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Mammals and agri-environment schemes: hare haven or pest paradise?

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Summary

1. Agri-environment schemes (AESs) are designed to create landscape-scale improvements in biodiversity. While the specific aims of AESs do not always include the enhancement of species of conservation concern, associated conservation strategies, such as the UK Biodiversity Action Plan, often rest on the assumption that AESs enhance environmental conditions and thereby improve the conservation status of target species. However, there is little evidence for the general efficacy of AESs in this respect.
2. To evaluate the effects of the Environmentally Sensitive Area (ESA) scheme, a widespread AES in Northern Ireland, a spotlight survey of the relative abundance of three mammal species, Irish hare *Lepus timidus hibernicus*, European rabbit *Oryctolagus cuniculus* and red fox *Vulpes vulpes*, was conducted. Of these, the Irish hare is a priority species for conservation action and the focus of a species action plan, while rabbit and fox are commonly considered agricultural pests. The effects of ESA designation and habitat on each species were assessed at 150 ESA and 50 non-ESA sites, matched for landscape characteristics.
3. The ESA scheme had no demonstrable effect on the abundance of Irish hares, and this agri-environment scheme did not target the landscape and habitat variables associated with hares.
4. In contrast, the abundance of rabbits and foxes was significantly greater within ESAs than the wider countryside. Agricultural factors such as reduced livestock stocking density, reduced overgrazing and field boundary enhancements may create more favourable conditions for both species. Aside from the implications for farm economics, the proliferation of rabbit populations within conservation areas may raise issues concerning the grazing of important plant communities, while increases in fox populations may adversely affect ground-nesting birds and other animal species of conservation concern.
5. *Synthesis and applications*. The abundance of rabbits and foxes corroborates recent work that suggests AESs may benefit common species but can not be relied upon to encourage rarer species. The Irish hare species action plan relies on agri-environment schemes to enhance the species' status and realize the target of increasing the hare population by 2010 by promoting suitable habitat. However, the ESA scheme is unlikely to help in achieving these objectives. Targeted and evidence-based agri-environment prescriptions are clearly required in order to ensure the realization of species-specific conservation targets.

Key-words: agriculture, environmentally sensitive areas, grassland, *Lepus timidus hibernicus*, species action plan, spotlight surveys

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Introduction

Agricultural intensification is widely accepted to be the cause of the decline of many wildlife populations (Pain & Pienkowski 1997; Krebs *et al*. 1999; Donald, Green & Heath 2001; Preston *et al*. 2002), including hares (Smith *et al*. 2004; Smith, Vaughan-Jennings & Harris 2005). Reforms of the Common Agricultural Policy to reduce subsidies and concerns over widespread loss of biodiversity initiated European regulations (EEC 797/85 and 2078/92; EEC 1985, 1992) leading to the introduction of agri-environment policies during the late 1980s. Agri-environment schemes (AESs) aim to reduce the environmental impact of agriculture by paying farmers to alter their management practices in an attempt to benefit biodiversity. Approximately £16·6 billion was invested in AESs across Europe during 1999–2003 (Kleijn & Sutherland 2003), representing considerable public expenditure.

Despite numerous evaluations (Smith 1997; Milsom *et al*. 1998; Hopkins *et al*. 1999; Bengtsson, Ahnstrom & Weibull 2005; Feehan, Gillmor & Culleton 2005), evidence of the positive changes in biodiversity that AESs promised remains scant (Kleijn *et al*. 2001, 2006; Kleijn & Sutherland 2003; Berendse *et al*. 2004). Of 62 studies examined by Kleijn & Sutherland (2003), most concentrated on the diversity and abundance of flora (32%), arthropods (32%) and birds (42%). One looked at the response of a mammal: Tapper (2001) demonstrated that, 3 years after implementation, brown hare *Lepus europaeus* Pallas populations had shown little response to the arable stewardship scheme in England. However, Browne & Aebischer (2003) later showed that, given sufficient time (5 years), brown hares responded positively to AESs in areas where arable farmland predominated, demonstrating the need to allow time for schemes to mature. Kleijn & Sutherland (2003) concluded that most evaluation studies were insufficiently rigorous to assess scheme effectiveness, because of weak design and poor analysis.

The Environmentally Sensitive Area (ESA) scheme is the UK's second most extensive agri-environment scheme, accounting for 35% of budget and 26% of land under AES prescriptions (DEFRA 2005). Some of the main aims of the ESA scheme are to reduce livestock stocking densities to prevent overgrazing, manage nutrient systems and retain and enhance existing field boundaries such as hedgerows and banks. We evaluated the effect of ESA management on three mammal species.

Of particular interest was the Irish hare *Lepus timidus hibernicus* Bell, an endemic subspecies of the mountain hare *Lepus timidus* L. that has recently attracted conservation concern following a long-term population decline (Dingerkus & Montgomery 2002). The Irish hare species action plan (SAP) in Northern Ireland (EHS 2000) forms part of the UK Biodiversity Action Plan (Anonymous 1995) and has recently been extended to the Republic of Ireland to incorporate the entire subspecies' range (EHS 2005). The plan's main objectives are to maintain the existing species range and demonstrate a population increase by 2010 (aimed at doubling spring numbers) by maintaining and increasing the area of suitable habitat. The habitat preferences of Irish hares are not well known and the species can occur in all habitats from mountain summits to coastal saltmarsh (Walker & Fairley 1968; Wolfe, Whelan & Hayden 1996; Hayden & Harrington 2000). None the less, the action plan states that 'agri-environment schemes such as Environmentally Sensitive Areas (ESAs) ... can make an important contribution to the maintenance and enhancement of suitable hare habitat'. Agri-environment schemes have been identified as central to achieving the Irish hare SAP targets (EHS 2000, 2005).

We also examined two common species that are not of conservation interest but might influence hare distribution and abundance: the European rabbit *Oryctolagus cuniculus* L. and red fox *Vulpes vulpes* L. Rabbits are selectively grazing lagomorphs and may compete with hares (Homolka 1987; Chapius 1990). They represent an opportunity to assess the impact of ESA on a species known for its ubiquity and high population densities. Rabbits are grassland species (Flux & Angermann 1990) and are generally associated with lowland dry sites with numerous habitat boundaries (Trout *et al*. 2000). The fox presents an opportunity to contrast the effects of ESAs on top consumers, as their diet in Northern Ireland includes both hares and rabbits (Looney 2001; O'Mahony 2003). Foxes are relatively unspecialized and have few specific habitat requirements. However, they are associated with fragmentary habitat structure that provides a diversity of habitat edges for hunting and foraging opportunities (Corbet & Harris 1996). Both rabbits and foxes are widely considered agricultural pests (Corbet & Harris 1996).

Northern Ireland was among the first countries to implement AESs; the ESA scheme was initiated in 1988 and encompasses 21% of the land area. Not all farmers within designated ESAs participate, but uptake is generally high and more than 65% of eligible land is included in the scheme (Cameron *et al*. 2004). During 2005, £5–7 million was invested in ESAs in Northern Ireland, accounting for approximately half of the Northern Ireland AES budget (DEFRA 2005). ESAs appear to have been successful in maintaining floral and invertebrate diversity relative to continuing losses in non-agreement areas (Cameron *et al*. 2004). However, marked improvements in plant and invertebrate biodiversity have not been realized and all other taxa, including mammals, remain data deficient.

We hypothesized that, after 17 years of AES management, some response would be evident in the populations of the three farmland mammal species. More specifically, we contended that the three species should be more abundant in areas subject to ESA prescriptions than in matched non-ESAs in the wider countryside.

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Materials and methods

STUDY AREAS

Northern Ireland's five ESA regions (Fig. 1a) are representative of the eight land class groups from drumlin farmland to mountain summit (Murray, McCann & Cooper 1992). The Mourne and Slieve Croob ESA, established in 1988, was implemented to protect highland landscapes and the surrounding lowland and coastal farmland. Slieve Gullion ESA, established in 1994, comprises predominantly marginal, settled uplands. the Antrim Coast, Glens and Rathlin Island ESA and Sperrins ESA, established in 1989 and 1994, respectively, are extensively farmed uplands with widespread blanket bog and moorland. The West Fermanagh and Erne Lakelands ESA, established in 1993, is mostly lowland semi-natural wet grasslands, interspersed by inland waterways and riparian habitats.

A sample of 150 1-km^2 ESA survey squares was randomly selected in proportion to the area of each ESA. A sample of 50 non-ESA squares was matched for the frequency of land class, altitude, category of bisecting road and distance from ESA boundary, as represented in the ESA sample. Therefore, while they were outside of the area under prescribed management, non-ESA sites were in the same locality and were judged comparable in all respects apart from their lack of prescriptions.

As time from scheme inception is important (Browne & Aebischer 2003), it would have been ideal to enter time from entry as a covariate for each site. Within each 1-km^2 square, farmers may have joined at different times or may have fields on the same farm at different stages of maturation. Equally, some land may formerly have been part of the ESA but been withdrawn.

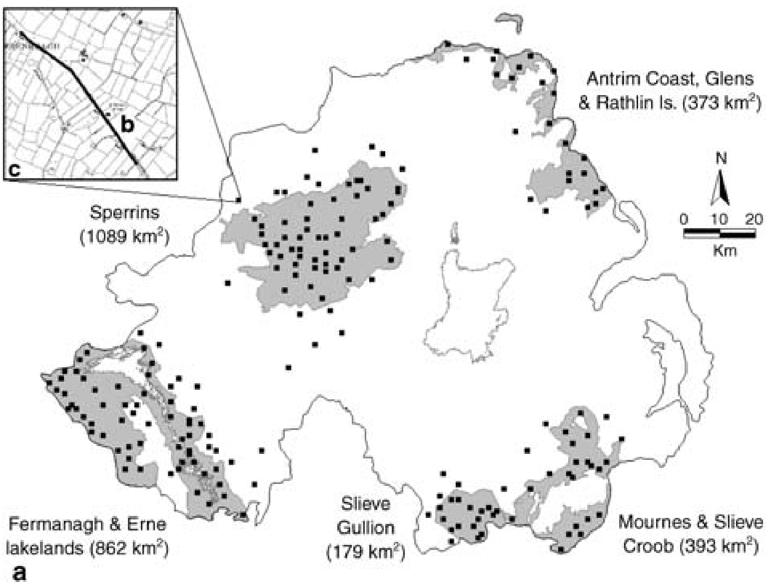

Fig. 1. (a) Northern Ireland's five ESA regions (shaded grey) with the area of each in parentheses and the locations of 200 associated survey sites (black squares). (b) A 1-km^2 survey square. (c) A 1-km line transect.

Therefore, we could not generate meaningful values for time from inception for whole squares. However, all land in this study had gained entry to the ESA schemes 10–17 years prior to the survey.

FIELD SURVEYS

Night-driven, spotlight surveys are a favoured method of estimating relative abundance of mammals because of their efficiency, repeatability and lack of interference with the subject (Langbein *et al*. 1999). Surveys were conducted during mid-winter, when ground vegetation was minimal, maximizing the detectability of animals. A 2-million candlepower spotlight was used from a platform on a pick-up truck elevating the observer's head height > 2 m above ground level, i.e. above most hedgerows. A 1-km line transect (Fig. 1b), following a minor road bisecting each survey square (Fig. 1c), was driven at 15–25 km h^{-1}. Both sides of the road were swept twice with the light and care was taken to cover ground behind obstacles. Relative abundance (animals km^{-1}) was recorded for hares, rabbits and foxes. Surveys were not conducted until 1 h after sunset and not less than 5 h prior to sunrise. Records for the illumination of the moon were obtained from the US Naval Observatory (http://aa.usno.navy.mil/data/docs/MoonFraction.html, accessed 1 June 2007).

HABITAT DATA

ArcView GIS 3·3 was used to compute landscape and habitat variables using the UK Land Cover Map 2000 (Fuller *et al*. 2002; Table 1). Spatial Analyst 2·0 and Patch Analyst 3·1 extensions were used to describe landscape metrics, including habitat patch edge density and Shannon's diversity index (Elkie, Rempel & Carr 1999). We calculated the distance of each survey square from the closest ESA boundary, as sites at the centre are surrounded by greater areas under prescription than those near the edge. Squares within ESAs were given positive distance values and those outside ESAs boundaries were given negative values.

STATISTICAL ANALYSES

Variance in the relative abundance of each species was investigated by fitting a generalized linear model using ESA variables, habitat variables and any parameters that may have confounded their effects (Table 1), assuming a Poisson error distribution and a logarithmic link function. Predictor variables were chosen intuitively based on landscape characteristics that were likely to influence the patterns of abundance of grassland species (e.g. area of improved grassland). Percentage data on the prevalence of habitat types were arcsine square-root transformed (Hosmer & Lemeshow 2000). All possible model permutations were created and ranked using the Akaike Information Criterion (AIC; Akaike 1983). As the primary focus was to investigate the

Table 1. Explanatory variables used to predict hare, rabbit and fox abundance. Percentage data were arcsine square-root transformed prior to analysis. Habitat variables were obtained from UK Land Cover Map 2000 database (Fuller *et al*. 2002)

Variable category	Variable name	Unit	Description
Species	Hare	Count	Relative abundance of hares
	Rabbit	Count	Relative abundance of rabbits
	Fox	Count	Relative abundance of foxes
Agri-environment designation	ESA	Categorical	ESA designated or non-ESA designated
	ESA uptake	Percentage (%)	Area under active conservation prescriptions for ≥ 10 years
	ESA distance	Kilometres (km)	Shortest perpendicular distance of the centre of each survey square from the ESA-designated boundary (km). Survey squares within ESAs were given positive values (+) and those beyond ESAs areas were given negative values (–)
Possible confounding factors	Region	Categorical	Antrim, Fermanagh, Gullion, Mourne or Sperrins
	Time	Minutes (min)	The number of minutes past sunset that the site was surveyed
	% moon	Percentage (%)	Illumination of the moon's disc
Habitat	Improved grassland	Percentage (%)	Area of high production swards dominated by agricultural grass species, e.g. *Lolium perenne*, that receive fertilizer annually
	Neutral grassland	Percentage (%)	Area of low production semi-natural swards (pH 5·5–7) that are not reseeded or fertilized. Management may obscure distinction from improved grassland
	Acid grassland	Percentage (%)	Area of low production semi-natural swards (pH < 5·5) that are not reseeded or fertilized
	Calcareous grassland	Percentage (%)	Area of low production semi-natural swards (pH > 7) that are not reseeded or fertilized
	Arable	Percentage (%)	Area of annual crops, recent leys, stubble fields and ploughed land
	Scrub	Percentage (%)	Area of semi-dry dense *Juncus* and gorse-dominated (> 25% of plant cover) grass often on ericaceous soils
	Habitat patch edge density	Kilometres (km)	Length of habitat patch perimeter within 1 km^2
	Shannon's diversity	Index	Measure of habitat patch diversity

explanatory power of the independent variables rather than building a predictive model, interaction terms were omitted. Furthermore, their inclusion would have limited resolution for some variables if the data were further divided with respect to nominal factors.

The Akaike weight (w_i) of each model was calculated within the top set of n models, where the value of delta AIC(Δ_i) ≤ 2 units (Burnham & Anderson 2002). The Akaike weight of each model is the relative likelihood of that model being the best within a set of n models. A model deviance ratio (MDR) test was used to assess the fit of the single best model assuming an F distribution. To calculate the relative importance of each variable relative to all other variables, the $\sum w_i$ of all models within the top set of models that contained the variable of interest was calculated and the variables ranked by $\sum w_i$ (McAlpine *et al*. 2006). The larger the value of $\sum w_i$ (which varies between 0 and 1), the more important the variable. Multimodel inference was used to determine the averaged effect size (β coefficient) of each variable across the top set of models (Burnham & Anderson 2002). To allow the direct comparison of regression coefficients, variables were standardized to have a $\bar{x} = 0$ and a $\sigma = 1$ prior to analysis (Schmidt *et al*. 2004). Variables that had equal $\sum w_i$ values were ranked in order of the magnitude of their model-averaged regression coefficients. All statistical analyses were performed using GenStat v6.

Results

A total of 89 Irish hares, 375 rabbits and 68 foxes was observed in 42 (21%), 66 (33%) and 48 (24%) of the 200 sites, respectively. A set of competing models was produced for relative abundance of each species with a single model predominant in each set (hares, $MDR_{10,189} = 7{\cdot}28$, $P < 0{\cdot}001$; rabbits, $MDR_{16,183} = 23{\cdot}47$, $P < 0{\cdot}001$; foxes, $MDR_{12,187} = 4{\cdot}08$, $P < 0{\cdot}001$). Illumination of the moon negatively affected observations of both lagomorphs. Numbers of hares and foxes seen decreased with time after sunset, while rabbit observations increased with time after sunset (Fig. 2). The abundance of all three mammal species differed among regions (Figs 2 and 3).

Neither ESA designation, local scheme uptake or distance from the nearest ESA boundary featured in the best model of hare abundance (Fig. 2a). There was no apparent difference in hare abundance between ESA and non-ESAs (Fig. 4). In contrast, ESA designation, scheme uptake and distance to the nearest ESA

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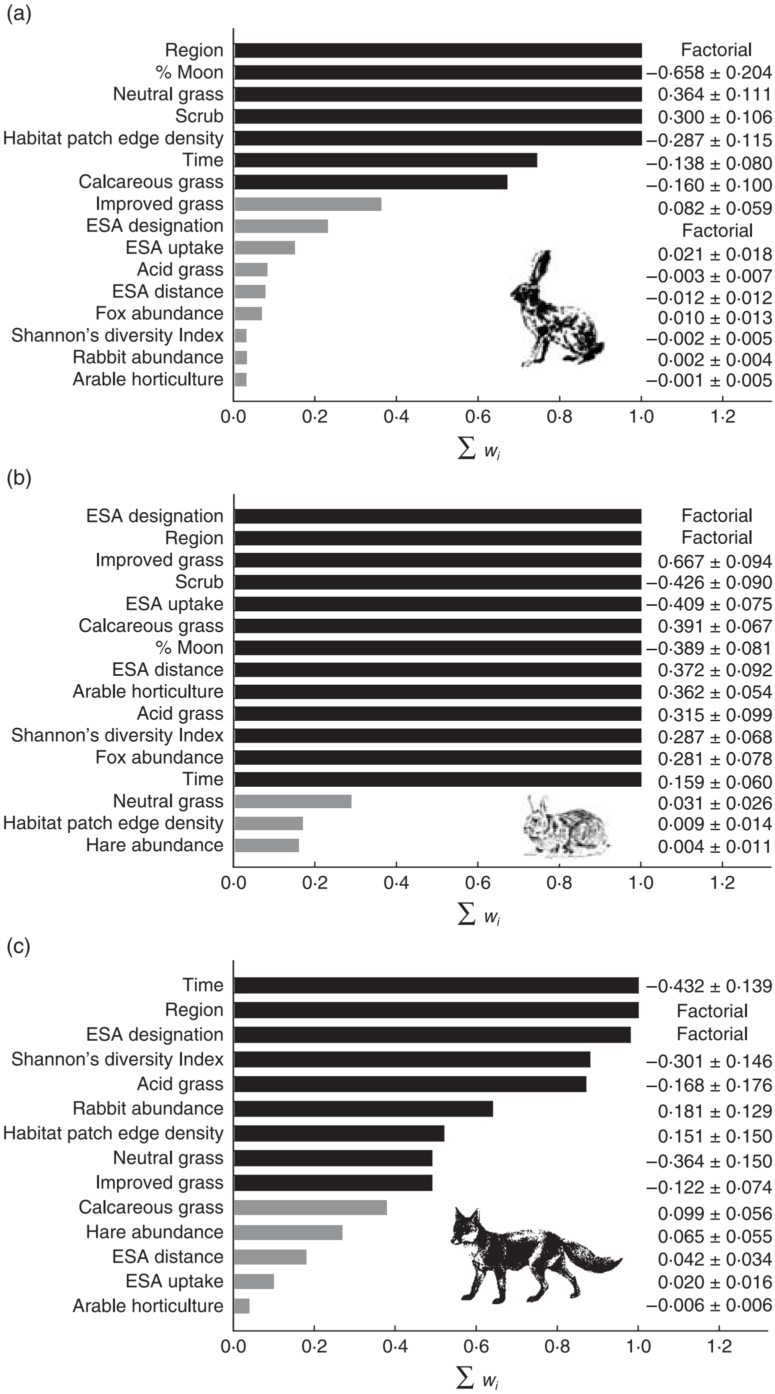

Fig. 2. Relative importance of factors in explaining variation in the relative abundance of (a) Irish hares, (b) rabbits and (c) foxes. Variables are ranked in order of the sum of their Akaike weights ($\sum w_i$) within the top set of models, i.e. models with $\Delta AIC \leq 2$. Black bars indicate those variables that were retained in the best single approximating model (i.e. that with the lowest AIC value) and grey bars indicate variables included in all other models within the top set. Notation to the right indicates the strength of the slopes for each standardized covariate.

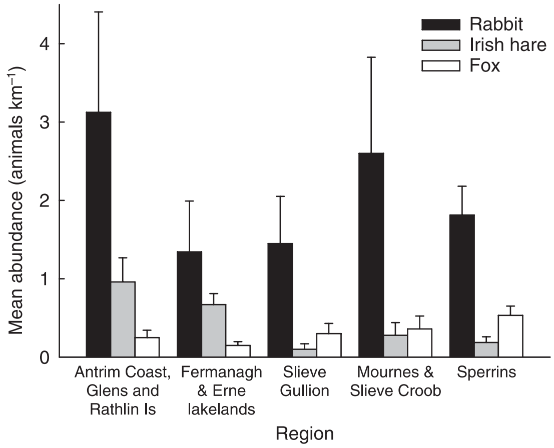

Fig. 3. Mean abundance ± SE of three mammal species across five regions in Northern Ireland during 2005.

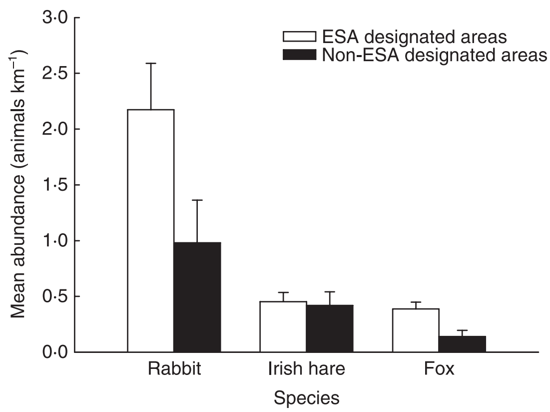

Fig. 4. Mean abundance ± SE. of three mammal species within ESA and the wider countryside in Northern Ireland during 2005.

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boundary were among the most important variables determining rabbit abundance and were represented in all models in the top set (Fig. 2b). Rabbits were more abundant in ESAs than in non-ESAs (Fig. 4), with abundance increasing towards the centre of designated areas but decreasing with degree of local uptake. ESA designation also had one of the greatest effects on fox abundance (Fig. 2c). Foxes were more abundant in ESAs than in non-ESAs (Fig. 4), but uptake and distance to the nearest ESA boundary had little effect.

Irish hares were positively associated with neutral grassland and scrub and negatively with habitat patch edge density and calcareous grassland (Fig. 2a). Rabbits were negatively associated with scrub but positively with improved, acid and calcareous grasslands, arable horticulture, Shannon's diversity index and fox abundance (Fig. 2b). Foxes were negatively associated with Shannon's diversity index and improved, acid and neutral grasslands and positively affected by rabbit abundance and habitat patch edge density (Fig. 2c).

Discussion

For rabbits and foxes, our results supported the hypothesis that ESA management enhances their abundance. This was not the case for hares. Biodiversity has been shown to have a positive association with the presence of apex predators (Schmitz 2003; Sergio, Marchesi & Pedrini 2004; Sergio, Newton & Marchesi 2005). Therefore, the positive response shown by foxes, a top carnivore, might be taken as an indication that AES management can enhance biodiversity. However, our study adds to mounting evidence that AESs may benefit only common species, such as rabbits and foxes, rather than those of conservation interest, such as hares (Kleijn *et al*. 2006). European farmland, because of its anthropogenic character, is almost exclusively inhabited by relatively common, generalist species (Kleijn *et al*. 1998, 2001) and so AESs benefit these species and appear to have limited utility for high conservation priorities (Kleijn *et al*. 2006).

The central aim of UK AESs is to increase biodiversity in general. If the intensity of modern farming practises affects rare species more than common species (Tucker & Heath 1994), failures to benefit species of conservation concern may be viewed as a general failure of AESs to increase biodiversity. Further, benefits to agricultural pest species may be a disincentive for AES uptake. Grazing by herbivores such as rabbits may damage rare plant species (Olff & Ritchie 1998), while foxes may impact other animal species of conservation priority, such as ground nesting birds (O'Mahony 2003).

Agricultural intensification and habitat destruction is widely accepted as the cause of European hare population declines (Smith *et al*. 2004; Smith, Vaughan-Jennings & Harris 2005). The mountain hare is a highly adaptable species and occurs in many habitats throughout its Palaearctic range (Flux & Angermann 1990). The Irish subspecies exhibits this adaptability perhaps best of all as, in the absence of other hare species, it inhabits almost all available habitats, from mountain summits to coastal salt marshes (Walker & Fairley 1968; Wolfe, Whelan & Hayden 1996; Hayden & Harrington 2000). The ecological plasticity of the Irish hare may mean that it does just as well in areas under conventional farmland management as those under conservation prescriptions. Thus, no effect of AES management on the abundance of Irish hares has been found. We demonstrate a strong positive influence of both neutral grasslands and scrub dominated by *Juncus* spp. and gorse *Ulex europaeus* L. Our results corroborate those of Dingerkus & Montgomery (2002), who suggested that Irish hares may select *Juncus*-dominated semi-natural grasslands. Neutral grasslands are usually more intensively managed than either acid or calcareous grasslands. The grass species that are common in neutral grassland swards (JNCC 2004) are also common in the diet of Irish hares (Walker & Fairley 1968; Tangney, Fairley & O'Donnell 1995; Jeffery 1996; Dingerkus & Montgomery 2001; Strevens & Rochford 2004). The importance of scrub to hare abundance may suggest that they select habitats offering both food and shelter (Hiltunen, Kauhala & Linden 2004; Smith, Vaughan-Jennings & Harris 2005), while use of radio-telemetry has demonstrated that between active nocturnal and inactive diurnal periods hares move between such habitats (Tapper & Barnes 1986). Consequently, habitat heterogeneity is important to hares living in pastoral systems (Smith, Vaughan-Jennings & Harris 2005).

In contrast to their lack of effect on hares, ESAs appeared to have a major positive effect on rabbit abundance. Prevention of overgrazing by restricting livestock density and enhanced grazing management are central to ESA management and are likely to reduce competition between livestock and rabbits. Trout *et al*. (2000) found that rabbit abundance was positively affected by the presence and density of habitat boundaries. Rabbits usually excavate warrens at field boundaries. Enhanced boundary management and an increase in the number and length of boundaries has been recorded in ESAs in Northern Ireland (Cameron *et al*. 2004). It seems likely that this intervention relative to ongoing boundary removal in the wider countryside (Cooper, Murray & McCann 1997) may have resulted in a relative increase in the availability of warren sites in ESAs.

Rabbit abundance increased with internal distance and decreased with external distance from ESA boundaries, suggesting that rabbit populations may respond to cumulative landscape-scale changes. This is an important point when considering the negative relationship between rabbit abundance and the local level of ESA scheme uptake. It is unlikely that many farmers manage their entire farms under conservation prescriptions; rather, only a few low-productivity fields may be invested in the scheme. Rabbits were positively associated with improved grasslands and arable horticulture, suggesting that they may benefit from high productivity. While intuitively this may suggest that they favour the wider countryside, it may be that landscape-scale benefits increase boundaries and the availability of warren sites.

Fewer records of both lagomorph species were made close to a full moon, suggesting that, as prey species, lagomorphs may change their behaviour during different phases of the moon to avoid detection by nocturnal predators (Daly *et al*. 1991; Gilbert & Boutin 1991). All of the species examined had some association with time past sunset. Both these factors may be important in planning future monitoring surveys.

Fox abundance was positively associated with habitat patch edge density and negatively associated with Shannon's diversity index. In farmed systems, patch edges are analogous to field boundaries as fields of differing type are usually delineated by hedgerows or fences. Foxes forage along such boundaries, which can account for up to 96% of the total species richness of a field (Kleijn *et al*. 2001). Therefore, foxes appear to be associated with relatively homogeneous environments with a high prevalence of linear features. Increases in field boundaries in ESAs (Cameron *et al*. 2004) will have also increased den site availability. Foxes were negatively associated with improved grasslands, which are less species rich and, thus, may provide poorer hunting and foraging opportunities. In this study, fox abundance

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and rabbit abundance were closely related. It seems likely that, in addition to habitat factors influencing fox abundance, the effects of ESA management on their main prey (Looney 2001; O'Mahony 2003) have contributed to the association of fox abundance with ESAs.

We have added to evidence that AES prescriptions bring greater benefits to species that are already common in agrarian systems (specifically those that tend to be generalist and tolerant of human alteration of the environment) than to species of conservation concern. The benefits of AESs to pests have the potential to create further problems for farmers and conservationists. AES measures designed to improve biodiversity in general should not be relied upon by specific conservation strategies, such as SAPs, to improve the status of species of conservation concern. None the less, it has been shown that schemes can be successfully tailored to meet the needs of particular species (Evans 1997; Peach *et al*. 2001) provided their specific requirements are taken into account (Bayliss, Simonite & Thompson 2005). For example, amendments to the Countryside Stewardship Scheme in Devon, UK, targeted at the cirl bunting *Emberiza cirlus* L. boosted local populations by 83% in just 6 years (Peach *et al*. 2001).

If agri-environment schemes are to deliver the increases in abundance required by the Irish hare SAP by 2010, we suggest that a specific hare measure should be developed and implemented. Any measure should aim to include strategies that increase the availability of adjacent patches of high-quality neutral grassland with *Juncus* or gorse-dominated scrub. Smith *et al*. (2004) also suggested that within-field habitat structural heterogeneity is important for hares and that proliferation of a patchwork quilt effect in habitat management is likely to benefit not only hares but farmland biodiversity in general. In order to be cost-effective, such a measure should undergo field trials to test its efficacy, prior to widespread implementation.

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