Interactions between livestock systems and biodiversity in South-East Ireland

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ABSTRACT

Botanical and arthropod surveys at field level, and bird counts within field boundaries were undertaken on the same random sample of fifty grass-based farms in SE Ireland. Additional data relating to farm system, farm-level nutrient inputs, stocking rates, and participation (or otherwise) in the Irish Rural Environment Protection Scheme (REPS) were collated. Generalized Linear Models (GLM) showed that farm system was a predominant influence explaining observed biological diversity. Both sward plant and arthropod diversity were greater on non-dairy (drystock) farms, but total arthropod abundance was greater on dairy farm swards. Both the abundance and species richness of bird populations in the breeding season were significantly greater in field boundaries on dairy, compared with non-dairy farms. Our data suggests varying influences of farm system on different aspects of biodiversity and indicates that, contrary to conventional thinking, some aspects of the more intensive dairy farm system are beneficial to some aspects of biodiversity. These insights have relevance to the debate regarding the most effective use of public expenditure on agri-environment policy, and suggest that such incentive schemes need to become more clearly customised to realise the conservation potential of different farming systems.

Keywords: bird populations; conservation ecology; invertebrate abundance; dairy farm

1. Introduction

Approximately 62% of land in the Republic of Ireland is managed by farmers (DAFF, 2009). Similarly, agriculture is the dominant form of land use across much of Western Europe. As a consequence, a significant proportion of European biodiversity is associated with the habitats created by agriculture (Robinson and Sutherland, 2002). Intensification of agriculture through increased mechanisation, loss of hedgerows and other 'non-cropped' habitats, and the increased use of exogenous fertilisers and other chemical inputs has been associated with a general reduction in landscape diversity (Robinson and Sutherland, 2002). In the Republic of Ireland, approximately 80% of agricultural land is devoted to livestock farming, including intensively grazed pasture and grass forage production (DAFF, 2009). The intensification of grassland management in Irish farming, especially through changes in reseeding and the frequency of new sward establishment, grazing and forage conservation systems and nutrient inputs, has mirrored the intensification of agriculture generally across much of Europe, which has resulted in an associated loss of biodiversity (McLaughlin and Mineau, 1995; Duelli, 1997; Hoffmann and Greef, 2003).

A recent European-wide study by Kleijn et al., (2009) demonstrated a non-linear negative relationship between farming intensity as expressed by nitrogen input level, and botanical diversity assessed at the individual field level. The relevance of this finding is, however, dependent on a widely presumed negative link between the intensity of within-field husbandry systems and biodiversity at all levels of the farmed landscape. It has been suggested that between 1970 and 2000, the species diversity of European farmland declined by 23% (de Heer et al., 2005). In particular, the decline in bird populations within agricultural landscapes throughout much of Europe has been widely studied, and found to be closely associated with the increased intensity of agriculture principally driven by the Common Agricultural Policy, particularly between 1970-1900 (Donald et al., 2001).

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Knowledge of the occurrence, ecological condition and management of both ‘cropped’ and ‘non-cropped’ habitats at the farm level is a prerequisite for effective evaluation of agri-environmental policy focused on the actions of individual farmers (Purvis et al., 2009). The term ‘cropped’ in this context refers to land used for production purposes, including annually cultivated (arable) land and managed pasture land. It has been highlighted that a relatively high proportion (approximately 14.3%) of the land area of typical commercial Irish farms is currently ‘non-cropped’, i.e. not utilised for production purposes; the majority of this ‘non-cropped’ land (approximately 9% of total farm area) being permanent hedgerow habitat (Purvis et al., 2009).

The importance of permanent field boundaries as a habitat for birds within agricultural landscapes is particularly well documented (e.g. Hinsley and Bellamy, 2000). Accurate methods for the ecological evaluation of field boundaries may therefore be especially useful tools for tracking and assessment of landscape and habitat changes that occur within farmed landscapes over time (Faiers and Bailey, 2005). Indeed, the Irish Field Boundary Evaluation and Grading System (FBEGS) (Collier and Feehan, 2003), which was derived from the Hedgerow Evaluation and Grading System (HEGS) of the UK (Clements and Toft, 1992), has been shown to be a potentially useful surrogate for prediction of likely effects on bird populations within Irish field boundaries (McMahon et al., 2005). The development of such methods provides a potentially invaluable, and relatively easily monitored indicator of the likely effects of changing farm practice on environmental quality (Smeets and Weterings, 1999; Thomassin, 1999; Onate et al., 2000; Primdahl et al., 2003), and a

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much needed practical means to evaluate the effectiveness of agri-environmental management strategies (CEC, 2006).

The Rural Environment Protection Scheme (REPS), an Irish agri-environmental scheme, which to date is designed for use in all types of Irish farming, and makes no distinction between farm different farm systems. In particular, the REPS focuses strongly on a requirement to limit farm inputs and stocking rates at the field level. As a consequence, relatively few dairy farms, compared with inherently less intensive non-dairy (drystock) farms participate in the scheme, and as dairy farming is much more prevalent in the south of the country, there is a clearly increasing south to north gradient in REPS participation (Lafferty et al., 1999). This entirely voluntary scheme, which could potentially benefit biodiversity within and beyond agricultural systems, is in contrast to other actions more specifically designed to benefit biodiversity, such as the designation of Natura 2000 sites, which is of course based on the ecological importance of habitats and the occurrence of endangered or rare species.

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Previous studies, explicitly comparing organic and conventional farming have shown that farm management system can clearly influence farmland biodiversity (e.g. Chamberlain et al., 1999; Rundlöf et al., 2008). In the current study, we aim to determine what influences different aspects of biodiversity, ranging from sward plants and ~~,~~arthropods and birds within farm boundaries, on a representative sample of Irish livestock farms. We use our findings to discuss practical implications with respect to optimising the likely benefits of agri-environment measures both within the specific context of Ireland's REPS scheme and the wider debate regarding EU policy.

2. Methods

2.1. Site Selection

Farm sites were chosen with the assistance of the Teagasc National Farm Survey (NFS), which maintains a nationally representative database of farm statistics for the Republic of Ireland derived from survey farms stratified nationally by farming type and size (Connolly et al., 2004). As grassland farming greatly predominates in Irish agriculture (DAFF, 2009), a representative sub-sample of fifty grass-based livestock farms stratified by county and livestock type within the southeast of Ireland (Counties Carlow, Cork, Kilkenny, Laois, Meath, Waterford, Wexford and Wicklow) was drawn from this database for our study. Individual farm systems within the Republic of Ireland are usually well established and handed down through the generations so they have been established for many years. Data relating to farm area, the input of organic and inorganic nitrogen (kg N ha^{-1} yr^{-1}) and livestock type were also collated. In addition, animal stocking rate ha^{-1} was calculated on the basis of livestock numbers and type, and the total Utilised Agricultural Area (UAA) of each farm. The UAA is calculated as the total area farmed = the land area owned, plus any rented land, minus any let land, minus any non-farmed ('uncropped') area (Connolly et al. 2004).

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2.2. Sward Botanical and Arthropod Data

Sward botanical and arthropod data were collected from a grazed grassland field representative of the overall management of each studied farm. Samples were collected mid-way through the sward recovery period when rotational grazing was practiseed. In order to reduce the effects of temporal variation, botanical samples were collected from three farms per day over a relatively constrained sampling period between 6th July - 10th August 2005. Using the dry-weight-rank method ('t Mannetje and Haydock, 1963) with yield correction (Jones and Hargreaves, 1979), the three most abundant plant species occurring within each of fifty randomly located circular quadrats 3dm^2 per field (total area sampled per field = 1.5m^2) were ranked. All other species which occurred in the quadrats were recorded. Additionally, mean sward height was estimated by recording height measurements at fifty random locations per field using a Filips Folding Plate Pasture Meter (www.jenquip.co.nz).

Vegetation arthropods were sampled within the selected fields, using a Vortis Insect Suction Sampler (Burkard Manufacturing Co Ltd, Rickmansworth, Hertfordshire, UK), (Arnold, 1994, Brook *et al.*, 2008). Sampling was carried out between 10am and 3pm. A total of 20 aggregate samples (each derived from six random points sampled for 10s duration) were collected from each field. The total area sampled in each field was 2.4m^2. Catches were preserved in 70% ethanol prior to sorting and identification. Five major arthropod groups dominated the samples; Araneae were identified to species level; Coleoptera to species with the exception of some Aleocharinae identified to morpho-species initially and subsequently to genera; Hemiptera were identified to species level with the exception of some Aphidoidea identified to morpho-species; parasitoid Hymenoptera were identified to genus-level. Only these groups were examined as the numbers of other groups was negligible. A wide range of other farm management statistics were collated as possible explanatory variables for sward and arthropod parameters (Table 1).

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2.3. Field Boundary and Bird Data

Field boundaries are an important habitat for bird populations within agricultural landscapes (e.g. Hinsley and Bellamy, 2000). A survey was therefore undertaken of bird populations within individual field boundaries on the monitored farms. To ensure complete independence in boundary selection, all field boundaries within a studied farm were designated an individual number, and one randomly selected field boundary was chosen per farm. Bird populations were surveyed once in selected field boundaries during winter (December-February) 2005/2006, and again during the breeding season (April-July) 2006. During each survey, selected boundaries were walked along the field margin, approximately 1.5m from the boundary edge. The speed of walking depended on the number of birds present; however, due to the open nature of the farmland habitats a standard overall speed of 2km per hour was generally observed (Bibby et al., 2000). Bird presence and abundance were recorded using both visual and aural identification. In winter, surveys were carried out at least one hour after dawn, and at least one hour before dusk. During the breeding season, the latest starting time was 07.00hrs and surveys were completed by 10.00hrs. As extreme weather affects bird activity and observer accuracy (Bibby et al., 2000), wind speed and weather conditions were recorded and no surveys were made during persistent, heavy rain, or when wind speeds exceeded Beaufort scale 4. The number and abundance of bird species observed, including raptors seen hunting overhead were recorded directly onto site maps. Other species flying overhead, but not making direct use of the surveyed boundaries, were not counted. Double-counting was minimised by the observer taking into consideration birds that were flushed to other parts of the boundary being surveyed (McMahon et al., 2006).

2.4. Statistical Analyses

The influence of farm system and management parameters on sward vegetation and vegetation arthropod populations within sampled grass fields was investigated using Generalized Linear Modelling (GLM). The response variables included in these analyses were the total number of plant species observed in monitored swards, the un-adjusted numbers of arthropod taxa (taxon density), arthropod taxon richness (see below) and total abundance of arthropods in pooled Vortis samples. Explanatory variables that were initially included in all models are listed in Table 1. Arthropod taxon richness (Gotelli and Colwell, 2001; Magurran, 2004), was determined using rarefaction to create standardised estimates of taxon richness. Rarefaction estimates were made using EstimateS version 7.5.0 (Colwell, 2005) to generate Coleman curves (Magurran, 2004) plotted against the numbers of individuals in cumulative sample catches. The combined data set for Araneae, Coleoptera, Hemiptera and Hymenoptera were used in this process, but because Diptera were identified only to family level, they were excluded from this calculation because their disproportionately high abundance in relation to their level of taxonomic resolution would have unduly skewed the resulting statistic. Separate models with and without the Diptera were created to explore farm management relationships with total sward arthropod abundance. GLMs were used to fit farm system/management variables to field boundary bird population statistics for the breeding season and winter surveys. Centred and log transformed field boundary length and calendar day of the bird survey were included in all models as primary covariates. The GLM procedure for all analyses was carried out using the statistical package R version 2.6.0. (R Development Core Team, 2007). Poisson distribution was specified when residual deviance approximated to the number of degrees of freedom. When there was evidence of overdispersion or underdispersion in the data, quasipoisson distribution was defined. In all cases, interaction terms were tested first, and when found significant ($P \leq 0.05$) were incorporated into an initial maximal model including all farm management variables. A process of model simplification was then undertaken to remove sequentially, any non-significant terms (Crawley, 2007). Minimal adequate models were identified by deletion tests using the chi-squared test where Poisson distribution was specified and F test where quiasipoisson specified ($P \leq 0.05$).

3. Results

A total of 50 randomly selected farms were surveyed, of which 35 were dairy farms and 15 were non-dairy (drystock) farms (See Supplementary Material for distribution of sites). There was no significant difference between mean (± SD) total farm size (dairy = 50.02 ± 13.40ha; non-dairy = 51.9 ± 26.64ha), mean field size (dairy = 3.55 ± 1.93ha; non-dairy = 3.52 ± 1.76ha), the mean surveyed field boundary length (dairy=236 ± 100.03m; non-dairy=17.80 ± 136.83m), mean standardised length (m/ha) of permanent field boundaries (Figure to be included) or mean farm stocking rate (dairy = 0.90 ± 0.21LU ha^{-1}; non-dairy = 1.05 ± 0.34LU ha^{-1}). However, the input of total organic and inorganic nitrogen was significantly ($P>0.01$) greater on dairy (357.59 ± 138.05kg N ha^{-1}) compared to non-dairy (243 ± 111kg N ha^{-1}). Further details relating to farm system and livestock associated with the sample farms are provided by Purvis et al. (2009).

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3.1. Effects on Sward Diversity

Farm system and sampling date were the only significant explanatory variables retained in the minimal adequate model describing total sward plant species richness. Model predictions of the total numbers of plant species recorded in surveyed fields declined steadily over the sampling period (early July to early August); and the model predicted significantly lower total sward species richness on dairy farms compared with non-dairy farms (Fig. 1).

Insert Figure 1.

3.2. Effects on Sward Arthropod Populations

The model fitted to arthropod taxon richness (standardised for differences in the numbers of individuals per sample), revealed a significant farm system effect with greater arthropod richness in pastures on non-dairy, compared with dairy farms, and a negative relationship with the total farm input level of nitrogen on cropped land (kg $N.ha^{-1}$), (Table 2, Fig. 2).

Insert Table 2.

Insert Figure 2.

In marked contrast, the models fitted to total arthropod abundance (with or without the inclusion of Diptera), and to taxon density (species taxon richness in samples, uncorrected for abundance) within sampled swards were ~~relatively~~ more complex (Table 2). Total arthropod abundance was significantly influenced by farm system, sward height variance and the date of sampling. The background influence of sampling date was best described by a second order polynomial indicating an increasing abundance during earlier sampling, which peaked in late July/early August and declined thereafter. With, or without Diptera included, the models predicted significantly greater total arthropod abundance on dairy compared with non-dairy farms, and a positive relationship between arthropod abundance and sward height variance. The model for total arthropod abundance (including Diptera) revealed an 11% increase in arthropod populations with each 5cm increase in sward height variance (Fig. 3).

Insert Fig. 3

In addition to a strong seasonal effect, the model fitted to the taxon density (un-adjusted numbers of arthropod taxa) revealed an additional~~ly~~ significant (P<0.001) interaction between farm system and the Shannon index of farm habitat diversity (Table 2). The nature of this interaction suggested a positive influence of farm habitat diversity on taxon density within swards on dairy farms, but a negative influence on non-dairy farms (Table 2).

3.3. Relationships with Bird Population Statistics

No significant relationships were found between farm management variables and winter bird population statistics. However, both the abundance (P>0.01) and species richness (P>0.05) of breeding season bird populations were significantly greater in field boundaries on dairy, compared with non-dairy farms (Fig. 4).

Insert Figure 4.

4. Discussion

The dairy vs non-dairy contrast was a consistently significant variable in all models exploring relationships between farm management and sward biodiversity. In contrast to the expected relationships between sward botanical and arthropod richness and farm system, total arthropod abundance (with, or without Diptera), was significantly greater in the more intensively managed swards of dairy farms. Our data also make it very apparent that both seasonality and physical sward heterogeneity have a strong influence on observed biodiversity within agricultural grasslands. Temporal effects are frequently an important determinant of observed biodiversity (Gotelli and Colwell, 2001) and our data emphasise the importance of including a temporal measure in any analysis of biological data collected over a seasonal time frame during which phenological changes can become apparent. The dairy vs non-dairy dichotomy can be interpreted as being predominantly a farming intensity effect, indicated ~~on one hand~~ by generally more intensive nutrient inputs and grassland husbandry on dairy farms ~~,~~ ~~and less intensive~~than ~~grassland husbandry~~ on non-dairy farms.

Sward height variance is influenced by mean sward height, which in turn is strongly influenced by grazing and grass utilisation pattern, especially the time between grazing cycles in rotationally grazed systems. Additionally, sward height variance is influenced by the type and mixture of livestock (Dumont et al., 2007), and by the growth characteristics of the plant species present. Although some of the non-dairy farms had sheep, the only significant difference observed was between dairy, and the collective sample of non-dairy farms. Longer and more variable swards probably provide more opportunities for arthropod populations from the perspectives of total habitat volume, microclimate and niche diversity, so that a greater abundance of individuals and taxa per unit area can co-exist (Gibson et al., 1992a; Gibson et al., 1992b; Morris, 2000). Interestingly, however, the relationship between sward structure and arthropod populations appears to break down following the process of standardising species richness estimates using rarefaction curves to remove the influence of differential abundance in samples. Such adjusted data show the theoretically expected negative relationship between faunal and sward botanical diversity, and between faunal diversity and management intensity expressed as either nutrient inputs level, or the contrast of dairy vs non-dairy farming systems.

The significantly greater absolute arthropod abundance in samples from dairy, compared with non-dairy farms is a less expected finding, and is probably evidence of the much greater resource base that is available for a narrower range of taxa in high nutrient input pastures. A similar positive relationship was evident between animal stocking rate and unadjusted arthropod taxon density (excluding Diptera). Curry et al., (2007) reported a similar positive invertebrate population response to increased nutrient input levels in an experimental comparison of grassland management systems, with enhanced total earthworm biomass in higher high nitrogen application treatments.

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The demonstration of significantly greater breeding bird species richness and abundance within our sample of field boundaries on dairy farms compared with non-dairy farms is also less intuitive, but can probably be explained by the previously demonstrated positive relationships between the abundance and diversity of bird populations in Irish field boundaries, and the conceptual Field Boundary Evaluation and Grading System (FBEGS) Index (McMahon et al., 2005). The FBEGS Index was conceived as a theoretical measure of the potential ecological value of a field boundary (Collier and Feehan, 2003), and its mean value for field boundaries surveyed in the current study was found to be significantly greater on dairy compared with non-dairy farms (Purvis et al., 2009). Part of the explanation for the enhanced bird population statistics observed in dairy field boundaries may therefore lie in the quality of their management. Dairy farmers are necessarily employed in their dairying enterprise on a full time basis. As a result, in contrast to many Irish non-dairy farmers who often supplement farm income with off-farm employment, both FBEGS scores and bird population statistics on dairy farms may benefit from full-time farm management, including maintenance and management of hedgerows. Whatever the explanation, these may be extremely important findings, since they seem to establish that some aspects of habitat quality and biodiversity can be of a superior status on inherently more intensively managed dairy farms. It has been observed that birds in winter are found in greater abundances on intensively managed fields feeding on invertebrates (Atkinson et al., 2005). A unique insight provided by the current study, is also the implied linkage between farm system effects on the abundance and species richness of different taxa, and evidence that the higher nutrient input levels associated with dairy farming practice, may be beneficial for the availability of invertebrate food, with consequent benefits for groups such breeding birds at the apex of trophic relationships.

It is generally accepted that less intensive systems are more beneficial to biodiversity. For example, Rundlöf et al.~~,~~ (2008), demonstrate the beneficial influence of organic vs. conventional farming systems, and the findings of Bas et al.~~,~~ (2009) support the view that agricultural intensity has a generally adverse affect on biodiversity, namely breeding birds populations. However, the latter study clearly indicates that ground-nesting bird species are more adversely effected by overall farming intensity, than are hedge-nesting species, which are more strongly dependant on the retention of quality breeding habitat (Bas et al 2009). This may help explain current study's findings, that hedgerow bird populations benefit from the combination of demonstrably greater invertebrate food resources, and enhanced hedgerow habitat quality on Irish dairy farms, compared with non-dairy farms. It is important to acknowledge that the field boundaries that were surveyed for the birds in the current study were not necessarily bordering the fields surveyed for invertebrates. However, suggested link between increased invertebrate abundance within fields and increased numbers of bird species nesting within field boundaries on the same sample of farms is a very plausible.

Following a recent study, Kleijn et al., (2009) argued that future conservation initiatives within agricultural ecosystems are likely to be more cost effective if implemented only in extensive agricultural areas that support particularly high levels of existing biodiversity. However, there were no confounding region effects in the data of ~~as experienced by~~ Kliejn et al., (2009), as the geographical variation was limited by the scale of the our study. In addition, in their interpretation Kliejn et al., (2009) ~~interpretation~~ make two important assumptions. Firstly, that increased intensity of farm management within the ‘crop’ (i.e. increased husbandry intensity) necessarily always affects biodiversity negatively at all levels within the farm landscape. Secondly, countries implementing agri-environmental schemes, especially in Europe, have enough readily identifiable areas of high biodiversity that would permit the ‘land sparing’ approach to conservation that was preferentially proposed by Green et al., (2005). The current study clearly casts doubt on Kleijn et al.’s~~,~~ (2009) first assumption by revealing unexpected complexity in the linkages between farm management intensity and biodiversity at different scales within the agro-ecosystem. Our survey of commercial farm sites also suggests that the heritage of ‘non-cropped’ habitats, in the form of traditionally maintained permanent field boundaries, remains an important conservation resource within mainstream Irish agriculture that clearly benefits aspects of farmland biodiversity within the wider, despite the undoubted increase in the intensity of grassland husbandry systems. In the Irish context, and perhaps in many other European regions, relatively few marginal areas of very extensive farming husbandry survive with notably higher than average levels of biodiversity.~~-~~ In addition, by excluding intensive forms of agriculture, the opportunity to engage large parts of Europe in the enhancement of biodiversity and conservation of remaining habitats and species will be lost.

The majority of Natura 2000 sites within Ireland are actually located on agriculturally active land, with approximately 90% of SACs being owned and managed by commercial farmers (Feehan, 2003). Within the Irish and perhaps many other European farming contexts, it may therefore be more beneficial that agri-environment

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schemes become much more targeted and customised to exploit the conservation potential of specific farm systems and geographical contexts, in order to maximise retention and enhancement of biodiversity within the agro-ecosystem (Whittingham et al., 2007). This would also enhance the ecological value of the comparatively few very special protected areas that remain within the European countryside, by connecting and revitalising the agricultural matrix that would otherwise be increasingly likely to fragment and isolate such regions (Donald & Evans 2006).

A more customised approach to agri-environmental policy was advocated in the development of the 'Agri-Environmental Footprint Index' (AFI), an index-based method developed for more effective policy evaluation and development (Purvis et al. 2009). The AFI concept views the totality of any agri-environment as a matrix of nine dimensions relating to three universal policy issues (protection of Natural Resources (air, soil and water), Biodiversity and Landscape) and three nested management targets for policy measures targeting these issues within different contexts (Fig. 7). Our findings, as summarised in Fig. 8, reveal the value of this conceptual model as a means to identify the potential of different farming systems to contribute to the well-being of the wider agri-environment whilst remaining sustainable competitive.

Insert Figure 5.

Insert Figure 6.

Like many such schemes throughout Europe, the REPS to date has sought to implement a single scheme designed for all types of farming, and in particular focuses strongly on a requirement to limit farm inputs and stocking rates at the field level. Changes in the most recent revision of the REPS (Anon., 2007) at least partially reflect recognition of the limitations of this approach, which clearly acts as a strong disincentive to the voluntary participation of more 'intensive' farmers (Kleijn and Sutherland, 2003). Should such an exclusion of perceived intensive farming persist, only minimum regulatory thresholds for agri-environmental quality are likely to be attained in regions with predominantly intensive farming systems (Downey and Purvis, 2005), and a valuable opportunity to recruit farmers as managers of the non-production dimensions of the agro-ecosystem (i.e. Physical Farm Infrastructure and Natural and Cultural Heritage – Fig. 7) will be lost.

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The success of agri-environment schemes largely depends on the establishment of clearly defined objectives, measures that have been empirically demonstrated to achieve these objectives, compliance, targeting and participation levels. However, our data suggest that a greater customisation of scheme design reflecting the fundamentally different influences of different farming systems within specific farm landscapes, and their potential to contribute to different dimensions of the agri-environment, could enhance the ability all farmers to make a more positive contribution to environmental improvement.

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Table 1 Farm and sampling variables included in initial maximal generalised linear models fitted to response variables (total numbers sward plant species, arthropod population statistics and field boundary bird population statistics) quantified for sampled farms.

system	– farm livestock type (dairy, or non-dairy)
totalN	– mean farm N input level (Kg ha^{-1} cropped land) from organic and inorganic sources
stocking rate	– livestock units per hectare (LU ha^{-1})
grassvar	– variance in mean grass height (cm) in the sampled field (arthropod models only)
plant species	– number of sward plant species recorded in the sampled field (arthropod models only)
propnoncrop	– proportion of the land area on the farm comprising "non-cropped" habitats
habitatdiv	– Shannon diversity index for habitats on the farm
reps	– participation of the farm (or not) in the Rural Environment Protection Scheme
lat	– geographical latitude
date	– offset of sampling date i.e. date minus mean sampling date (days from the beginning of the calendar year)
date^2	–offset of sampling date squared i.e. date squared minus mean sampling date squared (arthropod models only)

Table 2 Generalised Linear Models describing arthropod taxon richness, density and abundance in samples from monitored grasslands on the 50 farm sites (quasipoisson distribution).

Response variable	Other significant terms in the minimally adequate model	Dairy	Non-dairy	Standard error	d.f.	t	p-value
~~Adjusted arthropod~~ T~~t~~axon richness (adjusted) (excluding Diptera)	*system*	3.88	3.81	0.034	47	2.053	0.046
	totalN	2.7×10^{-4}		1.2×10^{-4}		-2.319	0.025
~~Un-adjusted arthropod~~ T~~t~~axon density (un-adjusted) (including Diptera)	*system*	4.16	4.47	0.100	41	3.098	0.004
	habitatdiv	0.21	-0.28	0.107		-4.602	<0.001
	plantspecies	0.016		0.007		2.182	0.035
	grassvar	0.015		0.003		4.454	<0.001
	Stocking rate	0.179		0.066		2.701	0.001
	date	0.016		0.002		8.610	<0.001
	date^2	-0.001		0.001		-4.078	<0.001
~~Total arthropod~~ A~~a~~bundance (excluding Diptera)	*system*	6.84	6.45	0.106	44	-3.779	<0.001
	grassvar	0.031		0.010		3.003	0.004
	date	0.038		0.005		7.181	<0.001
	date^2	-0.002		0.001		-5.224	<0.001
~~Total arthropod~~ A~~a~~bundance (including Diptera)	*system*	7.56	7.12	0.100	44	-4.492	<0.001
	grassvar	0.020		0.009		2.125	0.039
	date	0.020		0.004		4.285	<0.001
	date^2	-0.001		0.001		-3.511	<0.001

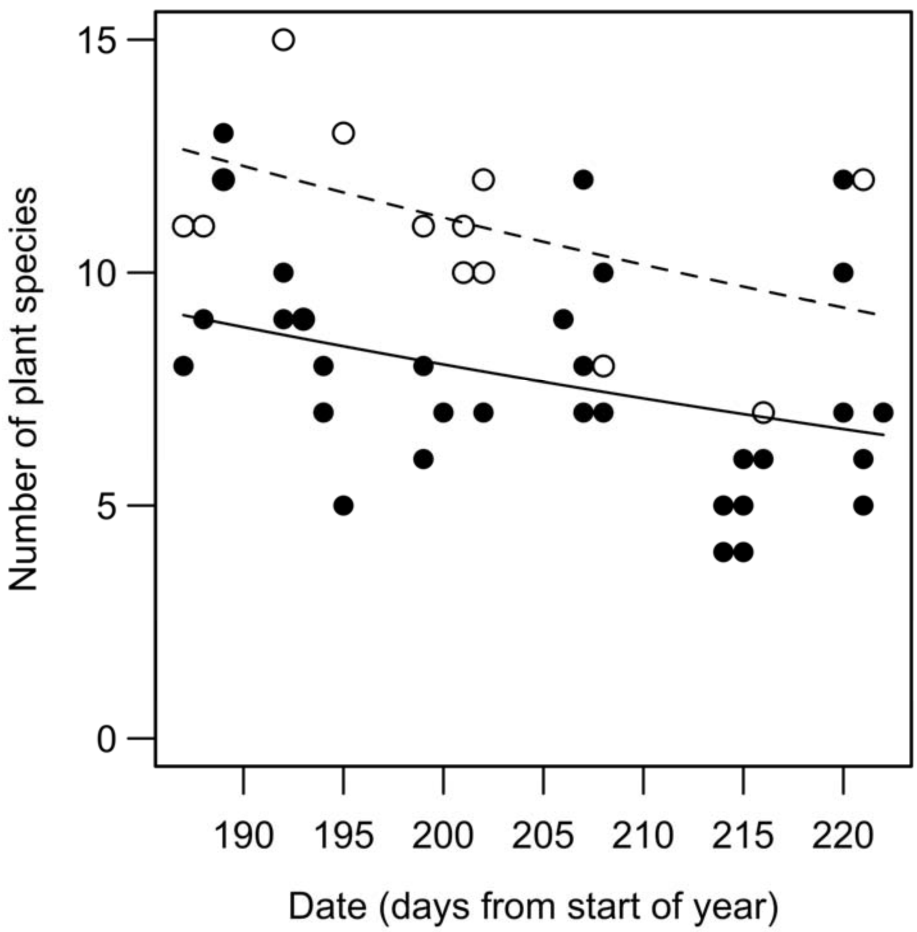

Fig. 1. Original data and predictions of the model describing the relationship between the total numbers of sward plant species recorded on surveyed fields and date of sampling (187 = 6th July; 222 = 10th Aug) on dairy farms (closed circles/solid line), and non-dairy (open circles/dashed line).

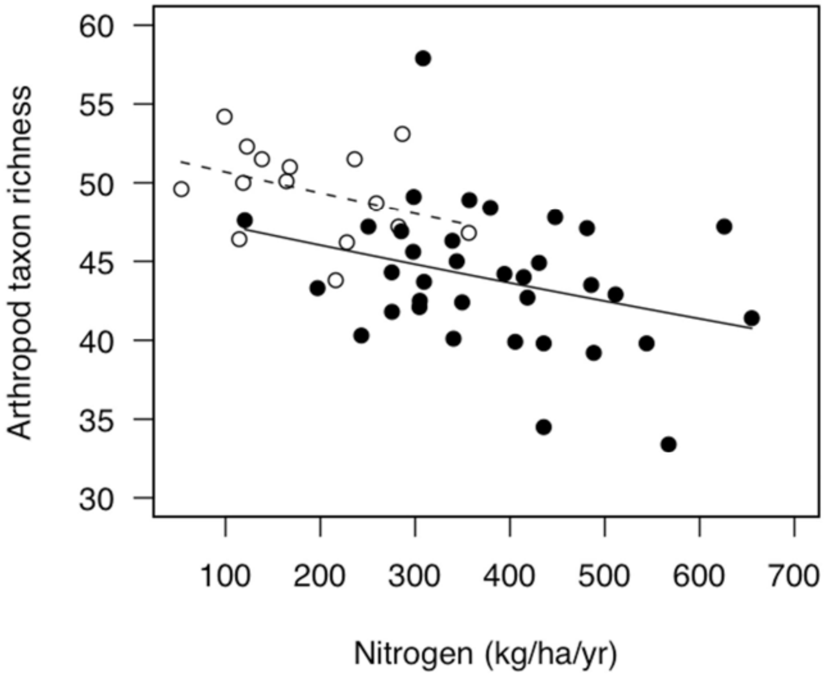

Fig. 2. Original data and predictions of the model describing the relationship between arthropod taxon richness (adjusted) (excluding Diptera) -in surveyed pastures and total farm nitrogen application on dairy farms (closed circles/solid line), and non-dairy (open circles/dashed line).

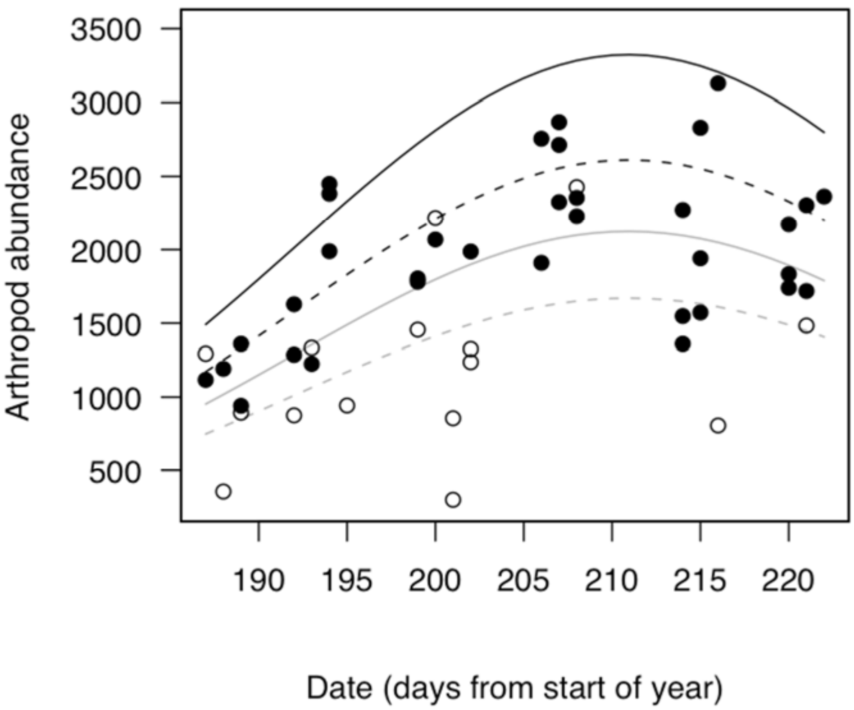

Fig. 3. Original data and predictions of the model describing the relationship between total arthropod abundance in surveyed pastures (including Diptera), and date of sampling (187 = 6th July; 222 = 10th Aug) on dairy farms (closed circles/solid line), and non-dairy (open circles/dashed line); fitted lines show predictions for high (18cm) and low (6cm) grass height variance (continuous and dashed lines, respectively).

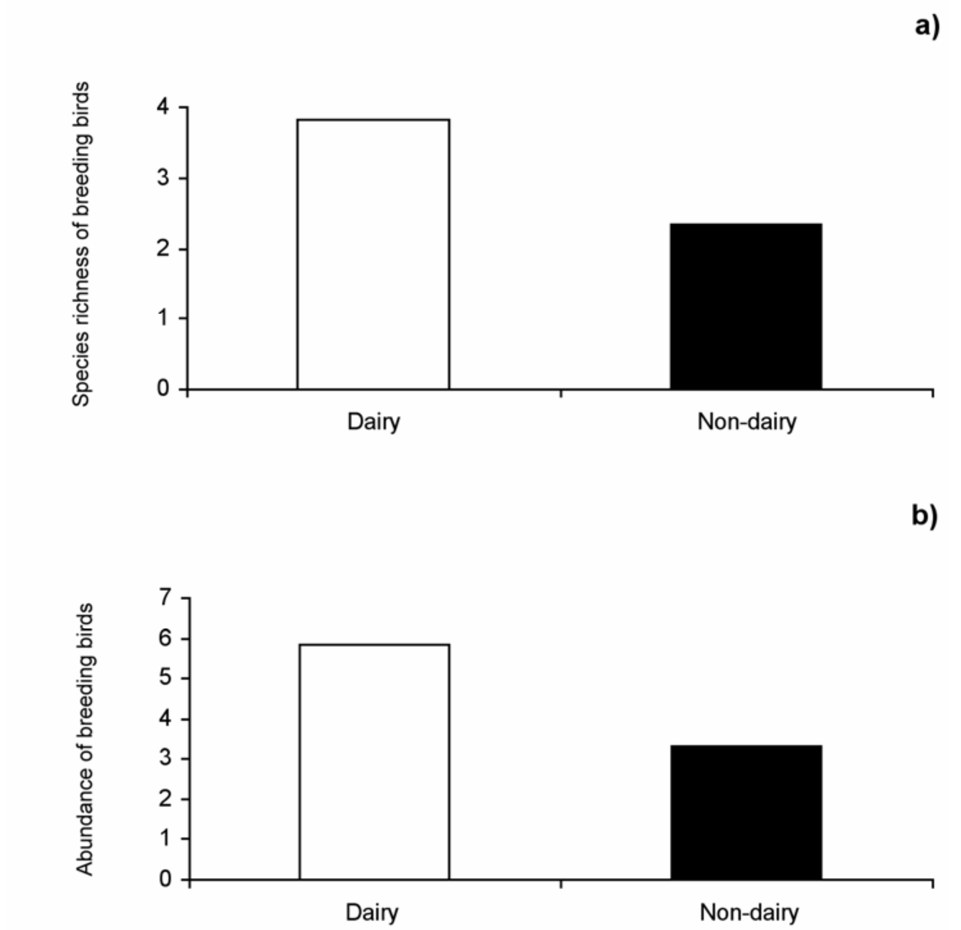

Fig. 4. Model predictions for; a) the mean species richness, and b) the mean abundance of breeding birds observed in surveyed field boundaries on dairy and non-dairy farm types.

AE Issues

Targeted Management Focus

	Natural Resources	Biodiversity	Landscape
Crop & Animal Husbandry			
Physical Farm Infra-structure			
Natural & Cultural Heritage			

Fig. 5. A conceptual framework for agri-environmental policy as developed by the AE-Footprint Project highlighting the significance of three strategic policy management targets; Crop and Animal Husbandry (CAH), Physical Farm Infrastructure (PFI) and Natural and Cultural Heritage (NCH) features of the wider countryside, which nest within each of three major identified agri-environmental issues (after Purvis *et al*., 2009).

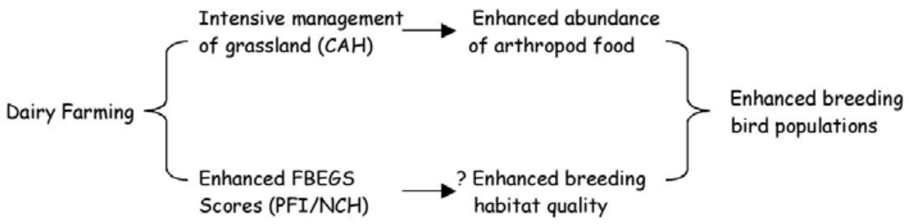

Fig. 6. Summary of the positive relationships observed in the sample of Irish dairy farms and environmental parameters, relative to non-dairy dry-stock farms; CAH, PFI and NCH refer to the Crop & Animal Husbandry, Physical Farm Infrastructure and Natural & Cultural Heritage management dimensions of agri-environment identified in Fig. 5, respectively.