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Rethinking Agricultural Systems in the UK

Regional and farm system drivers of avian biodiversity within agriculture ecosystems

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Summary

Farm-wide bird surveys were carried out on 119 grass-based farms located in three separate regions in Ireland during the winter and breeding seasons. Data relating to livestock production system (dairy or non-dairy) and participation in the Irish agri-environment scheme (AES) at the time, the Rural Environmental Protection Scheme, were collected. GLMMs were used to establish the factors influencing bird populations during the winter and breeding season. Region and farming system had significant effects on avian biodiversity and there were frequently greater numbers on more intensively managed dairy farms, compared with less intensive non-dairy farms. AES participation had no significant effect on bird populations. Our findings demonstrate a clear influence of region and farm system on avian biodiversity, and suggest that the greater resource availability in more intensive farm systems may actually be beneficial for certain components of farmland biodiversity.

Key words: Biodiversity, conservation, farmland birds, agricultural policy

Introduction

Approximately 4,600,000 ha, representing 62% of total land area in the Republic of Ireland (ROI) is managed by farmers (DAFM, 2013). Similarly, agriculture is the dominant form of land use across much of Western Europe and as a consequence, a significant proportion of biodiversity is associated with farmland habitats (Robinson & Sutherland, 2002). In the ROI, approximately 80% of agricultural land is devoted to livestock farming, including land used for intensively grazed pasture and for grass forage production (DAFM, 2013).

Global targets to reverse the decline in biodiversity by 2010 have not been achieved, and new targets need to be formulated (Butchart *et al*., 2010). Specifically, the conservation status of European farmland birds has caused great concern in recent years (Krebs *et al*., 1999). The decline in bird populations within agricultural landscapes throughout much of Europe has been closely associated with a general increase in the intensity of agricultural production systems principally driven by the Common Agricultural Policy (CAP) (Donald *et al*., 2001). However, this relationship may be more nuanced with some species actually benefiting from intensification through increased availability of food resource (Donald *et al*., 2006). It has also been recently reported that hedgerow-nesting species are not as adversely affected by agricultural intensity as ground-nesting species (Bas *et al*., 2009). In addition, there is widespread acceptance that the enhancement of ecological heterogeneity at multiple spatial and temporal scales can help to reverse declines in biodiversity within agro-ecosystems (Benton *et al*., 2003; McMahon *et al*., 2008; Fahrig *et al*., 2012).

Despite their questionable effectiveness (Kleijn & Sutherland, 2003), a very significant investment has been made in the implementation of European agri-environment incentive schemes, many of which make an implicit assumption that there is a universally negative relationship between farming intensity and biodiversity. This relationship is not always true (Donald *et al*., 2006; Purvis *et al*., 2009; McMahon *et al*., 2010*a*). It has been suggested that all such schemes would be much more beneficial for wildlife, if they exhibited greater customisation to exploit conservation potential within different geographical contexts (Whittingham *et al*., 2007). In addition to geographical variation, it has also been established that a considerable variation can exist in biodiversity within different farming systems (e.g. Chamberlain *et al*., 2010). The majority of these studies, however, have concentrated on the comparison of organic and conventional production systems, often concluding that the former is more beneficial to biodiversity. However, this study aims to establish the most important drivers of biodiversity on conventional livestock farms within the ROI and seek to better understand the more important determinants of avian biodiversity within the agricultural ecosystem.

Materials and Methods

Site selection

Grass-based farms were selected for bird surveys in three separate geographical regions of ROI in counties Sligo/Leitrim, Offaly/Laois and Cork. These regions were selected to represent a gradient of agricultural intensity and agri-environment scheme (AES) participation; with greatest intensity in the southern-most region, i.e. Cork and least in the northern-most, i.e. Sligo/Leitrim. AES participation was inversely related to intensity, with greatest participation in Sligo/Leitrim (Lafferty *et al*., 1999; Emerson & Gilmor, 1999). In 2007 and 2008, before each breeding season five 10 km squares within each study region were randomly selected and four individual farms were selected across at the centre of the central 1 km squares. The mean (± SE) farm size of 48 ± 3.03 ha. The 10 km squares within each study region were less than 250 m in elevation and had an average percentage agricultural land was greater than 70%. In total, 20 farms were selected within each region in 2007 and an additional 20 were selected in 2008. A total of 120 farms were selected in total over the 2 years, but only 59 farms were surveyed in the 2008–09 seasons because of logistical reasons. As a result only three farms were surveyed from one square in the Cork region.

Bird data

Each farm was surveyed once in the winter season (December–February) and once in the breeding season (April–June). The same surveyor carried out all surveys according to a standardised protocol. During each survey, field boundaries across the farm were walked at a distance of approximately 1.5 m from the field edge. The speed of walking depended on the numbers of birds present; however, because of the open nature of farmland habitats the recommended average speed of 2 km per hour was maintained where possible (Bibby *et al*., 2000). The route of each survey was consistent within each site in the breeding and winter season. Bird species presence and abundance was recorded using both visual (10 × 42 binoculars) and aural methods. In addition, because some species are known to avoid or prefer field boundaries, pre-determined transects included walking across larger fields (Bibby *et al*., 2000). During the breeding season, surveys were carried out between 07:00 and 12:00 and between 10:00 and 15:00 in the winter season in order to standardise the time of day each survey was carried out within each season. The mean duration (± SD) of surveys in the winter season was 61 ± 13 mins and 67 ± 18 mins in the breeding season. As extreme weather affects bird activity and observer accuracy (Bibby *et al*., 2000), no surveys were carried during periods of persistent heavy rain, or wind speeds greater than Beaufort scale 4. The number, abundance and location of bird species were recorded directly onto site maps, including raptors seen hunting over fields and field boundaries. Other species seen flying overhead, but not interacting with fields or field boundaries, were not recorded.

Statistical analyses

Bird count data for the winter and breeding season were analysed separately. Total bird species richness and abundance, and the species richness and abundance of Farmland Indicator species (Gregory *et al*., 2004) were analysed as response variables. Initially all response variables were modelled with GLMMs using Poisson error and a log link function. Centred and log-transformed survey duration (minutes) and calendar day were included in all models as primary covariates. Region (Sligo/Lietrim, Offaly/Laois, Cork), system (dairy, beef, suckler and other) and participation in the agri-environment scheme at the time, the Rural Environmental Protection Scheme-REPS (REPS-participation, non-participation) were used as categorical explanatory variables to assess effects on bird populations. Where there were no significant differences between non-dairy farm systems (beef, suckler and other) data where modelled to test the system variation between dairy and non-dairy farms. Data quantifying the mean field boundary quality on each farm, using the Field Boundary Evaluation and Grading System (FBEGS) Index (Collier & Feehan, 2003), was calculated for a minimum of 10 field boundaries per farm. This index is a useful predictor of birds within field boundaries (McMahon *et al*., 2010*b*). Animal stocking rate, calculated as standardised livestock units per ha (LU ha^{-1}), was used to quantify agricultural intensity following the methodology of the Irish National Farm Survey (Connolly *et al*., 2009). Year (2007, 2008) and 10 km sampling square (1–10 in each region) were initially included in all models as fixed effects, and subsequently removed when found to be non-significant. However, square was retained in all final models as a random effect. Using GLMMs, model selection was conducted using likelihood ratio (χ^2) tests. Models for Farmland Indicator species richness in the breeding season showed underdispersion (residual deviance/residual df < 0.5), and here approximate F ratio tests were used to select the best model. All analyses were performed in R 2.12 (R Development Core Team, 2010).

Results

In the winter period, sixty farms were surveyed in a total of fifteen 10 km squares in 2007–08 and 59 farms were surveyed in 2008–09. During the breeding season, only 42 farms were surveyed in 2007 due to poor weather conditions and 59 farms were surveyed in 2008.

The quality of field boundaries as measured by the FBEGS Index did not differ significantly between region, system or REPS. However, stocking rate (LU ha^{-1} ± SD) was significantly higher on dairy (1.876 ± 0.670) compared to non-dairy (1.102 ± 0.813) farms ($F = 25.11$, $P<0.001$). In the winter season, fifty bird species were recorded in 2007–08 and 49 species in 2008–09. Totals of 47 and 48 species were recorded in the breeding seasons of 2007 and 2008, respectively.

During the winter and breeding season, system and region were significant model parameters, with overall bird abundance, and the species richness and abundance of farmland indicator species, all greater on dairy, compared with non-dairy farms (Table 1; Fig. 1 and Fig. 2), with the exception of breeding bird species richness and abundance.

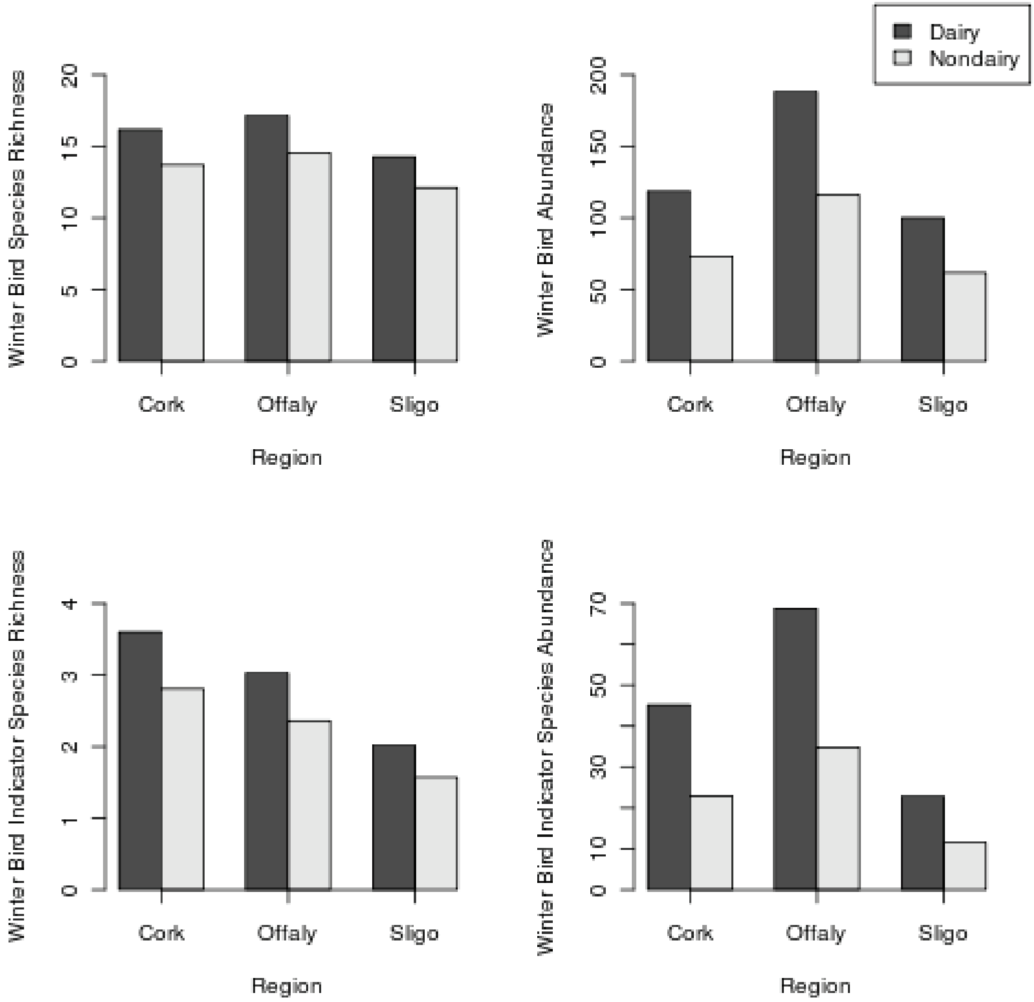

Fig. 1. Winter model predictions of total bird species richness and abundance, and the species richness and abundance of farmland indicator species on dairy and non-dairy farms in the three different regions.

Discussion

Apart from strong regional effects, the current study highlights a major influence of farming system on bird populations at the farm scale. Whenever farm system was found to be a significant explanatory variable, dairy farms, which practice more intensive grassland management with substantially greater nutrient inputs, stocking rates and short-term (21–28 day) grazing cycles (Purvis *et al*., 2009; Humphreys *et al*., 2008), had greater species richness and abundance compared to non-dairy livestock farms. If the often assumed universally negative relationship between production intensity and biodiversity is actually true and effectively explains the observed decline and range contraction in European farmland bird populations, this is an almost counter-intuitive finding. However, in some studies invertebrate feeding birds have been shown to prefer relatively more intensively managed grasslands during the winter season (Atkinson *et al*., 2005). Our study demonstrated that more intensive dairy farms had greater bird populations during both the winter and breeding season. This strongly suggests that any presumption regarding a universal effect of production intensity is a generalisation. Our data lend credence to the argument that the availability of trophic energy is a key factor in determining breeding bird species diversity (Haberl *et al*., 2005). It should be noted here, however, that in the latter study, endangered bird species were negatively associated with available energy therefore conservation of overall avian biodiversity within an ecosystem may not be linked conservation of specific species (McMahon *et al*., 2013). The current study clearly indicates that the greater production intensity of Irish dairy

Table 1. *Model fitting for winter and breeding bird response variables with Region, Dairy, System and REPS. Terms were selected on the basis of likelihood ratio test (χ^2).* P *values are given except for non-significance (ns) where* P*>0.05*

Explanatory variable	df	Winter Species Richness (χ^2, *P* value)	Winter Abundance (χ^2, *P* value)	Winter Species Richness of Farmland Indicators (χ^2, *P* value)	Winter abundance of Farmland Indicators (χ^2, *P* value)	Breeding Species Richness (χ^2, *P* value)	Breeding Abundance (χ^2, *P* value)	Breeding Species Richness of Farmland Indicators (*F*, *P* value)	Breeding abundance of Farmland Indicators (χ^2, *P* value)
Region	2	15.29, <0.001	35.75, <0.001	21.30, <0.001	18.90 <0.001	ns	ns	6.17, 0.003	36.24, <0.001
Dairy	1	9.05, 0.003	18.39, <0.001	3.86, 0.037	7.09, 0.006	ns	8.57, 0.004	3.03, 0.085	14.42, <0.001
System	3	ns	ns	ns	ns	ns	ns	ns	ns
REPS	1	ns	ns	ns	ns	ns	ns	ns	ns

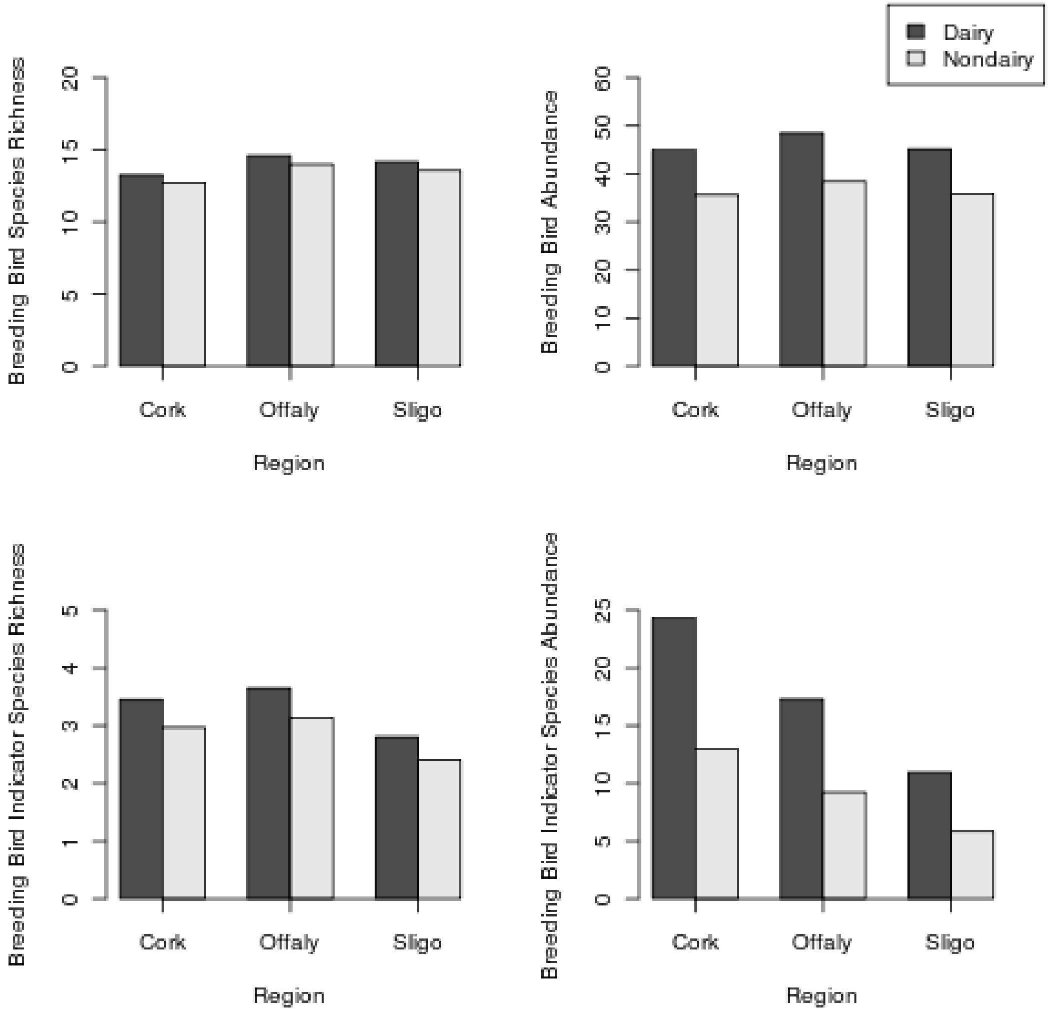

Fig. 2. Breeding model predictions of total bird species richness and abundance, and the species richness and abundance of farmland indicator species on dairy and non-dairy farms in the three different regions.

farming, probably due to the greater nutrient/food availability compared with non-dairy farms, supports significantly larger bird populations, including farmland indicator species.

Increases in agricultural production over the last thirty years have been largely driven by the CAP, and closely linked to bird population decline throughout Europe (Donald *et al*., 2001). Intensification has been achieved through multiple coincident changes, involving much more than increased stocking rates and use of nutrient inputs. Other significant coincident changes include a marked up-scaling of production units (fields and farms) and a resulting homogenisation of landscapes across the continent, with an associated reduction in the amount of 'non-cropped' habitat within farmland (Benton *et al*., 2003). As a consequence, a considerable investment has been made in seeking to understand and establish specific habitat predictors for bird diversity on farmland throughout Europe (e.g. Chamberlain *et al*., 1999; Söderström *et al*., 2001). Our data hint at a much more complex relationship between bird populations and the effects of both increased production intensity (as measured by nutrient input levels or stocking rates), and the often closely associated loss of 'non-cropped' habitats within the wider farmed landscape. In a related but completely independent study of 50 (predominantly dairy) livestock farms in SE of Ireland, Sheridan *et al*. (2009) found that approximately 14% of the land area of sampled farms comprised 'non-cropped' (semi-natural) habitats, of which 88% comprised traditional field hedgerows amounting to an average of almost 11.5 $km.km^{-2}$. This is substantially more than has been reported for other European countries (Jeanneret *et al*., 2003; Manhoudt & de Snoo, 2003). This research also found that arthropod abundance (but not diversity) was significantly greater in intensively managed dairy farm pastures, compared with pastures on non-dairy farms (McMahon *et al*., 2010). Our current data therefore could reflect the improved opportunities for bird populations when there is a certain level of agricultural activity in combination with retention of necessary habitats.

In the absence of appropriate baseline data our study can shed little light on the effectiveness of past REPS policy. Evaluation of REPS was not the main aim of the current research, which sought to identify of the main management drivers of biodiversity within Irish livestock farming. In this regard, our findings have significant value, not only to Irish agri-environment policy, but to all such policies within Europe. They clearly suggest that increase in farming intensity, does not necessarily always have a negative effect on biodiversity.

At appropriate scales, intensity can potentially bring significant biodiversity benefits. The application of the land sparing or land sharing approach to agricultural ecosystems is irrelevant without the incorporation of spatial scale, as this will influence biodiversity (e.g. Gabriel *et al*., 2010; McMahon *et al*., 2012) and production. At the farm scale, heterogeneity in production intensity may itself add to the benefits of habitat heterogeneity. This is the subject of on-going analysis of our data set. Our current study demonstrates that relatively intensive agricultural production systems, can have a positive role to play in the creation of an optimal agro-ecosystem matrix for the preservation of biological diversity up to a certain level (Donald & Evans, 2006; McMahon *et al*., 2012). Our study also indicates that AES can be made much more effective by regional targeting of appropriate measures (Whittingham *et al*., 2007), that best suit the environmental conditions and drivers created by different farm systems. Clearly, in Ireland there is a strong case for the customisation of AES measures, separately targeting dairy and non-dairy enterprises.

In order to reverse the recent declines in European farmland biodiversity and optimise agricultural production systems, EU policy must take into account the variation that exists within and between geographical regions and farming systems and implement flexible policies that reflect the differences in biodiversity levels within. Scientists and policy makers must take cognisance of the fact that there are few generalities in ecology. The often assumed detrimental link between farming intensity and biodiversity, is not necessarily universally valid, and context-dependant policy that truly understands the ecological effects of different farming systems, is much more likely to be effective.

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