ Friedman's non-parametric χ^2 test. Where these were significant, mean bird values were compared pairwise by the Tukey HSD post hoc test. ns, $P>0.05$; N/A, not applicable for post hoc testing; bold, $\mathbf{P<0.05}$.

3.4 Species richness

The organic farms, across all regional triplets, scored the lowest or joint lowest farm-level species richness for both the FBI (19 species) and Siriwardena et al. (1998) (42 species) categorisations (Figure 5 and 6). However, one-way analysis of variance revealed no significant difference in FBI species richness between farm types ($F_{2,\ 6}$ = 2.63, p=0.152, ns) and no significant difference in Siriwardena et al. (1998) species richness between farm types ($F_{2,\ 6}$ = 3.47, p=0.100, ns). The means and standard errors are presented in Table 5. Five species that overwinter in lowland England from the FBI (19 species) category (grey partridge *Perdix perdix* L.; stock dove *Columba oenas* L.; tree sparrow *Passer montanus* L.; greenfinch *Carduelis chloris* L.; corn bunting *Miliaria calandra* L.) were not present on any farm. Furthermore, 7 species that overwinter in lowland England from the Siriwardena et al. (1998) (42 species) category (grey partridge; moorhen *Gallinula chloropus* L.; stock dove; blackcap *Sylvia atricapilla* L.; tree sparrow; greenfinch; corn bunting) were not present on any farm.

Table 5. The means and standard deviations of species richness for the FBI (19 species) and Siriwardena et al. (1998) (42 species) categories.

		Conservation Grade		**Organic**		**ELS**	
Species Richness	***n***	Mean	SE	Mean	SE	Mean	SE
FBI (19 species)	3	6.33	0.67	4.33	0.33	7.33	1.45
Siriwardena et al. (1998) (42 species)	3	18.67	0.88	15.00	1.16	18.33	1.20

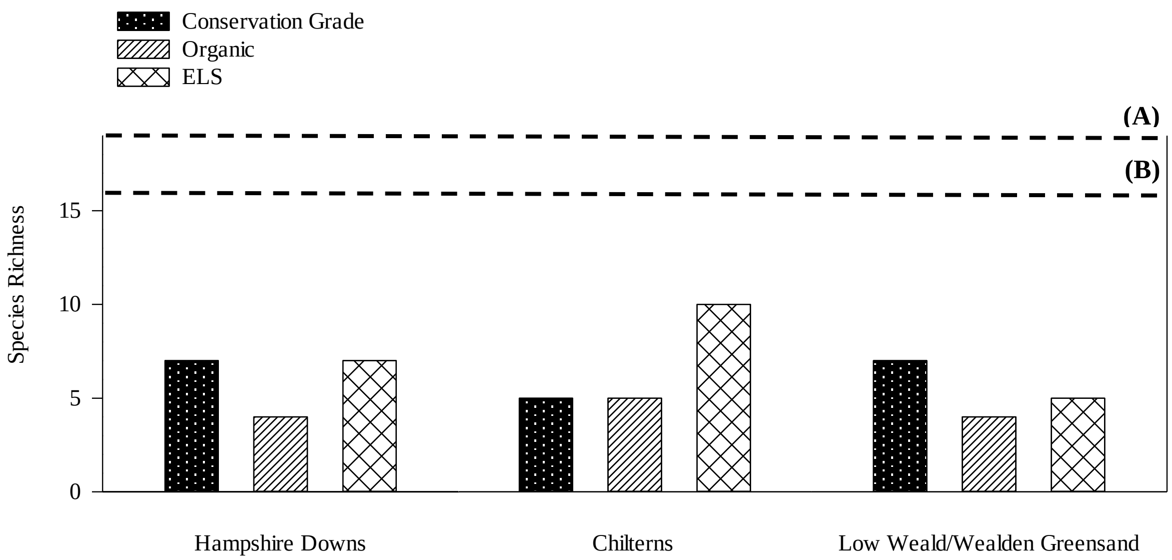

Figure 5. The species richness of all study farm sites using the Farmland Bird Index (FBI) categorisation. (A) including summer migrant species; (B) excluding summer migrant species.

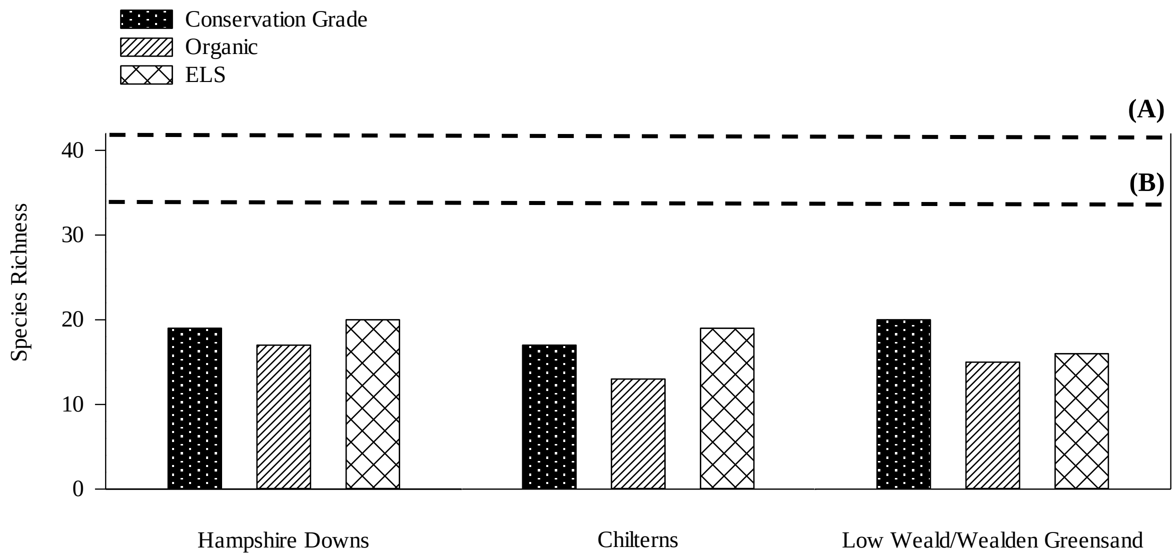

Figure 6. The species richness of all study farm sites using farmland bird species listed by Siriwardena et al. (1998) categorisation. (A) including summer migrant species; (B) excluding summer migrant species.

Linear regression analysis was used to test if the number of infield habitat types significantly predicted species richness on farms. Two species richness categories were used. (A) FBI category: the results explained a significant proportion of the variance (r^2 = 0.54, $F_{1,\ 7}$ = 8.06, p=0.025). It was found that number of habitat types significantly predicted species richness (β = 0.94, t = 2.84, p=0.025). (B) Siriwardena et al. (1998) category: the results explained a significant proportion of the variance (r^2 = 0.48, $F_{1,\ 7}$ = 6.54, p=0.038). It was found that number of habitat types significantly predicted species richness (β = 1.11, t = 2.56, p=0.038) (Figure 7).

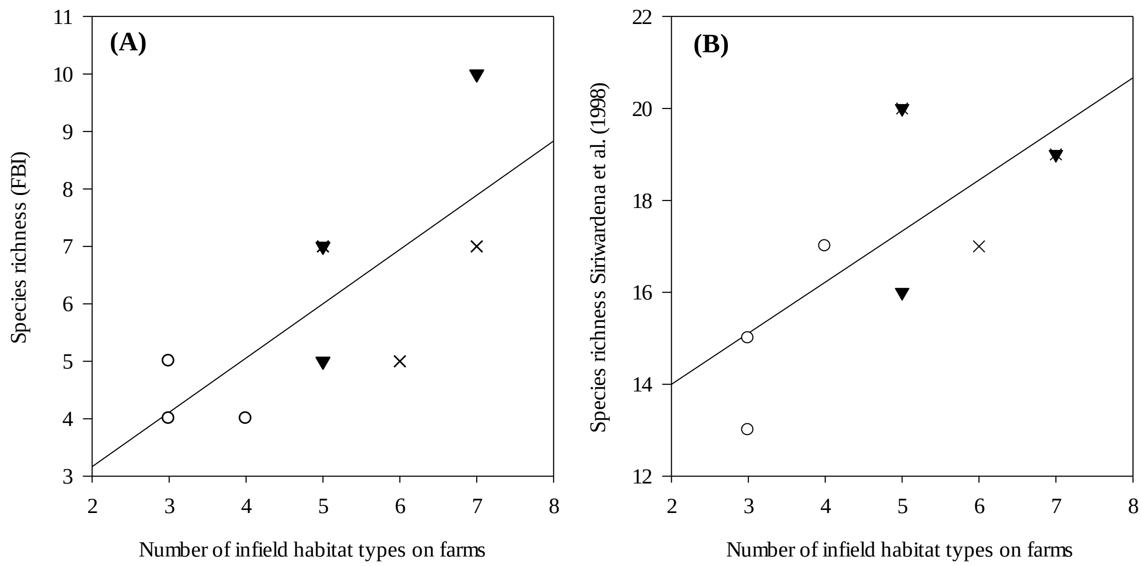

Figure 7. The relationship between total numbers of infield habitat types on farms in winter and (A) FBI species richness and (B) Siriwardena et al. (1998) species richness (× = Conservation Grade, ○ = Organic, ▼ = ELS). The regression lines were fitted by (A) y = 1.2778 + 0.9444x; (B) y = 11.778 + 1.1111x. Note that the graph's y axes are set to different scales.

4.0 Discussion

4.1 General trends

The novel sampling design employed by this paper has allowed farm-scale specific analysis for farmland bird abundance and richness, reflecting the differences of infield habitat arrangements from differing conservation schemes. A key question that remains is how do differing conservation schemes impact overwintering farmland birds? Several key findings emerge from this study with respect to the potential value of different conservation schemes for overwintering farmland birds. Firstly, the study contributes to the knowledge gap about the scales at which different bird populations respond to habitat characteristics with large variations between species (Pickett & Siriwardena, 2011). The results suggest that the abundance of granivorous passerines was positively related to the food availability of infield habitats at the farm-scale; but this was not the case for insectivorous passerines. This provides a proof-of-concept that farm-scale management can have positive farm-scale effects for birds; whereas, previous studies have failed to do so, focusing on the wider landscape effects of agricultural management (Smith *et al*., 2010). Secondly, the results show that the increased availability of differing infield habitat types on farms can explain some of the variation in species richness across conservation schemes. Thirdly, this experimental design, despite the small sample size (n=9) of farms, demonstrated that the Organic farm management scenarios provided significantly less infield habitat types across all schemes. This reflects similar findings to Norton et al. (2009) who used a much larger sample size (n=161) of farms, where Organic farms contained more grassland habitats and non-organic farms contained more cropped habitats.

4.2 Potential limitations

It is important to consider the scope of the sampling design when interpreting these results. Farm habitat categories used, were only inclusive of infield types. Woodland, hedgerows and farmyards are important habitats for farmland birds (Vanhinsbergh *et al*., 2002), but weren't recorded or explicitly surveyed in this study. This may have had a limiting effect to the species abundance and richness observed on farms. However, the scope of the study was consistent across farms.

The CG farm located in the Chilterns was not under any HLS agreements and therefore didn't match the prescriptions of the other CG farms, holding only ELS agreements (Table 3). This is unlikely to have influenced results after Field et al. (2011) has demonstrated limited additional benefits of HLS over ELS agreements for wintering farmland birds.

The bird density estimates per hectare used in this study are based on pooled data sets that didn't allow for mean estimates or significance testing. However, the density estimates are useful for describing the observed patterns of population change over the winter period.

4.3 Granivorous passerines and the winter hunger gap

Granivorous passerines were a key target group for this study, with an emphasis on the winter hunger gap. The Organic farms have been the least favourable to granivorous passerines over the winter, with higher abundance and density estimates recorded on ELS and CG farms. Moreover, CG farms were significantly different to Organic farms. Here, the granivorous passerines are showing strong aggregative responses to the seed rich infield habitat categories. The conservation arrangements of the ELS and CG schemes provided larger proportions of 'wild bird crops', 'game cover crops' and 'cereal stubbles'. These are essential foraging habitats providing grain and weed seed food resources to granivorous birds (Brickle, 1997; Moorcroft *et al*., 2002; Henderson *et al*., 2004; Gillings *et al*., 2005).

It was also noted in the field, that farms which provided 'game cover crop' also provided supplementary grain feeding stations for Pheasant shooting. Finches were observed making use of this resource in January before the shooting season ended 01/02/2013. This may have had a positive impact in attracting more birds to farms in January, explaining why observed density estimates were highest in January. Although not measured in this study, it is common practice for farmers and land managers to remove 'game cover crops' soon after January; thus, taking food resources out of the landscape. The decline in density estimates from January-March for Organic and ELS farms are in line with the theory of the winter hunger gap (Figure 4A); where seed resources become depleted by late winter, causing either bird mortality or migration (Siriwardena *et al*., 2008). Interestingly, the CG farms did not show continuous declines in density estimates between January-March. The compulsory CG 2% 'wild bird crop' provision is likely to be the primary reason responsible for retaining higher density estimates in March, where this provision wasn't consistent across other farm types. Siriwardena et al. (2008) suggests that ES does not provide sufficient winter food resources in late February and March. Therefore, the late winter bird recordings were important in determining the overall significant difference in granivorous passerine abundance between CG and Organic farms.

The yellowhammer is a granivorous farmland bird specialist which has been declining rapidly in the UK since 1980 and was red listed for conservation concern in 2002 (Baillie *et al*., 2012). Siriwardena et al. (2000) have shown that the breeding performance of yellowhammers per attempt has been higher since population declines. There is a growing consensus that the most probable factor for declines is caused by poor winter survival, which is preventing recoveries (Siriwardena *et al*., 2000;

Vickery *et al*., 2004). The ELS and CG farms had a significantly higher yellowhammer winter abundance compared to Organic farms (Table 4); suggesting that these schemes support better winter survival. Three combined factors can explain this result. Firstly, the Organic farms in the present study were dominated by grassland habitats. Bradbury & Stoate (2000) show that yellowhammers avoid fields with grassland habitat in both summer and winter. Moreover, intensively managed grass fields are less preferable to virtually all other farm habitat types for yellowhammers (Morris *et al*., 2001). Secondly, the ELS and CG farms provided larger proportions of 'wild bird crops', 'game cover crops' and 'cereal stubbles' which are preferable to yellowhammer foraging (Bradbury & Stoate, 2000; Gillings *et al*., 2005). Thirdly, ELS and CG farms provided larger proportions of field margin habitat, where two Organic farms didn't provide any field margins. Bradbury et al. (2000) suggests that cropping or grazing to the field edges, adversely affects the potential for yellowhammer nesting and foraging sites. This is relevant, because yellowhammers are a fairly sedentary species, where there is a strong association between winter habitat and summer territories (Whittingham *et al*., 2005). Therefore, the farm conservation management schemes which provide preferable winter habitats in the proximity of suitable breeding habitats are likely to enhance farm-scale populations of yellowhammers all year round. Stoate et al. (1998) suggest that farming systems that increase habitat diversity and reduce pesticide applications to arable crops will benefit yellowhammer abundance. This present study is in broad agreement, but suggests that winter habitat diversity is the more critical factor in determining farm-scale abundance.

The most common granivorous passerine recorded across all farms was the chaffinch. Its abundance did not differ significantly between farm types, reflecting the generalist foraging behaviour of the species. Furthermore, the chaffinch is not a highly sedentary species, where overseas immigration contributes to peak winter abundances in lowland England (Swann, 1988). Thus, observed chaffinch recordings in large flock sizes may have been in a constant flux of temporary movements showing low fidelity to specific habitat provisions (Calladine *et al*., 2006).

Unlike the patterns shown by other granivorous passerines, the skylark was not present on any farms during January. However, large numbers of skylarks appeared on ELS and CG farms in February, and observed density estimates were greatest in March (Figure 4B). This upward trend in skylark detection doesn't support the theory of the hunger gap, but suggests winter immigration to lowland farmland for foraging requirements. There is limited information to the movements of British skylarks, but some studies show breeding birds at higher altitudes disperse to lowland areas in winter (Dougall, 1996; Copland *et al*., 2012). Interesting, abundance was much lower on Organic farms where ELS farms were significantly greater. This can be explained by the proportion of 'cereal stubbles' present on each farm, the favoured foraging habitat for skylarks. What is more, skylarks prefer open habitats and avoid small fields and hedgerows which may have been more prevalent on Organic farms (Donald *et al*., 2001b).

4.4 Insectivorous passerines and other species

Previous research has shown permanent grass fields to be preferable for most invertebrate feeding birds during winter, supporting the highest densities on farmland (Tucker, 1992). The grassland arrangements on farms in the present study predict Organic farms to have the highest abundance of insectivorous passerines. This was the case, but the differences weren't significant. Interestingly, the density estimates on ELS and CG farms increased dramatically in March, whereas estimates for Organic farms showed a slight decrease (Figure 4C). These results may be the influence of highly mobile, large flocking migrant species such as the fieldfare. However, Atkinson et al. (2002) shows that smaller invertebrate-feeding species, such as the starling, blackbird, meadow pipit (*Anthus pratensis* L.) and pied wagtail (*Motacilla alba* L.) move away from, or out of pastoral areas in the winter. They could be showing preferences to mixed arable landscapes. Moreover, cereal stubbles provide good winter foraging habitat for insectivorous passerines such as the starling (Tucker, 1992). Consequently, this supports the present results, where ELS farms had the highest abundance of starlings and largest proportions of cereal stubble.

Other wintering insectivorous farmland birds, such as the lapwing are known to feed on grassland (Tucker, 1992). This contradicts this papers findings where grassland dominated Organic farms didn't have any lapwing recordings, whereas ELS and CG farms did. However, the BTO/JNCC Winter Farmland Bird Survey found only 25% of lapwings on pastures compared with up to 50% on crops, stubbles and bare soil (Sheldon *et al*., 2004). This validates the observed differences within this study, where ELS and CG farms offered greater proportions of crop, stubble and bare soil habitat.

The wren/dunnock/robin guild, covid guild, blackbird and woodpigeon did not show significant differences in winter abundance with similar measurements of standard error between farm types. This suggests that these species are generalists and sympathetic to the infield habitat arrangements of farms. Interestingly, the wren/dunnock/robin density estimates follow the same pattern over time between farm types (Figure 4D); perhaps reflecting monthly climatic conditions.

The winter abundance of tits was the only significant result that favoured Organic farms, where density estimates were similar between January-March (Figure 4E). The causes of this are probably the result of more abundant and established hedgerow habitat, although this suggestion lies outside the scope of this study (Gillings *et al*., 2005). The density estimates on CG farms crashed in March compared to Organic and ELS. It is not clear why this might have happened.

4.5 Species richness and habitat heterogeneity

A mosaic of different infield habitats consisting of cropped and non-cropped areas (in the present study: other margins, game cover crops and wild bird crops) is a priority to aid species persistence and thus enhance farmland biodiversity (Benton *et al*., 2003). There are advantages to studying species richness at the farm-scale, as it allows the possibility to pin-point the relative importance of the specific farm habitat arrangements. Whereas, larger spatial landscape scales may lose clarity to habitat arrangements. Here, this study suggests that infield habitat heterogeneity has a marked effect on the farmland bird species richness at the farm-scale. This supports the generalised findings of Pickett & Sirriwardena (2011) that habitat heterogeneity plays a key role in promoting the abundance of most farmland bird species. Species richness wasn't significantly different between farm types. However, there was a significant positive relationship between the numbers of infield farm habitats and species richness (Figure 7). This provides an explanation as to why the Organic farms had the lowest mean species richness scores. Interestingly, this pattern was most revealing when using the FBI species richness category, opposed to the Siriwardena et al. (1998) category. The FBI category is composed of specialist farmland bird species whereas the Siriwardena et al. (1998) category includes many generalist species. This suggests that the ELS and CG farms provided better habitat provisions for specialist farmland species. It is likely that the ELS and CG farms have performed better for species richness because of their habitat arrangements providing greater proportions of winter bird food provisions, thus attracting a greater variety of granivorous passerines.

The species which weren't present on any farms such as the corn bunting, tree sparrow and grey partridge are those which have shown the most severe national population declines. However, other species such as the stock dove and green finch were probably not observed because of their association with farmyard habitats, which were not surveyed in this study (Gillings *et al*., 2005).

4.6 Recommendations and conclusions

The results demonstrate that the availability of winter bird food resources can explain some of the variation in farmland bird abundance and species richness at the farm-scale, across three differing farm conservation schemes. Cereal stubbles, wild bird crops and game cover crops are potentially an extremely valuable and practical way of providing food for overwintering farmland birds. Similar to Chamberlain et al. (2010), this paper shows that organic farming may not provide significant benefits to overwintering granivorous passerines that are limited by winter seed resources. In contrast, ELS and CG farms have provided some significant benefits for granivorous passerines. It has been suggested by Atkinson et al. (2002) that the majority of farmland bird species in winter are most abundant in landscapes with arable and pastoral components. This research reflects similar findings, but they have been demonstrated at the farm-scale. The implications of this, should remind conservation practitioners that effective farm-scale management for overwintering birds is dependent upon habitat arrangements, rather than the overall theology of conservation schemes. Therefore, recommendations to be up taken by policy makers should consider a similar approach to the CG scheme for effective winter bird conservation. The CG protocol is unique in that it requires 10% of farmed area to be managed for wildlife. This could be an effective framework mechanism for ensuring wild bird food provisions and greater habitat heterogeneity at the farm-scale, which has been demonstrated to benefit granivorous passerines in this study. Organic and ELS conservation approaches are dependent upon farmers, who may choose the easiest AES options to implement, which won't always be beneficial to overwintering birds.

Future research using the current experimental design for the following breeding season will be useful in understanding the interactions between winter and summer populations at the farm-scale; and how these may differ between conservation schemes. In a broader narrative and in relation to the winter hunger gap, research examining the value of game bird shooting for granivorous passerines is required. It is not known whether the closing date of the shooting season decreases granivorous passerine abundance on farms, where supplementary game bird feeding may cease.

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Appendix 1

Composition of guilds used for bird analysis

Granivorous passerines (finches/buntings/sparrows)
House Sparrow *Passer domesticus*
Tree Sparrow *Passer montanus*
Chaffinch *Fringilla coelebs*
Brambling *Fringilla montifringilla*
Greenfinch *Carduelis chloris*
Goldfinch *Carduelis carduelis*
Linnet *Carduelis cannabina*
Redpoll *Carduelis flammea*
Bullfinch *Pyrrhula pyrrhula*
Snow Bunting *Plectrophenax nivalis*
Yellowhammer *Emberiza citrinella*
Reed Bunting *Emberiza schoeniclus*
Corn Bunting *Miliaria calandra*

Insectivorous passerines
Blackbird *Turdus merula*
Fieldfare *Turdus pilaris*
Song Thrush *Turdus philomelos*
Redwing *Turdus iliacus*
Mistle Thrush *Turdus viscivorus*
Starling *Sturnus vulgaris*
Meadow Pipit *Anthus pratensis*
Pied Wagtail *Motacilla alba*

Wren/Dunnock/Robin
Wren *Troglodytes troglodytes*
Dunnock *Prunella modularis*
Robin *Erithacus rubecula*

Tits (Paridae)
Long-tailed Tit *Aegithalos caudatus*
Blue Tit *Parus caeruleus*
Great Tit *Parus major*
Coal Tit *Periparus ater*
Marsh Tit *Poecile palustris*
Willow Tit *Poecile montanus*

Corvids
Jay *Garrulus glandarius*
Magpie *Pica pica*
Jackdaw *Corvus monedula*
Rook *Corvus frugilegus*
Carrion Crow *Corvus corone*
Raven *Corvus corax*

Skylark *Alauda arvensis*

Appendix 2

The composition of species richness categories

Species in Siriwardena et al. (1998)

Mallard *Anas platyrhynchos*
Pheasant *Phasianus colchicus*
Grey Partridge *Perdix perdix*
Red-legged Partridge *Alectoris rufa*
Moorhen *Gallinula chloropus*
Lapwing *Vanellus vanellus*
Stock Dove *Columba oenas*
*Turtle Dove *Streptopelia turtur*
*Cuckoo *Cuculus canorus*
Skylark *Alauda arvensis*
*Swallow *Hirundo rustica*
Pied Wagtail *Motacilla alba*
Wren *Troglodytes troglodytes*
Dunnock *Prunella modularis*
Robin *Erithacus rubecula*
Blackbird *Turdus merula*
Song Thrush *Turdus philomelos*
Mistle Thrush *Turdus viscivorus*
*Sedge Warbler *Acrocephalus schoenobaenus*
Blackcap *Sylvia atricapilla*
*Garden Warbler *Sylvia borin*
*Lesser Whitethroat *Sylvia curruca*
*Whitethroat *Sylvia communis*
Chiffchaff *Phylloscopus collybita*
*Willow Warbler *Phylloscopus trochilus*
Long-tailed Tit *Aegithalos caudatus*
Blue Tit *Parus caeruleus*
Great Tit *Parus major*
Treecreeper *Certhia familiaris*
Jackdaw *Corvus monedula*
Magpie *Pica pica*
Carrion Crow *Corvus corone*
Starling *Sturnus vulgaris*
Tree Sparrow *Passer montanus*
Chaffinch *Fringilla coelebs*
Greenfinch *Carduelis chloris*
Goldfinch *Carduelis carduelis*
Linnet *Carduelis cannabina*
Bullfinch *Pyrrhula pyrrhula*
Yellowhammer *Emberiza citrinella*
Reed Bunting *Emberiza schoeniclus*
Corn Bunting *Miliaria calandra*

*****species that overwinter outside of lowland England

The UK Farmland Bird Index (FBI)

Kestrel *Falco tinnunculus*
Grey Partridge *Perdix perdix*
Lapwing *Vanellus vanellus*
Woodpigeon *Columba palumbus*
Stock Dove *Columba oenas*
*Turtle Dove *Streptopelia turtur*
Skylark *Alauda arvensis*
*Yellow Wagtail *Motacilla flava*
*Whitethroat *Sylvia communis*
Jackdaw *Corvus monedula*
Rook *Corvus frugilegus*
Tree Sparrow *Passer montanus*
Starling *Sturnus vulgaris*
Greenfinch *Carduelis chloris*
Goldfinch *Carduelis carduelis*
Linnet *Carduelis cannabina*
Yellowhammer *Emberiza citrinella*
Reed Bunting *Emberiza schoeniclus*
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* species that overwinter outside of lowland England