TEAGASC Biodiversity Conference

CONSERVING FARMLAND BIODIVERSITY

Lessons learned & future prospects

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Teagasc Biodiversity Conference

Conserving
Farmland
Biodiversity

Lessons learned & future prospects

Edited by Daire Ó hUallacháin and John Finn

A Chara,

On behalf of the Conference Committee, I would like to extend a warm welcome to everyone attending this Teagasc conference ‘Conserving Farmland Biodiversity: lessons learned and future prospects’.

For the European Union and its Member States, biodiversity continues to be a key environmental objective. The EU target to halt biodiversity loss by 2010 has not been met, and the EU is strengthening its policy framework and commitment to halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as possible. Thus, the success of biodiversity measures (in a variety of policies and sectors) will increasingly be judged by the extent to which they halt the loss of biodiversity and halt the degradation of related ecosystem services. In the context of the agriculture sector, these policy commitments are likely to be strengthened in the post-2013 CAP, although there remains considerable uncertainty about the specific policy instruments, measures and especially funding that will be used to achieve them.

Naturally, these European-scale policy commitments will be translated into national commitments. In its recent Government strategy for agriculture, the Food Harvest 2020 report outlines a vision for the agri-food sector in which the conservation of biodiversity appears as one of the priority environmental goals. The updated Irish Biodiversity Action Plan 2010-2015 also comes into effect this year and, in addition to the protection of designated areas (and other targets), clearly highlights the importance of biodiversity conservation in the wider countryside, most of which is farmland.

The problem with the wider countryside is that it is so wide! In addition, it is highly varied with biodiversity being distributed in a very uneven way. Some farmland areas contain a level of biodiversity that rivals the quality of that in Natura 2000 sites and other designated areas; others support a lower (but still valued) level of biodiversity that persists within pockets of semi-natural habitats that interact with and are located within a wider matrix of more intensively-managed farmland. This variation generates a number of questions: How effective have previous conservation initiatives been in conserving farmland biodiversity, and what are the drivers of success or failure? What relative emphasis will policies place on the conservation of designated sites and the wider countryside, and the different objectives of habitat protection, restoration and creation? Do we have sufficient information on the distribution of biodiversity (and its threats) across the wider countryside and, if not, how best to get it? How can farmers appropriately manage specific habitats and species whilst producing food and making a livelihood? What is the ‘best’ allocation of limited budgets for conservation between higher- and lower-quality habitats in the wider countryside? These questions are deceptively simple, but the answers are certainly not.

We hope that this conference contributes to progressing efforts toward addressing these questions, and look forward to the conference being as enjoyable as it will be informative.

Dr John Finn

On behalf of the Conference Committee:
Dr John Finn (Chair)
Dr Daire Ó hUallacháin
Mr Pat Murphy
Ms Catherine Keena
Mr Stuart Green

Wednesday 25th May

09.00-10.00 Conference registration

10.00-11.10 Session 1

10.00	Dr Noel Culleton	Introduction and welcome
10.10	**Keynote: Dr David Baldock**	
	Environmental public goods and the post-2013 CAP	
10.50	A. Bleasdale	Agri-environmental policy perspectives of the National Parks and Wildlife Service

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11.10-11.40 Coffee (poster session)

11.40-13.20 Session 2

11.40	**Keynote: Prof Nick Sotherton**	
	Arable management options in the UK agri-environment scheme: the research behind the options	
12.20	M. Jebb	Important areas of plant diversity outside of designated areas: where are they?
12.40	D. Doody	A critical source area approach to the development of supplementary measures for high-status waterbodies
13.00	Panel discussion	

13.20-14.20 Lunch

14.20-15.30 Session 3

14.20	**Keynote: Dr Sharon Parr**	
	The Burren Farming for Conservation Programme: lessons learned and progress to date	
15.00	Three minute poster presentations	

15.30-15.50 Coffee (poster session)

15.50-17.30 Session 4

15.50	**Keynote: Dr Guy Beaufoy**	
	HNV farming policy – progress to-date & future challenges	
16.30	J. Finn	The environmental impact of REPS: lessons learned & future prospects
16.50	N. Smyth	Invasive species in Ireland
17.10	Prof. Gerry Boyle	Summary and panel discussion

20.00 Conference dinner

Thursday 26th May

09.00-10.40	Session 5		
	09.00	**Keynote: Dr Simon Mortimer**	
		Biodiversity options in agri-environment schemes for more intensive farmers	
	09.40	R. Fritch	Improving floral and invertebrate diversity in grassland field margins
	10.00	C. Sullivan	What is the conservation potential of grasslands on lowland farms?
	10.20	J. Martin	High nature value meadows: results from a national grassland survey
10.40-11.00	Coffee (poster session)		
11.00-13.00	Session 6		
	11.00	**Keynote: Mr Daniel Fuchs**	
		Identification and distribution of HNV farmland in Germany	
	11.40	H. Sheridan	Habitats in the Irish farmed landscape
	12.00	J. Stout	Pollinators and pollination networks in Irish farmland: implications for conservation of pollination services
	12.20	J. McAdam	Monitoring previous agri-environment schemes in Northern Ireland- a review
	12.40	Panel discussion	
13.00-14.00	Lunch		
14.00-15.10	Session 7		
	14.00	**Keynote: Dr Evelyn Moorkens**	
		Evidence-based selection of catchments and measures for conservation and recovery of freshwater pearl mussel population in Ireland	
	14.40	Three minute poster presentations	
15.10-15.30	Coffee (poster session)		
15.30-16.30	Session 8		
	15.30	K. Buckley	The role of habitat creation in the recovery of the Irish grey partridge *Perdix perdix*
	15.50	A. Copland	REPS and farmland bird populations: results and recommendations from the Farmland Birds Project
	16.10	Panel discussion	
	16.30	Close of conference	

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Oral Presentations

Agri-environmental policy perspectives of the National Parks and Wildlife Service

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Introduction

Ireland has significant obligations under the Habitats and Birds Directives which require us

- to designate SACs and SPAs (the Natura 2000 network),
- to maintain, and in many cases improve, the status and condition of habitats and species in designated areas (which will require measures inside, and sometimes outside, these sites),
- to protect national populations of naturally occurring bird species (in the wider countryside).

As the designation process is substantially completed, the focus is now on the protection and management of sites, habitats and species. As most of the lands of the State are managed through farming, agricultural policy, schemes and initiatives are central to the conservation of farmland biodiversity.

Financial supports for biodiversity-focused farming are critical, including, but not confined to, agri-environmental schemes under Pillar II of the of the Common Agricultural Policy (CAP). In addition, direct (Pillar I) supports to farmers are conditional on adherence to the Birds and Habitats Directives, under cross compliance. Appropriate targeting of future funding, provided through the national Rural Development Programme 2014-20 (RDP), is critical if farmland biodiversity is to be protected in designated areas and in the wider countryside.

Policy Drivers

Ireland's performance in relation to the appropriate management of Natura 2000 sites has been assessed by the EU through a number of European Court of Justice infringement cases. To date, it is clear that agricultural supports have not always ensured adequate protection of biodiversity. Ireland must report to the EU in 2013 under Article 17 of the Habitats Directive on the "conservation status" for a suite of habitats (and species supported by these habitats). This report is likely to indicate that farming has a significant role to play in delivering "favourable conservation status". The challenge is to ensure that agriculture and conservation policies are sufficiently aligned to achieve this goal.

In the coming years, Ireland will be expected to address the following issues:

- management of freshwater systems,
- conservation of the freshwater pearl mussel,
- management of overgrazed (and undergrazed) uplands,
- conservation of birds in serious decline, including species associated with agriculture such as the corncrake, breeding waders, partridge, barn owl etc.,
- protection and restoration of bogs and other wetlands.

As many of the above issues are influenced by farming systems and supports, it is imperative that all policies are "Natura 2000 proofed", to ensure appropriate management of this biodiversity resource. This will require the tailoring of direct supports <u>and</u> agri-environment schemes (and measures) to provide the best solutions to meet Ireland's obligations.

Research Gaps

The Irish National Platform for Biodiversity Research (NPBR) is a forum for policy makers, scientists and other interested stakeholders involved in the field of biodiversity research. The platform is run under the auspices of NPWS and the Environmental Protection Agency (EPA) and is administered by a secretariat. The aim of the platform is to facilitate the targeting and co-ordination of biodiversity research in Ireland to meet the current and future policy needs. To this end, a cross-sectoral Agriculture Working Group was established to identify key research questions. In synopsis, the emerging research gaps that need to be urgently addressed are as follows (NPBR, 2011):

- national inventories of species and habitats supported by agricultural systems, including remedial actions to protect them,
- an investigation of the effect of various management techniques in a range of farmed habitats,

- an investigation of the impacts of alternative land-uses in marginal agricultural areas,
- guidance on the future grazing of extensive upland habitats (including commonages),
- a description of the agricultural systems that support High Nature Value (HNV) farmland,
- an assessment of the socio-economics of farming for conservation,
- a description of the ecosystem services of different farming systems (with different associated biodiversity attributes),
- development of tailored, tested prescriptions for roll-out through AE schemes,
- development of indicators for monitoring at farm and scheme level,
- the establishment of long-term study sites.

Discussion

Article 8 of the Habitats Directive provides for funding arrangements towards the cost of managing priority species and habitats. The EU Commission takes the view that funds are made available through, and should be sourced from, the existing instruments, in particular the CAP supports.

A substantial part of funding under the current RDP is earmarked for spending related to the environment, in particular in the areas of biodiversity, water protection and climate change mitigation. From an NPWS perspective, the implementation of Pillar I and Pillar II payments to farmers have not, to date, always ensured that farmland biodiversity has been adequately protected.

An appropriate allocation of CAP funding in the next cycle (2014-2020) is critical to delivery of some of Ireland's obligations under the Habitats and Birds Directives. NPWS supports the continuation of agri-environment supports from Pillar II, but greater targeting of these supports, to meet some of the challenges identified previously, is required. This will necessitate cross-departmental co-operation between policy makers.

The HNV farmland concept is one that should be advanced through the CAP and the national RDP. Low-intensity, extensive farming allows biodiversity to flourish and can result in HNV type farmland outside of designated areas (Smith *et al.*, 2011). Through the proposed "greening" of Pillar I, NPWS would like to see direct financial supports in place that would incentivise the production of "biodiversity added value" (i.e. HNV farmland).

The Burren Farming for Conservation Programme (BFCP) model shows that, with a tailored and tested prescription and with the close co-operation of departments and the farming community, real advances can be made in the area of biodiversity protection and enhancement (Dunford, 2011). This model is admired throughout Europe, has been shown to work, meets all the requirements of HNV farmland and will contribute towards favourable conservation status within SACs. There are lessons to be learned here that could be usefully applied in other parts of the country.

Conclusion

It is imperative that payments and supports to farmers are targeted to address issues of EU and national concern, including the protection of Natura 2000 sites and wider biodiversity and ecosystem services.

Acknowledgements

We are grateful to Louise Scally (BEC Consultants Ltd, Secretariat of the NPBR) and the members of the NPBR Agriculture Working Group, which included representatives from the EPA, NPWS, DAFF, the Heritage Council, Teagasc, UCD and the Sligo Institute of Technology.

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Arable management options in the UK Agri-environment scheme: the research behind the options

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Introduction

The Game & Wildlife Conservation Trust's (GWCT) involvement in agroecology dates back to the 1930s when concerns for the demise of the population status of the UK's most abundant gamebird, the grey partridge (*Perdix perdix*), became apparent. Over the last 40 years, this species has declined by 88% (Marchant *et al*., 1990) and reduced its range by 19% (Gibbons *et al*., 1993). Of all the farmland birds, grey partridges are the species most closely associated with the farmed landscape and have therefore become the iconic farmland bird. Because of our interest in grey partridges, we were acutely aware of the plight of farmland wildlife and the problems caused by intensive agriculture decades before the rest of the UK conservation community woke up to this problem and before the Biodiversity Action Plan process was initiated in the mid 1990s. To this day, the grey partridge remains the best studied farmland bird.

By this time we had already conducted the large-scale, multi-year experiments to unravel the causes of decline and indicate the mitigation measures that should be taken to initiate population recovery (Sotherton, 1991; Tapper *et al.,* 1996). The majority of these mitigations involved habitat creation and management schemes to create essential nesting cover, insect-rich brood cover to feed young chicks and winter cover to provide food and shelter from weather and protected predators, especially raptors.

When agri-environment schemes (AES) were being developed, the GWCT already had a menu of management prescriptions available for incorporation into a UK AES and for immediate use. Of the 36 options available in the AES in England six were entirely developed by the GWCT and in a further 23, our research had played a major role in their scientific evaluation.

Arable Prescriptions

Such prescriptions developed by the GWCT, where the rigorous scientific evidence of efficacy is in place, are listed below. We believe that such an evidence base to support management prescriptions is an absolute prerequisite for an AES to give confidence to users and funders alike.

Conservation headlands
The use of selective pesticides, both herbicides and insecticides, along the edges of arable crops to protect the flora and the invertebrate life *per se* but that includes the chick-food insect groups that feed young birds in the first few weeks of life (Potts, 1986). Selectivity allows pernicious weeds, not tolerated by farmers, to be removed whilst leaving key insect host plants. This is a compromise that works.

Conservation headlands remaining unharvested
These are designed to feed young chicks during the summer. The unharvested, selectively sprayed cereal crop edges are left uncut to provide food and shelter into the winter.

Conservation headlands with low rates of fertiliser
These are designed to protect our rare arable flora and associated invertebrates.

Grassy margins
These are from two to six metres wide and provide nesting cover for ground-nesting birds. They also support many groups of wildlife and buffer boundary habitats and watercourses from adjacent agricultural operations.

Beetle banks
Raised grassy banks of perennial grasses sown across the centres of large arable fields to break them up, providing habitats for a more diverse invertebrate fauna and nest sites for ground-nesting birds and harvest mice.

Wild bird cover mixtures
Adapted from the concept of game cover crops, these are sown blocks of seed-bearing crops designed to feed and shelter birds in winter and especially see birds through the hungry gap.

Secrets of Success

As a Non-Government Organisation and registered charity, how have we been so influential in helping determine Agri-environment policy?

Evidence based
Evidence for efficacy of our management options was in place and published in peer-reviewed journals.

Costed
We could calculate levels of compensation needed or amounts of profits foregone.

Farmer-friendly
Our scientists have farming backgrounds so our prescriptions were workable, simple and

achievable by a farming workforce. There must be flexibility over pesticide and fertiliser use when managing land in an AES prescription. If growing a crop of kale (to produce seed to feed farmland birds in winter), applying 80kg/ha of nitrogen fertiliser produces far more seed than when applying 40kg or less. Also farmers are concerned when Agri-environment habitats revert to plots of pernicious weeds. Selective herbicides on a pre-approved list should be available to target specific weeds and give farmers confidence to **farm** for wildlife.

On-going research
Management options are constantly reviewed and renewed, especially with regard to problems identified by farmers. Regular feedback is given to the authorities to fine-tune or tweak the scheme.

Clear objectives
Specific targets of species or groups are identified and management specifically targeted at them. Such targets in arable ecosystems include grey partridge, farmland birds (species that also feed their chicks on insects), chick-food insects, annual arable wildflowers. Rarity, BAP status, knowledge of successful mitigation and ecosystem function have informed this choice.

Grassland Prescriptions
Arguably, wildlife losses in grassland farming landscapes in the UK have been as great if not greater than losses from arable land. Our limited experience of designing agri-environment prescriptions for grass farms, especially intensive dairy enterprises, is that it is difficult and expensive. All schemes need stock protection and therefore will require expensive fencing. Specific grassland measures will be described elsewhere by other key speakers but wildlife will benefit from some of the arable prescriptions transposed into a grassland landscape, if only to recreate the mixed arable/grassland farming system that would have once been more common.

The Future
Many questions have been asked about the efficacy of the agri-environment measures across Europe (Kleijn & Sutherland, 2003). We believe they are working, but they could be delivering more environmental protection and be more effective at species recovery. To do this, the next generation of schemes in the post-2013 CAP reform should:

(a) Be better targeted to species relevant to that area so, for example, measures do not support applications to support rare arable chalk floras on clay soils.
(b) Improve the payment rates for these prescriptions that are more difficult to implement to discourage farmers opting for the easy options. For example, in England, the target for permanent grass margins around arable fields has been exceeded by nearly three-fold, whereas the more taxing targets for flower-rich margins, low-input field margins and wild bird seed mixtures have all failed to reach their 2010 targets. Permanent grass margins are easy, qualify for relatively attractive rates of payment and are easy to maintain. Therefore they are over-subscribed. Also, schemes should constantly review payment rates to account for the volatility of markets and the popularity and uptake of the most valuable prescriptions.
(c) Make the prescriptions multifunctional. So far we have achieved prescriptions for six-metre wide strips of nesting cover, brood cover and winter cover. With wheat selling at €200/tonne, uptake of Agri-environment may be low and so what Agri-environment land we have will have to deliver more. Designing schemes for the management of such land will be the job of research scientists.
(d) Predator control should be an integral part of Agri-environment schemes and payments should be made available for those prepared to do it. We do not doubt that species declines were caused by a changing and increasingly intensive agriculture. Declines were not caused by predation. However, we increasingly believe that species recovery in the presence of first class habitat management may be made difficult or impossible by predation. In the UK there have been big increases in common, ubiquitous generalist predators such as foxes, crows and rats. Experimental removal of these predators during the nesting season to protect the sitting hen and their nests leads to big increases in productivity and subsequent breeding densities (Tapper *et al*., 1996; Fletcher *et al*., 2010). The same is true for the brown hare (*Lepus europaeus*) where fox control protects the leveret production extremely well (Reynolds *et al*., 2010).
(e) Management prescriptions should come in bundles. If your target is species recovery, then all the elements (not just some) of the recovery package must be chosen. “Cherry picking” some options but not others from a package should not be permitted. For example, if you chose to recover your grey partridge population you would need to opt for the provision of all the covers needed (nesting, brood, winter) and predator control.
(f) AES deliver more when the farmer has received specialist advice compared to where he/she has not.

(g) Given the scale at which farmland wildlife operates, greater consideration and support should be given to applications where farmers have worked together within a district or parish.
(h) The success of a scheme should be judged by outputs, not numbers of participants/schemes signed up. 70% of UK eligible land is in a scheme, but many species of farmland still fail to recover. Perhaps we start with the wrong question? Farmers are asked to join a scheme not "what wildlife would you like to see back on the farm"?

Conclusions

Elsewhere in this conference (see contribution from Buckley *et al*.), you will be able to learn more about the National Grey Partridge Conservation Project in County Offaly. There, using all the potential elements of an Agri-environment scheme, the NPWS and others have saved the most westerly population of grey partridges in Europe from extinction. Their success should be a model for others. In the UK, I believe Agri-environment is working but I am even more certain that we can do better.

Acknowledgments

We thank Teagasc for their invitation to attend this conference.

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Important areas of plant diversity outside of designated areas: where are they?

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Introduction

Having failed to halt biodiversity loss by 2010, the EU has strengthened its commitment to prevent further biodiversity loss by 2020. Biodiversity goals will not be met solely from protection of designated nature conservation sites, and the conservation of biodiversity on farmland outside of protected areas (e.g. Natura 2000 sites) will be critical to halting the loss of biodiversity (Jackson *et al*., 2009). Halting the loss of biodiversity will require targeting of effort towards those species most at risk of extinction or most threatened. Achieving this policy objective will require information on the spatial distribution of important areas for biodiversity that occur outside of protected areas.

Here, we describe a project that aims to resolve this knowledge gap (whilst acknowledging that there are several other projects aiming to do so also). This research is timely (and now time-critical) to provide the evidence base to anticipate and address more stringent policy requirements for environmental protection, and to facilitate the spatial targeting of agri-environment payments that will be required in the post-2013 Common Agricultural Policy, and by Ireland's National Biodiversity Plan 2010-2015.

Materials and Methods

We will describe and prioritise the biodiversity value of different areas within the 26 counties of the Republic of Ireland, based on objective and transparent criteria that reflect a hierarchy of importance of plant diversity. In this way, we will identify important areas of plant diversity within each county of the Irish countryside. We will compare the distribution of these hotspots with the distribution of protected areas (i.e. Natura 2000 sites).

This project will collate available data on the distribution of individual rare plant species (available from National Botanic Gardens, Ireland). This represents over 900,000 records for plants of conservation interest at the scale of hectads (10km x 10km squares) and about 135,000 records at the scale of tetrads (2km x 2km squares). Here, we examined the hectad-scale distribution of each of the 63 named Flora Protection Order species (FPO, 1999), and examined how many of the hectads coincided with an area of Special Area of Conservation (SAC).

Using available records of rare plants in Co. Leitrim (at a 2km x 2km resolution), we collated plant species occurrence data for the following groups (at least); legally protected species (FPO, 1999; CEC, 1992), nationally threatened species (Curtis and McGough, 1998], axiophytes* and indicator plant species that identify Annex I priority habitats (CEC, 1992). A provisional county-level map of plant biodiversity hotspots was plotted. We plotted the tetrads according to a number of rules, in approximate order of biodiversity importance: contain at least one FPO species; contain at least one Red Data book plant species; contain ≥ 30 axiophyte species; contain at least 50% of the indicator species for priority EU habitats (not listed here). These methods are based upon preliminary work undertaken for the Flora of County Waterford (Fitzpatrick and Green, in prep). [*'Axiophytes' refer to plant species of particular botanical interest, they are usually indicators of stable, diverse sites of botanical conservation value.]

Results and Discussion

The number of hectads occupied by the 63 FPO species ranged from 1 hectad (five species: *Carex depauperata* Starved Wood Sedge, *Callitriche truncata* Short-leaved Water-Starwort, *Hydrilla verticillata* Irish Hydrilla, *Minuartia recurva* Recurved Sandwort, *Saxifraga nivalis* Alpine saxifrage) to 113 hectads (*Omalotheca sylvatica*, wood cudweed), and had a median of 10 hectads. Across each species, there was very large variation in the percentage of hectads with an FPO species that also contained an area of SAC. Based on all records, 32 of the 63 species had ≥25% of their distribution outside of a hectad that coincided with an area of SAC. For 14 species, ≥50% of the hectads in which they occurred were not located in a hectad that coincided with an area of SAC. Note that a designated site (SAC) only needed to occur in part of a hectad for the whole hectad to be identified as a 'designated' hectad. Thus, this method certainly overestimates the extent to which the distribution of Flora Protection Order species coincide with SAC areas. The role of agri-environment schemes in protecting these species outside protected areas may be of critical importance to their survival.

In a provisional analysis of records from Co. Leitrim, a total of 43 tetrads (out of a county total of about 400 tetrads) were identified as important areas of plant diversity (note that some tetrads satisfied more than one criterion). Twenty-two tetrads contained at least one FPO species; twelve contained at least one Red Data book plant species; five contained ≥ 30 axiophyte species, and; fourteen contained at least 50% of the indicator species for priority EU habitats.

At present the number of plant records (900,000) in the data set represents scarcely 13 records per km^2, and some areas of the country have been more intensively surveyed than others. We therefore analysed a number of different counties from which the plant record density varied by two orders of magnitude (Waterford, Leitrim and Galway). We found that the methods gave a comparable number of tetrads for each. This suggests that even when sparse, the records for rare or interesting species tend to be most thorough, whilst species of least concern are omitted. It is likely that gathering more data will give a diminishing return on such an investment (Grantham *et al.*, 2008) and that the present data set will prove robust.

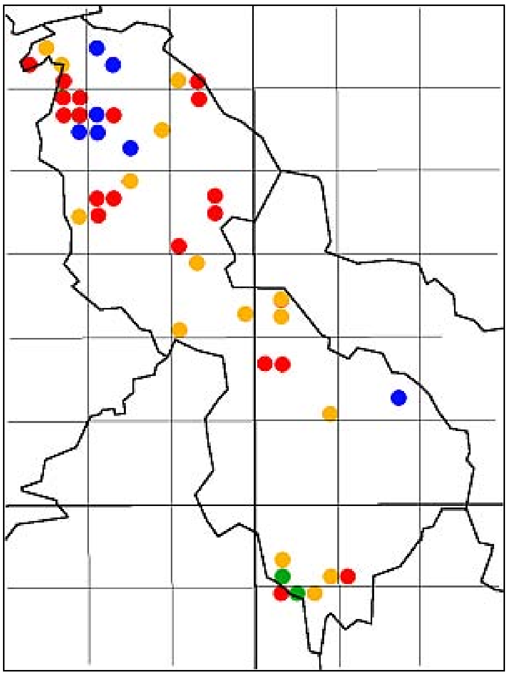

Fig. 1. Preliminary application of methodology to distribution of records of rare plant species in Co. Leitrim. Each point represents multiple records of different types of rare plant species. In order of decreasing importance: Flora Protection Order Species (red); Red Data Book species (blue); species of conservation value (green); indicator species for Priority habitats (yellow). Note that some tetrads satisfied more than one criterion. County Leitrim has about 12,500 tetrad-level records. Further work could, for example, compare these distributions with the distribution of Natura 2000 sites and participation in agri-environment schemes.

Conclusions

These data on Flora Protection Order species indicate that a considerable distribution of these species occurs outside of designated areas. Halting biodiversity loss of these most threatened species could be facilitated by agri-environment measures that are highly spatially targeted in the wider countryside. The approach proposed here could be used to identify and protect important areas for plant diversity, and could contribute to effective spatial targeting of agri-environment schemes.

Acknowledgments

This work draws upon the considerable efforts of many skilled voluntary recorders of plant records over more than a century, and the Botanical Society of the British Isles is thanked for providing the data.

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A critical source area approach to the development of supplementary measures for high status waterbodies

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Introduction

Article 11 of the EU Water Framework Directive (2000/60/EC) (WFD) requires that in catchments where the basic programme of measures are deemed to be insufficient for achieving the quality objectives, supplementary measures are to be designed and implemented. These measures should be technically feasible, cost effective and environmentally sustainable. Supplementary measures for high status water bodies are of particular importance due to their sensitivity to anthropogenic impacts and the catchment specific nature of many threats. While alternative quality objectives may be set for waters in certain specified circumstances, this does not apply to high status water bodies which may not be allowed to deteriorate.

The basic measure to control phosphorus (P) use in agriculture under the WFD is the Nitrate regulations (S.I. No. 610 of 2010). Frequently these regulations have few consequences for more extensively farmed areas, which often coincide with the location of high status water bodies. However, despite low stocking densities, phosphorus export in such areas can still pose a threat to high status water bodies and may require supplementary measures to mitigate P export effectively. Targeting critical sources areas (CSAs) of P in such catchments could significantly improve the environmental efficiency and cost effectiveness of supplementary measures while minimising the impact on farm management. This paper considers how a CSA-approach to the development of P supplementary measures could be integrated into the exiting WFD structures, through an exploratory case study of the implementation of such an approach in the Lough Melvin catchment.

Methods

Lough Melvin is unique amongst Irish lakes, supporting a fish community typical of a natural post-glacial salmonid lake. Due to its unique ecosystems and biodiversity it has been designated as a Special Area of Conservation (SAC) under the EU Habitats Directive (92/43/EEC). In addition, three sub-catchments are classified as high status water bodies under the WFD.

Between 1991 and 2007, P concentration in the lake increased from 19 to 29 µg L^{-1} bringing the nutrient status of the lake close to eutrophic. Despite the predominance of extensive farming (average stocking density of 0.5 LU/ha) agriculture is estimated to be contributing 62% of the P load to Lough Melvin. Total P export from the Glenaniff sub-catchment, which has little forestry, a sparse population and is classed as a high status water body, increased from 0.71 tonnes yr^{-1} in 1990 to 1.27 tonnes yr^{-1} by 2007.

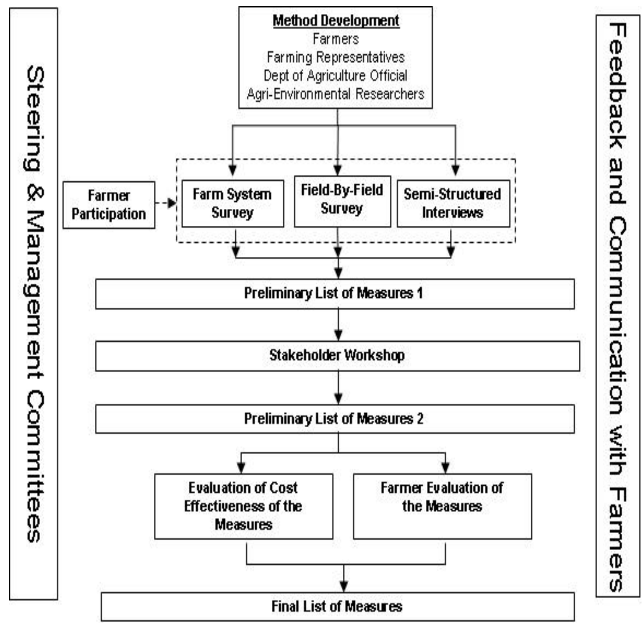

Figure 1: Development of P mitigation measures in the Lough Melvin catchment (Doody *et al.* 2009)

Due to the increase in P export from agriculture, Schulte *et al*. (2009) implemented a study in the catchment with the aim of developing technically feasible, cost effective and environmentally sustainable mitigation measures. Throughout the study, an explicitly participatory approach was adopted in which the input of local farmers and agricultural stakeholders were integrated into the development of the measures (Doody *et al*. 2009) (Figure 1). A field-by-field risk assessment, using the P risk index approach, was carried out on 50 farms in the catchment in conjunction with semi-structured interviews with each farmer. This data was then used to develop a preliminary list of measures which were presented at a stakeholder workshop. Subsequently the measures arising from the workshop were evaluated by the farmers and for cost effectiveness and a final list of measures to mitigate P export from agriculture in the catchment identified.

Results

The field-by-field risk assessment highlighted that 31% of the fields surveyed were a high risk for P loss, with a further 30% categorised as a medium risk. In total 20 measures were identified to mitigate the risk of P loss from these fields. The cost effectiveness and preference of the farmers for six of the top measures is presented in Table 2. The most cost effective measures were also those ranked mostly highly by farmers. Schulte *et al.* (2009) calculated that implementation of these measures would result in a 36% reduction in the total P exported for less than 1% of total potential costs; while over 50% of the total potential reduction in P loss could be achieved at just over 5% of total potential costs. .

Table 2. The cost effectiveness and farmer preferences for a selection of the P mitigation measures identified for the Lough Melvin catchment. Category A indicates highest cost-effectiveness/ highest popularity.

Measures	Cost effectiveness	Popularity
Feed low P conc.	A	A
Zero P on Index 4 silage area	A	B
Free advisory service	A	A
Reduce stocking rate (sheep)	B	B
Sedimentation barriers in ditches	B	A
Reduce stocking rate (suckler cows)	B	B
Run-off interception ditches	C	B

Discussion

Article 14 of the WFD encourages the active involvement of stakeholders in the development and implementation of the WFD. As such the approach of Schulte *et al.* (2009) provides a template by which cost-effective scientifically robust supplementary measures can be developed in consultation with the local farming community. To help achieve the objectives of the WFD, this approach could be integrated into a tiered risk assessment that builds on the WFD Article 5 risk assessments and uses (for example) the P Indicator Tool (Heathwaite *et al.,* 2003) to identify high risk areas for P loss at a scale of 1 km^2 within catchments with high status water bodies. The implementation of the methods of Schulte *et al* (2009) would then be focused within these 1 km^2 high risk areas and supplementary measures developed from the outputs of the survey.

Conclusions

The development of effective supplementary measures is vital to protecting the water quality and biodiversity in high status water bodies. The threats posed to many high status water bodies are catchment specific and as such, supplementary measures should be developed that take the site specific nature of those threats into consideration. This paper has presented how such an approach could be successfully utilised to identify supplementary measures to mitigate P loss in catchments with high status water bodies.. The participation of farmers and other stakeholders is central to the successful development of measures that are cost effective, environmentally efficient and that can be successfully implemented within existing farming systems.

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HNV farming policy – progress to-date and future challenges

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Introduction

The HNV farming concept emerges from a recognition that certain patterns of farmland are inherently of high biological richness, especially when existing at a landscape scale, particularly landscapes that contain a significant proportion of land in a semi-natural condition, such as permanent pastures and meadows, grazed woodlands and traditional orchards.

Many studies have shown that greater heterogeneity, connectivity and area of semi-natural elements in an agricultural landscape tend to have a positive influence on species richness and abundance, across a range of wildlife groups. The semi-natural patches need to be not only of sufficient quality, but also of sufficient size and connectivity. At a general level, experts in France have estimated that for a farming landscape to support high levels of biodiversity, it should include a minimum of 20% semi-natural land cover (Le Roux *et al*., 2008).

In intensified agricultural landscapes, these beneficial conditions for biodiversity have been lost and their (partial) restoration generally occurs only at a cost to public finances, e.g. through agri-environment schemes. On HNV farmland these conditions broadly exist already, and the biodiversity challenge is to prevent their decline in the face of powerful socio-economic and policy drivers.

Semi-natural farmland types, and their associated biodiversity, extend well beyond designated protected areas. According to EEA estimates, HNV farmland may account for 30 per cent of EU farmland (Paracchini *et al*., 2008). If we want to conserve nature in Europe, we should look at this big land-use picture, not just the detail of how to manage particular habitats within designated areas.

Many of Europe's semi-natural farmland habitats are continuing to decline in area, and/or are in poor condition. A main and continuing cause of this decline is a parallel process of intensification on land with more production potential, and abandonment of land with production limitations. In some regions, this process can be seen at the scale of entire landscapes (e.g. in parts of southern and eastern Europe). In most of the lowlands of north-west Europe, where semi-natural farmland no longer occurs at the landscape scale, similar processes of abandonment and intensification continue to affect the small-scale remnants, for example on semi-natural fields or parts of fields within farms.

In response to these processes and in order to halt biodiversity decline, there is an urgent need to develop an economic basis for farming on semi-natural land. This requires a combination of public remuneration for the public goods generated, through targeted CAP payments, and the development of greater socio-economic resilience, for example through marketing of high-value farm products. Both need to occur on a scale commensurate with the challenge existing on the ground.

In simple terms, HNV farming is a policy concept that aims to give greater priority to farming landscapes that still retain a significant proportion of semi-natural land within the farming system, whether within or outwith designated areas such as Natura 2000 sites. It promotes a more strategic and integrated approach than occurs under present policies, by taking greater account of the socio-economic realities of different farming situations, and recognising that these realities are central to achieving biodiversity goals.

Since 2005, identifying, supporting and monitoring HNV farmland and farming systems have been priorities for EU rural development policy. The European Forum on Nature Conservation and Pastoralism (EFNCP) has been closely involved in the development of suitable approaches to these tasks at the European level. Exploring how it all should work, through real examples at local level, is a particularly important complement to top-down desk studies, and in 2010 EFNCP joined up with local partners to run a series of projects to examine various aspects of HNV farming and policy in parts of England, Wales, Ireland, France and Spain (Navarra) (see http://www.efncp.org/projects/). Funding has been from local/national partners and from DG Environment of the EC. These projects aim to explore how HNV farmland and farming systems can be identified and their socio-economic needs assessed, as the basis for developing strategies for their effective long-term support.

EU policy context

Although the concept was first introduced in 1993 (Baldock *et al*., 1993), HNV farming did not become firmly established in EU policy until the start of the present rural development programming period. In its 2006 communication on halting biodiversity decline, the European Commission emphasised that Natura 2000 and the conservation of threatened species will not be viable in the long-term without a wider terrestrial, freshwater and marine environment favourable to biodiversity. Key actions highlighted included optimising the use of available measures under the reformed CAP, notably to prevent intensification or abandonment of high nature value farmland, woodland and forest and supporting their restoration (COM, 2006)

In the same year, the EAFRD regulation Strategic Guidelines on rural development established HNV farming as one of three priorities for Axis 2 of Rural Development Programmes (RDPs). In order to include effective measures for HNV farming in their RDPs, Member States should assess the practical needs on the ground and how best to address them. Specifically, the EAFRD implementing regulation states that they should produce an analysis of:

"Environment and land management: the handicaps facing farms in areas at risk of abandonment and marginalisation; overall description of biodiversity with focus on that linked to agriculture and forestry, including high nature value farming and forestry systems […]"

The 2007-2013 RDPs should have measures in place to maintain HNV farming and forestry systems. The effects of programmes will be evaluated against this objective, by applying specific HNV indicators under the Common Monitoring and Evaluation Framework (CMEF).

The CMEF Result Indicators include "Area under successful land management contributing to: (a) biodiversity and high nature value farming/forestry (e) avoidance of marginalisation and land abandonment".

The CMEF Impact Indicators include "Maintenance of high nature value farmland and forestry", for which a baseline situation must first be established.

The European Evaluation Network for Rural Development (EENRD) Help Desk has produced guidelines for the application of HNV indicators (Beaufoy and Cooper, 2008). These are intended to help Member States assess the baseline situation of HNV farming and monitor how it evolves.

In 2010, the Help Desk organised a Thematic Working Group of experts to develop guidance on the application of all CMEF indicators, including HNV indicators. The report of this group adds further practical detail and examples of current practice to the 2009 guidance (Lukesch and Schuh, 2010).

Summarising the thinking in these documents, HNV farming can be seen from two perspectives:

- HNV *farmland*: land-cover types such as semi-natural pastures/meadows and traditional orchards, mosaics of low-intensity crop types with semi-natural patches.

- HNV *farming systems:* how the above land-cover types are managed, especially grazing and mowing regimes, low-intensity systems of crop management and weed control in orchards, practices such as transhumance. Socio-economic aspects are also part of the farming system, for example income levels, part-time farming.

To be meaningful and effective, monitoring and evaluation should address both these perspectives, so that policy makers designing programmes have the information they need concerning trends in the extent and condition of HNV farmland types, in the farming systems and practices that use them, and in their socio-economic situation.

Progress to date and future challenges

When the current round of RDPs was introduced in 2007, few if any Member States had a reliable basis for estimating their baseline extent or condition of HNV farmland. Some turned to the JRC-EEA CORINE-based HNV farmland maps and figures, which are not intended for use as CMEF indicators, or used the extent of Natura 2000 sites as a proxy, or simply provided no baseline indicator due to lack of data.

Since then, a great deal of work has been developed across the EU by national agencies and research bodies. Much of the effort to-date is focused on developing methods for the identification of HNV farmland, using national data sets. Work has moved on from the basic mapping of land-cover types and protected areas as first introduced by EEA, to more complex combinations of criteria including aspects such as field size and land-use diversity. Many Member States have work ongoing that is generating robust results; the following are a few examples.

In Spain, a project started by the Ministry of Environment in 2008 to identify HNV farmland is now in its second phase under the new combined Ministry of Environment and Rural and Marine Affairs. This work puts considerable emphasis on species and habitat distribution as indicators of HNV farmland. Meanwhile the regional government of Navarra has a project with EFNCP involvement to develop HNV farming and forestry indicators at the regional level, and also sets of indicators for monitoring changes in HNV farming and forestry systems within the region.

A study in Finland is developing the national HNV farmland indicator based on 5-8 farm-level variables with varying weighting factors. The amount of semi-natural grasslands, permanent grasslands, grazing animals and area in special agri-environment scheme contracts supporting biodiversity will have a relatively large weight and some other farming statistics lower weights in determining the HNV value of a farm. The total area of farms exceeding a threshold value will be considered as HNV farmland, the area of which will be monitored at intervals of a few years.

HNV farming is largely about determining priorities, and in this context, processes for dialogue are as important as desk studies. In Estonia a national HNV working group was formed in July 2009 by the Agricultural Research Centre (ARC). This working group includes representatives from the Ministry of Agriculture and Ministry of Environment, State agencies administrated by these Ministries, and experts from Estonian University of Life Sciences. The HNV working group sees its work in three stages: 1) Identifying and working out HNV baseline criteria; 2) Evaluation of the application possibilities; 3) Proposals for HNV in the RDP context (e.g. support measures, combinations of measures).

Much of the work undertaken by national and regional authorities has focused on land cover, and especially on methods of mapping the land-cover types associated with HNV farming. This work has tended to come up against the limitations of European and national data bases. CORINE provides only a very approximate picture, and national land-use data are often not much more useful. However, experience shows that the challenges are far from insuperable.

The Land Parcel Identification System (LPIS) which all Member States are required to develop for administering CAP payments offers potential solutions. Some countries have more detailed, and therefore more useful, LPIS than others. For example, LPIS in Spain has numerous categories of permanent pasture, some of which are by definition semi-natural, such as pastures with scrub and trees. Identification of broad types of HNV farmland in Navarra (Spain) has been possible using LPIS in combination with regional land use data bases. In England by contrast, LPIS has only one category of permanent pasture, that includes a range of types from moorland to highly productive pastures that are frequently reseeded, and is thus less useful.

LPIS becomes even more useful when data on the presence of environmentally valuable land cover is recorded on the system. This is the case in Slovakia, where a national survey of semi-natural grasslands has been undertaken and incorporated in LPIS, thus producing an accurate and detailed baseline for the main type of HNV farmland in the country.

As explained in another conference paper (see paper by D. Fuchs), Germany has established a baseline and monitoring system for HNV farmland extent and condition, using a sampling approach similar to that used by many countries for the Farmland Birds Index, and also by the UK Countryside Survey.

Farming systems have received less attention. In Italy, data from the Farm Structures Survey has been used to estimate the distribution and extent of broad farm types with characteristics such as low livestock density. The government project in Navarra has developed a typology of broad HNV farming and forestry systems, and is studying these to establish indicators that focus on aspects such as particular farming practices characteristic of the system and known to be vulnerable to change. Indicators of the socio-economic condition of HNV farming systems will also be considered, in order to allow effective policy responses to the threat of abandonment. As with HNV farmland condition, a sampling approach is probably the most practical way of monitoring these more detailed aspects of HNV farming systems.

Turning to the EAFRD priority for supporting HNV farming, this has been taken up most explicitly by new Member States, with many giving considerable emphasis to the theme in their RDPs. The Romanian and Bulgarian RDPs mention HNV farming 58 and 82 times respectively, compared with 4 times in the RDP for Wales. Some ambitious schemes have been established, such as the agri-environment measure for HNV grassland in Romania targeting the Carpathian uplands zone, and measures for HNV orchards in Bulgaria. Slovakia has developed a country-wide measure for all HNV grasslands registered on LPIS.

The old Member States have been more inclined to assume that what they are doing already ticks the “HNV box”, especially through agri-environment. However, in a local HNV farming project in south-west England we found that considerable areas of HNV farmland were not participating in agri-environment measures, suggesting a need to review current approaches.

Conclusions

EFNCP believes that basic economic support for maintenance of HNV *farmland* is best targeted through farm-level criteria. At its simplest, this would consist of a premium payment for specific land-cover types identified on LPIS, particularly permanent pastures and meadows, in return for a minimum level of positive management and a commitment not to intensify through reseeding.

This would provide an incentive for preventing abandonment and intensification and thus for maintaining the basic public goods values of these land-cover types, right across the EU. Such a measure is perfectly feasible at present with no need for new maps or zoning.

A more sophisticated approach to be developed over time is to record on LPIS more specific land-cover types, as has been done in Slovakia with the HNV grassland survey. This would allow implementation of a premium for other semi-natural farmland types, such as traditional orchards.

In parallel, simple systems for monitoring the extent and condition of these HNV farmland types can be set up, using LPIS with appropriate categories (Spain), baseline inventories as in Slovakia, Estonia and Wales, and sample surveys as in Germany.

HNV *farming systems* require a different but complementary approach. The support needs are various and quite complex, including the need to maintain and incentivise particular farming practices and combinations of practices, to improve socio-economic viability and living conditions of farming communities, and to achieve a critical mass at the landscape scale by encouraging farmers to work together. In terms of policy architecture, Pillar 2 seems the appropriate place for putting together programmes of measures to address these needs.

Programmes should target particular HNV farming systems, for example those of exceptional public goods value, and/or that are highly threatened, as has been done in several Member States already. Indicative maps of HNV farming systems may be useful for this purpose, as illustrated by the work in Navarra, not necessarily to define precise boundaries of zones eligible for support, but as a way of prioritising systems and structuring tailored support programmes.

Policy makers have been known to declare that the HNV farming concept is unclear, or impossible to implement. Experience is now showing that this is not the case, especially if the concept is broken down into manageable components – distinguishing measures to support HNV farming from instruments for monitoring and evaluation; distinguishing semi-natural farmland from other types of farmland; and distinguishing HNV farmland from HNV farming systems.

There are data difficulties, but these can be overcome at no great cost, as has been shown. The result should be more effective policy design and more cost-efficient delivery of EU goals.

We have failed to meet our goals for halting biodiversity decline by 2010, and are now setting new ambitious targets. To meet these, we need an integrated system for monitoring not only biodiversity itself, but also the types of farmland and farming that are of most biodiversity value. This should be done in a way that generates meaningful information for policy makers, leading to policy adaptation and improvement.

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Evidence on the environmental effectiveness of REPS: a literature review

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Introduction

As a formal requirement of the Rural Development Regulation, Member States are obliged to monitor and evaluate the environmental, agricultural and socio-economic impacts of their agri-environment programmes. Summary reports on policy evaluation of agri-environment schemes have concluded that there has been insufficient measurement of their precise environmental outcomes (DG Agriculture 2004; Oréade-Brèche 2005). The European Court of Auditors will report in 2011 on its audit of the environmental effectiveness of agri-environment schemes, which may lead to significant changes in policy implementation. The World Trade Organisation (WTO) also requires that the environmental benefits of agri-environmental payments are clearly demonstrated, to ensure that such payments are not disguised trade subsidies. One of the best (if not only) ways to address these various pressures is to quantitatively demonstrate the environmental benefits and value-for-money of agri-environment schemes. This policy context highlights the need for quantitative demonstration of the environmental impact of agri-environment schemes, and why this will become increasingly important.

A variety of research projects have been undertaken that investigate the environmental effects of REPS, through an examination of either specific environmental measures or specific geographical areas. Here, we review the publications from these projects, and assess the extents to which they can inform an environmental assessment of REPS.

Materials and Methods

An attempted systematic review with a number of various relevant search terms in Web of Knowledge only resulted in a total of about ten relevant research articles. As an alternative, we collated and reviewed available literature on these studies, with an emphasis on empirical research that is directly relevant to the environmental effects of REPS.

Results and Discussion

A variety of research projects have been conducted on REPS. Publications from these are grouped under the relevant broad environmental objectives as indicated in Table 1, and each of these groups discussed in turn. This list is not intended to be exhaustive, but includes most of the published research studies as well as many of the unpublished ones.

An increasing number of studies are available with which to learn about the actual or likely environmental effectiveness of REPS. A considerable proportion of these studies has not been published in international journals, and is only available as national reports, theses, conference papers and conference abstracts. Compared to the high standard of evidence associated with journal articles, care is required in the interpretation of evidence from other sources (although some of this is of a very high standard).

On the basis of this review, a number of conclusions arise that are relevant to institutional efforts to assess the environmental impacts of REPS:

- There is insufficient evidence with which to judge the environmental effectiveness of the national-scale implementation of the whole Rural Environment Protection Scheme. This makes it equally likely that the full benefits of the scheme have not been measured, as well as reducing the opportunity to learn how to improve it.
- Some individual studies provide evidence to scientifically assess the environmental effect of individual REPS measures; however, most studies lacked national-scale coverage.
- There is a distinct lack of studies that use baseline data to compare change over time (longitudinal studies).
- Of the studies undertaken to date, there has been an emphasis on biodiversity studies, but these have had little or no co-ordination in their aims, methods, temporal scales or spatial scales.
- There have been surprisingly few studies on the impact of REPS on nutrient management and water quality, but the available evidence is generally positive.
- A considerable number of studies have investigated the environmental effects of REPS, although relatively few of these have been published in journals.
- Some evidence currently exists to guide advice/recommendations about the environmental effectiveness of REPS.

Conclusions

A review of available publications confirmed the absence of a comprehensive, national-scale study of the environmental impacts of REPS. Because of this, there is insufficient evidence with which to judge the environmental effectiveness of the national-scale implementation of the whole scheme. It is important to note that this does not necessarily mean that REPS has not delivered environmental benefits, but that there has been insufficient collection of evidence of the environmental performance of the whole REPS programme. Thus, the full benefits of the scheme have not been measured, and there has been reduced opportunity to learn how to improve the scheme. For many of the newer supplementary measures and options that have been introduced since REPS 3, no empirical evidence is available with which to judge their *ex post* environmental effects, which hinders an overall assessment of the whole scheme. For some specific measures, however, sufficient evidence is available to inform an objective assessment in some cases, and to help learn how to improve environmental effectiveness in most cases.

Acknowledgments

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Table 1. References relevant to the environmental effectiveness of REPS across different environmental categories. (Full list of references available in Finn and Ó hUallacháin, in press.)

Topic	References
Nutrient management and gaseous emissions	McEvoy (1999), Casey and Holden (2005, 2006), Lanigan *et al*. (2008), Hynes *et al*. (2007, 2008b), Richards *et al*. (2007), Doody *et al*. (2009), Schulte *et al*. (2009)
Archaeology	O'Sullivan (1998, 2001), Sullivan (2005, 2006), Sullivan *et al*. (1999)
Measure A farmland habitats	Dunford and Feehan (2001), Williams *et al*. (2009), Walsh (2009), Visser *et al*. (2007), Moran *et al*. (2008), NPWS (2008), van Rensburg *et al*. (2009), O'Rourke and Kramm (2009)
Non-designated farmland habitats	Hickie *et al*. (1999), Bohnsack and Carrucan (1999), DAF (1999), Jones *et al*. (2003), Hyde (2003), Aughney and Gormally (2002), Gabbett and Finn (2005), Copland (2009), Copland and O'Halloran (2010), Egan (2006), Hynes *et al*. (2008a), Speight (2008), Purvis *et al*. (2009a, p. 17-20)
Field margins	Feehan *et al*. (2005), Fritch *et al*. (2009, 2011), Purvis *et al*. (2009a), Sheridan *et al*. (2008, 2009)
Hedgerows	Flynn (2002), Copland *et al*. (2005), Copland (2009)
Assessment across multiple environmental objectives	Bartolini *et al*. (2005), Viaggi *et al*. (in press), Finn *et al*. (2007, 2009), Finn *et al*. (2008b), Kelly (2008), Carlin *et al*. (2010),
Financial effects	McEvoy (1999), Connolly (2005), Connolly *et al*. (2005, 2006, 2009), Kinsella *et al*. (2007ab) (and others)
Others	In addition to the above, a number of other publications address a variety of issues in the context of REPS, including landscape preferences, economic commentaries and general critiques. These are listed in Finn and Ó hUallacháin (in press).

Invasive species control Case Study: Hottentot fig (*Carpobrotus edulis)* control in Ireland.

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Introduction

Hottentot fig (*Carpobrotus edulis*) is a popular garden plant from South Africa. Unfortunately it is also an aggressive invader of coastal habitats, forming vast mats to the exclusion of all other plants. On the Gower peninsula of Wales and along the Cornish and Devon coasts of Great Britain it has formed extensive colonies smothering many kilometres of coastal cliffs. On the drier eastern coasts of Ireland it poses a serious ecological threat.

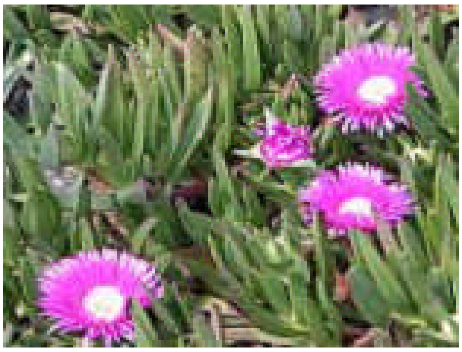

Plate 1. Hottentot Fig.

Nothing eats Hottentot fig in Ireland, thus a colony not only displaces native plants, which are a food source for bees, butterflies and moths, but the dense carpets represent a dead zone in regard to insects, and thus the birds that feed on them (the only known beneficiary are rats, that eat the fruits). The consequence is that the cliffs are becoming a life-less zone for insects and birds. This project aimed to ultimately eradicate Hottentot fig from Howth Head, Co. Dublin with initial pilot studies carried out in The Murroughs, Co.Wicklow and control efforts are due to be expanded to all known Irish sites (Reynolds, 2002) in 2011.

Materials and Methods

Pilot control experiment

To determine the best control method to use for Hottentot fig, herbicide experiments were carried out in Wicklow during March 2010. Physical control was deemed fruitless, due to the issues of dealing with the hazardous waste and the sheer volume of material (stems were found to weight in excess of 10kg). The area affected by Hottentot fig on Howth Head lies within Howth Head SAC 000202, so no experimental work or treatments could be carried out during nesting season March - September. The pilot experimental chemical treatments were carried out at an alternative coastal site in Wicklow.

Tetrads of $1.5m^2$ ($2.25\ m^2$) were treated with each of the three herbicide products trialled. The patches were marked using white pebbles, and each patch was separated by 1m from the next treatment. The spray was applied until all leaf surfaces were fully wetted. About ¼ litre was used for the two tetrads of each treatment.

Herbicides used in pilot experiment

1. *B&Q Lawn weedkiller* (0.358 g/l mecoprop-P and 0.191 g/l dichlorprop-P soluble).
2. *Resolva weedkiller 24H Action Westland garden health* (3 g/l glyphosate and 0.3g/l diquat).
3. *Monsanto, Fast action Roundup weedkiller* (7.2 g/l glyphosate acid, present as 9.7 g/l isopropylamine salt of glyphosate).

The treatments were applied on a dry still day. No rain fell in the following 24 hours, and the herbicide was applied according to the manufacturer's instructions to prevent contamination of the surrounding habitat. After thirty seven days, results from the pilot experiment were obvious, using 3 g/l glyphosate and 0.3g/l diquat (Resolva Weedkiller 24 H Action) the Hottentot fig mortality rate was >95%.

Plate 2. Chemical treatment (3 g/l glyphosate and 0.3g/l diquat) of Hottentot fig showing >95% mortality.

Control of Hottentot Fig on Howth Head

The results of the pilot study helped demonstrate the most effective herbicide. The target site at Howth head was tackled during October 2010 during dry calm days. A wheelbarrow power sprayer (KS, 120 litre tank, petrol motor) was wheeled to access points along the cliff path and the 30m hose extension from the tank meant that operators could access the Hottentot fig along the cliff without having to wear a cumbersome knapsack sprayers. Knapsack sprayers (10 litre) were used at the sites near Sutton Sailing Club, Sea cottage and Lion's Head where it was safe for operators. Volunteer labour was used in the main and professional climbers were used where the cliff face was too steep for volunteers. The chemical found to be most successful in the

Wicklow trails (3 g/l glyphosate and 0.3g/l diquat) was mixed on site. Water was filled at Howth pier or brought along in drums and transported by wheelbarrow once on site. The site was revisited in February 2011 and chemical was applied to small populations which were missed previously. A preliminary botanical survey of species regeneration at treated sites was also carried out using 50cmx50cm quadrats, placed where Hottentot fig had been treated. Species present were identified where possible using Webb, Parnell & Doogue (1996).

Results and Discussion

Best control results were obtained using 3 g/l glyphosate and 0.3g/l diquat (Resolva 24 H) with mortality rate >95%. Seed pods treated with chemical were collected from dead and dried out stems in spring 2011 and the seed contained within were found to be capable of germinating and growing. This was a worrying result as there was evidence at many of the sites of gnawing of the seed pods by rats.

A survey in spring 2011 of the emerging likely replacement vegetation to Hottentot fig, found that native grass species such as *Festuca rubra*, *Agrostris stolonifera* & *Dactylis glomerata* were dominant replacement species, with seedling of herbs such as *Cochlearia sp*., *Armeria maritima*, *Plantago maritima* and *Apium graveolens.*

Conclusions

The herbicide treatment that worked most effectively on Hottentot fig was 3 g/l glyphosate and 0.3g/l Diquat (*Resolva* 24H Action) which was used to treat the invaded sites at Howth Head. Other sites which were discovered during fieldwork near Sutton and Dun Laoghaire were also included in herbicide control in late October 2010. The herbicides used in this control effort differed to those recommended by Kelly & Maguire (2009) for Hottentot fig control. The pilot chemical trails in Wicklow clearly demonstrated that the ratio mixture of glyphosate and diquat was the more effective as a “killing cocktail”.

Following the success of the project in Howth, we will expand and treat Hottentot fig at Carlingford, Wexford, Waterford and Cork i.e. all the currently known locations of this invasive species in Ireland (Reynolds, 2002). This is the first project to address a known invasive alien species with a small Irish range. We deem the policy of dealing with known alien invasive species which are still below “the radar” can provide that vital “stitch in time” before species such as Hottentot fig become dominant on coastal cliffs throughout the Island.

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Options for enhancing the biodiversity value of intensive livestock farms: experience from the English agri-environment schemes

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Introduction

Permanent grassland makes up a greater proportion of the agricultural area in the UK and Ireland than in any other EU country, representing 60% and 72% of UAA respectively (Eurostat, 2007). Of the permanent grassland in the UK, approximately half (about 6 million hectares) comprises improved grassland on moist or free-draining neutral soils typical of lowland livestock farms. These swards tend to have low plant species richness and are typically dominated by perennial ryegrass (*Lolium perenne*). The aim of this paper is to review the ways in which biodiversity of such farmland can be enhanced, focussing on the evidence behind management options in English agri-environment schemes (AES) at a range of scales and utilising a range of mechanisms.

Development of AES in England

AES were first introduced in Europe in the mid 1980s, and have been obligatory for EU member states since 1992. In England, the initial focus was on protecting areas of high landscape value containing threatened habitats of conservation importance. This led to the designation of Environmentally Sensitive Areas (ESAs) from 1987, within which payments were available to encourage appropriate land management practices. The approach was broadened to the wider farmed landscape in 1991 with the introduction of the Countryside Stewardship Scheme (CSS), which sought to enhance the environment of areas of countryside outside of the ESAs. Within this scheme, funds were still largely focussed on protecting, restoring and creating high nature value farmland habitats. Concern about farmland birds and other taxa typical of arable farmland led to development of arable options under the Arable Stewardship Scheme and these were incorporated into CSS from 2001. The Curry Report (Policy Commission 2002) on the future of farming, advocated the introduction of a ‘broad and shallow’ scheme as a means of incentivising environmental management amongst a larger proportion of farmers, and this led to the development of the current Environmental Stewardship scheme in England, comprising an ‘Entry Level’ (ELS) and a ‘Higher Level’ (HLS) available from 2005. However, concerns have been raised about the additionality achieved by the ELS, the weak spatial targeting at both landscape and within-farm scales, and the attractiveness of options for intensive livestock enterprises (Hodge and Reader 2010; Butler *et al.*, 2007; Defra, 2008).

AES and grassland diversity

The botanical diversity of grasslands is primarily controlled by levels of soil fertility and disturbance and their effects on competitive interactions. In intensively-managed agricultural grasslands, high productivity is promoted by inputs of inorganic fertilizers and the sowing of competitive grass varieties, allowing higher stocking densities or more frequent cutting of fields for silage. The decline in plant species richness and the replacement of plant species of conservation value with those typical of eutrophic, disturbed conditions is further exacerbated by the use of herbicides.

The invertebrate diversity of agricultural grasslands is driven by botanical composition and vegetation structure and their combined effects on food resource abundance and microclimate. The use of insecticides, fungicides and veterinary pharmaceuticals limit invertebrate abundance and diversity. The relationship between management and the abundance of vertebrate taxa is more complex, relating not only to provision of food resources, but also their accessibility and interactions with factors such as predation risk.

Enhancement of grassland diversity under AES

In the early AES schemes in England, the focus was on the protection of high nature value grasslands through prescriptions controlling stocking densities and input regimes (Critchley *et al.*, 2004). As the focus of AES broadened to include restoration and enhancement, the problems of high soil fertility and a paucity of sources of propagules or colonists in the landscape came to the fore (Edwards *et al.*, 2007; Woodcock *et al.*, 2008, 2010). Consequently, grassland restoration options are targeted on sites of low fertility and/or close to areas of high nature value grassland.

Given this, what is the biodiversity value of the approximately 6 million hectares of agriculturally improved, species poor grassland in the UK? In spite of the general negative impact of grassland intensification on wildlife, some taxa do utilise intensively-managed grasslands, for example certain bird species (e.g. starlings, swallows) (Møller, 2001). Improved grassland left to seed can provide winter food resources for buntings and finches (Buckingham and Peach, 2006). High stocking densities can be useful in providing sufficient dung fauna for bats (Jennings and Pocock, 2009).

Within the ELS scheme, options for intensive livestock farms can be grouped according to their location within the landscape: (a) in-field options; (b) options for grassland field margins; (c) options for boundary features; (d) options to protect adjacent habitats and (e) options to enhance provision of food resources in the wider landscape (Table 1). Of these options, those for hedgerow management, ditch management and reduced inputs on permanent grassland are most frequently chosen (Defra, 2008).

Table 1. Selected management options relevant to intensive lowland livestock farms (Natural England, 2010).

Code	Description
Management within grassland fields	
EK2-3	Permanent grassland with low inputs
EK5	Mixed stocking
EC2	Protection of in-field trees on grassland
EE7	Buffering in-field ponds in grassland
Managing margins of grassland fields	
EE4	2 m buffer strips on intensive grassland
EE5	4 m buffer strips on intensive grassland
EE6	6 m buffer strips on intensive grassland
EC25	Hedgerow tree buffer strips on grassland
Managing boundary features	
EB1-3	Hedgerow management
EB6-7	Ditch management
EB11	Stone wall protection and maintenance
EB12	Earth bank management
EC23	Establishment of hedgerow trees
Protection of adjacent habitats	
EC3	Maintenance of woodland fences
EC4	Management of woodland edges
EJ11	Maintenance of watercourse fencing
Increasing landscape-level diversity	
EF2	Wild bird seed mixture
EF4	Nectar flower mixture
EG4	Cereals for whole-crop silage

Development of options and evidence base

The evidence base for the development of scheme prescriptions has a long history of funding by Defra (previously MAFF), especially through BD14 programme. The focus has shifted from an initial focus on high nature value grassland and the relationship between soil fertility, grazing management and botanical composition, to a focus on wider grassland biodiversity with a strong emphasis on interactions between taxa in different trophic groups and providing a mechanistic understanding of factors controlling diversity and species composition.

Management within grassland fields

Options prescribing grazing or cutting regimes and input use in grasslands may yield environmental benefits through the reduced management intensity protecting natural resources, but gains in biodiversity may be slow. Of the improved and semi-improved grasslands sampled in the UK ESA schemes, only 30% showed signs of restoration of botanical diversity following the introduction of prescriptions relating to fertilizer inputs and grazing intensity (Critchley *et al.,* 2004).

Some attempt has been made to identify plant species that have wildlife value and are likely to persist in the fertile conditions of improved grasslands (Mortimer *et al.,* 2006). Many of the plant species identified had beneficial agronomic characteristics, including high productivity and feed value, especially amongst the grasses and legumes. However, most of the forb species identified have problems persisting in swards on soils of high fertility, although a number of robust species of high wildlife value were identified that perform reasonably well in grassland enhancement schemes on moderately fertile soils, for example yarrow (*Achillea millefolium*), knapweed (*Centaurea nigra*), ox-eye daisy (*Leucanthemum vulgare*) and ribwort plantain (*Plantago lanceolata*). Options for the establishment of wildflowers in grasslands are available in the HLS scheme, but not in ELS.

Management of grassland field margins

As with arable fields, the biodiversity value of grassland field margins tends to be greater at the margins of fields rather than in the centre. Focussing agri-environmental management at the margins has benefits in terms of the protection of boundary features and adjacent habitats, and is usually more attractive a strategy to farmers. However, the tendency for farmers to select agri-environmental options relating to field boundaries and field margins within the ELS may mean that some biodiversity objectives are not met (Butler *et al.,* 2007).

Research on management options for the margins of intensively-managed grassland, has been carried out on various combinations of restrictions on input and disturbance regimes. A recent study in southwest England manipulated the sward architectural complexity and botanical composition in intensive grassland field margins, through various combinations of fertilizer rate, cattle grazing and differences in the timing and height of cutting. The study found responses differed between different insect groups, with beetles and butterflies benefitting from the low input/low disturbance combinations (Woodcock *et al.,* 2007), but bumblebees only responding to the treatments in which botanical composition was manipulated by seed sowing (Potts *et al.,* 2009). In Ireland, more interventionist management, including the exclusion of livestock from field margins using fencing, and the sowing of species-rich seed mixtures, has shown the potential of more costly prescriptions (Sheridan *et al.,* 2008).

Current uptake of field margin options in the ELS scheme ('buffer strips on intensive grassland') is much lower than that for the arable equivalents (Boatman *et al*., 2010), with the majority of points being earned for field boundary management rather than the creation of field margin buffer strips.

Management of boundary features
Options for management of hedges and ditches are amongst the most frequently chosen by farmers in ELS agreements and typically make up one third of the points requirement (Defra, 2008). Whilst the biodiversity benefits of sensitive management of hedgerows and ditches are well documented, the enhancement of wet habitats on intensive farms could be developed in the current schemes (Fig. 1). The creation of small scale wet features in farmland could not only provide new habitats for plants and animals, but also confer additional benefits in terms of regulation of diffuse pollution and flooding (Bradbury and Kirby, 2006).

Fig. 1. In an experimental study, artificial bunds were created in farmland ditches in a mixed farming area of Leicestershire.

In an experimental study, artificial bunds were created in farmland ditches in a mixed farming area of Leicestershire. Bunds were created in ditches bordering permanent pasture and arable fields and compared to paired stretches of ditches without bunds. The abundance of emergent aquatic insects was significantly greater in bunded sections of ditch than in the controls, and significantly higher in the ditches adjacent to pasture than those in arable fields (Aquilina *et al.,* 2007). Low cost bunding of existing ditches in pastoral areas therefore has the potential to deliver biodiversity benefits and contribute to other environmental benefits (Bradbury and Kirby, 2006).

Enhancing landscape level diversity
As a result of increased specialisation of farm enterprises and the loss of mixed farms, many landscapes in the west of England are dominated by intensively managed grassland or forage maize. Such areas have suffered particular declines in farmland bird populations, especially seed–eating species. Intensively-managed grasslands and forage maize crops are poor sources of food for seed- and invertebrate-feeding birds and can be hostile nesting environments. Uptake of options for the provision of food resources for birds or invertebrates, such as the wild bird seed mix or the nectar flower mix has proved to be low amongst livestock farmers in the ELS scheme (Boatman *et al.,* 2010).

Research by the RSPB, CAER and Harper Adams University College examined the potential of cereal-based whole crop silage as an alternative to grass or maize silage production. Seed-feeding birds were found to feed preferentially on fields growing cereals for whole crop silage in the summer rather than on maize of grass silage fields, and also preferred barley stubbles over winter (Peach *et al.,* 2011). The pattern of bird usage of fields in summer and winter reflected differences in the densities of seed-bearing plants. The costs of producing whole crop silage from cereals were similar to those for making maize silage, and lower than those for grass silage. Cereals grown for whole crop silage and followed by overwintered stubble are now an option in the ELS scheme.

Future prospects
It is clear that the range of options available for intensive grassland farmers in the current schemes provide the basic ingredients for enhancing the biodiversity value of their land. However, many research studies have underlined the importance of spatial targeting of appropriate options, both at within-farm and landscape levels, if biodiversity gains are to be optimised. Therefore, the balance of resources between 'broad and shallow' schemes such as the ELS, with low administration costs and little guidance to farms regarding option choice, and more demanding prescriptions such as those of the HLS, needs careful examination.

Given the increasing focus on natural resource protection, for example the implementation of the Water Framework Directive, it is likely that some options within current AES may be incorporated into other policy types, such as cross compliance or regulation. For the more demanding options that may remain in AES, there is still a considerable need to investigate landscape-level factors, such as the optimum density and spatial configuration of agri-environmental measures, in order to inform spatial targeting and the provision of appropriate advice about option selection and placement.

Recent developments in AES implementation in other European countries, such as agri-environment agreements entered into by groups of farms in environmental co-operatives, offers a mechanism which might provide greater effectiveness for AES through the adoption of a landscape-level approach.

The current basis of payment levels in use for AES, that of 'income foregone', also needs revision, as it takes no account of the environmental value of the land concerned. As some land may now have been under AES agreement for approaching 25 years, the value of the habitat produced as a result of the scheme needs to be recognised in the payment levels received, especially if the long-term management necessary for delivery of biodiversity is to be incentivised. Schemes which incorporate a 'payment by results' incentive to grassland agri-environmental measures are likely to contribute to the development of the long-term approach necessary for biodiversity enhancement (Klimek *et al.*, 2008).

For those farmers without high nature value habitat on their land, it is important that we move towards a culture where farmland biodiversity is not perceived by farmers to be a separate product, paid for by the public at the behest of powerful NGO lobby, and that we seek to internalised wildlife friendly farming as part of a sustainable production system. There is a clear trend towards recognition of the ability of certain agri-environmental measures to deliver benefits across a range of ecosystem services and the research described here illustrates the potential for such a multifunctional approach.

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Improving floral and invertebrate diversity in grassland field margins

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Introduction

Plant and invertebrate diversity within grassland farming systems has been declining, and protection of biodiversity is one of the aims of the CAP. Field margin management is a common measure in agri-environment schemes, but most research has been conducted in arable conditions. Grassland field margins are not as well researched as those in arable systems. Plant diversity in grassland field margins is usually limited by the impoverished seed bank, high soil nutrient status, and dominance by rank vegetation (Pywell *et al.*, 2002; Critchley *et al.*, 2002). This experiment investigates the establishment and management methods to increase plant and invertebrate diversity within grassland field margins.

Materials and Methods

The experimental site was located on the dairy farm of the Teagasc research centre at Johnstown Castle, Co. Wexford. A stratified randomised split-plot field margin experiment was established in spring 2002. Nine 90 m long strips of grass sward along existing fences were fenced off from the surrounding paddock. One of three field margin widths (1.5m, 2.5m and 3.5m) was randomly assigned to each strip. Three field margin establishment methods were randomly assigned to three plots of 30m in length within a 90m strip. The establishment methods (Est. method) were: (1) fenced only; (2) rotavated and allowed to regenerate naturally; (3) rotavated and reseeded with a grass and herb seed mixture (n=41 species). Three replicates of each combination of width and establishment treatments were made. Grazing was introduced to half the length of each 30m plot in June 2003. Control plots consisted of existing pasture vegetation which had no subsequent application of nutrients or herbicide. Ungrazed plots were cut annually in September and the harvested biomass removed.

Sampling and analysis

Botanical data were collected using permanent nested 1m x 3m quadrats in which presence of plant species was recorded in July of 2003, 2007 and 2008. Invertebrates were sampled in four of the treatments, using emergence traps, from May to August in 2007 and 2009. Spiders and parasitic wasps were identified to species level. Species richness and abundance data were analysed using the PROC GLIMMIX statement of SAS using repeated measures.

Results and Discussion

A total of 64 higher plant species were recorded, this included 43 herb, 15 grass, three tree, two rush, and one sedge species. Establishment method and grazing had a significant effect on plant species richness (Table 1). Reseeded plots had highest species richness in all sampling periods (p < 0.0001). Grazing significantly increased quadrat species richness (p< 0.0001). The interaction between these two factors over time was also highly significant (Table 1) as the grazed half of plots increased in species richness over time while the ungrazed half of rotavated and reseeded plots remained unchanged (Fig. 1)

Table 1. Effects of establishment, year, grazing, and width and the interactions of these on the plant species richness in 2003, 2007 and 2008. Significance levels: ns, not significant; *, p<0.05; **, p, 0.01; ***, p< 0.005.

Factor	DF	F	Significance.
Establishment	(2, 68)	366.89	***
Grazing	(1, 76)	68.15	***
Grazing x establishment	(2, 76)	6.93	**
Width	(2, 68)	1.23	n.s.
Width x establishment	(4, 68)	2.83	*
Year x establishment	(4, 68)	9.18	***
Year x grazing	(2, 76)	9.24	***

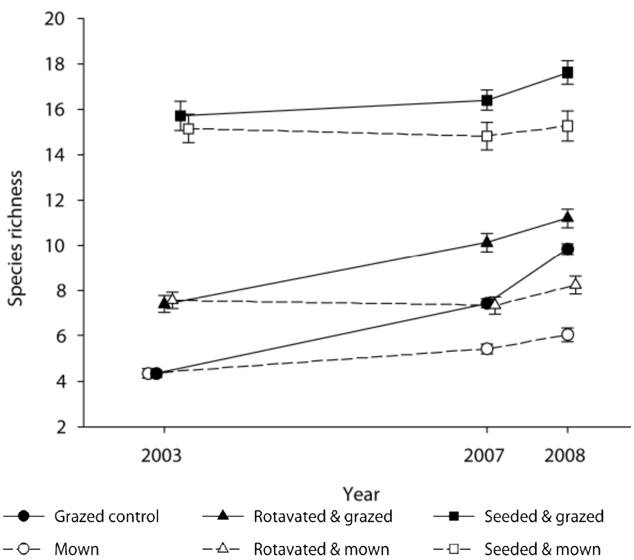

Fig. 1. Mean plant species richness (± s.e.) within each field margin establishment method over each of three sampling periods (2003, 2007 and 2008).

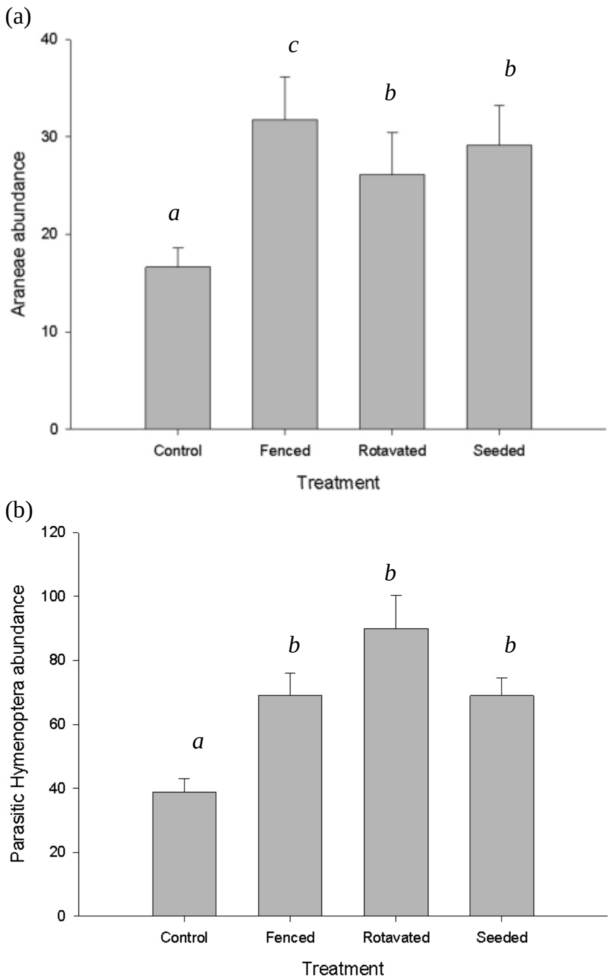

Fig. 2. Mean plant species richness (± s.e.) within each field margin establishment method over each of three sampling periods (2003, 2007 and 2008).

Table 2. Effects of treatment on abundances of different invertebrate groups over six sampling periods (2007 & 2008) in ungrazed margins compared to controls.

	Effect of establishment method		
Abundance	*DF*	*F*	*Sig.*
Spiders	(3, 102)	42	***
Wasps	(3, 102)	*15.9*	***

A total of 7,473 parasitic Hymenoptera individuals were trapped, comprising 132 genera from 16 families. A total of 2,902 spiders were trapped. These included 43 species of mature spiders (n = 816).

Fenced field margins (regardless of establishment treatment) resulted in increased abundance of invertebrate groups, in comparison to the grazed control (Fig. 2, Table 2). This may be due to the reduction/exclusion of grazing pressure within these treatment plots, which facilitated the development of a more diverse sward architecture. These results concur with many arable field margin studies which show that the provision of an uncropped field margin enhances invertebrate abundance when compared to a cropped margin (Denys & Tscharntke, 2002; Thomas & Marshall, 1999). In arable systems, leaving an uncropped field margin requires that the area adjacent to the field boundary remains uncut, unploughed and unsprayed. However, as grasslands are generally grazed by livestock, the development of an uncropped margin requires the installation of fencing in order to exclude grazing, as well as excluding inputs from livestock.

Conclusions

The use of wildflower and grass seed mixtures was most successful in establishing a botanically species-rich field margin habitat. This would be most appropriate in conditions where there is no existing field margin flora, and the objective is habitat creation. In this experiment, grazing had a significantly positive effect on plant species richness over time.

However, reduced grazing was required for increased invertebrate abundances. No single establishment treatment was best for overall invertebrate abundance as each taxa responded differently.

Management methods for increasing one taxa may conflict directly with the management requirements for other taxa. For example, mowing and grazing management increases plant species-richness in most grasslands; however, the maintenance of invertebrate diversity may require taller vegetation with less disturbance.

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What is the conservation potential of grasslands on lowland farms?

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Introduction

Semi-natural grasslands and practices such as haymaking were much more widespread throughout Ireland in the past (Stowe *et al.*, 1993). Since 1990, semi-natural grassland, heathland and wetlands and mixed farmland have all decreased, while arable and permanent pastures increased by over 30% (EPA, 2006). Redressing the negative impacts of intensification on biodiversity has been one of the major European agri-environment policy drivers (Henle *et al*., 2008). As a result, marginal grasslands of moderate conservation value that are not intensively managed have recently gained recognition, even though they may have been reseeded in the past (Beaufoy, 2008). Though not exemplary species-rich meadows, they are often more extensively farmed and provide important ecological services. The identification of these grasslands is necessary to accurately assess current biodiversity levels on farms. This has implications for grassland conservation and restoration and would be particularly useful for High Nature Value (HNV) farmland identification and monitoring, a requirement under the current Rural Development Plan (2007-2013).

Materials and Methods

Ten percent of farms were selected randomly, outside nature designation sites, from six different District Electoral Divisions (DEDs) in east Co. Galway (a total of 603 fields). A W-shape was walked through each field and the abundance of each plant species present recorded using the DAFOR (Dominant, Abundant, Frequent, Occasional, Rare) scale.

All grassland types within the field boundaries were identified according to Fossitt (2000). Nonmetric Multidimensional Scaling (NMS) analysis was carried. NMS was chosen as it avoids the assumption of linear relationships among variables and allows the use of distance measures suited to non-normally distributed data (McCune and Grace, 2002). Average Ellenberg values, indicators of plant species preference for positions along ecological gradients, were calculated for Ellenberg N as a measure of each species' response to nitrogen (Hill 1999). This was done for each field as a community calculation, using species Ellenberg N values (1-9) and abundance. A one-way ANOVA was used to test for differences between the mean species richness of the grassland groupings (log transformed to achieve normality). For further details see Sullivan *et al.* (2010).

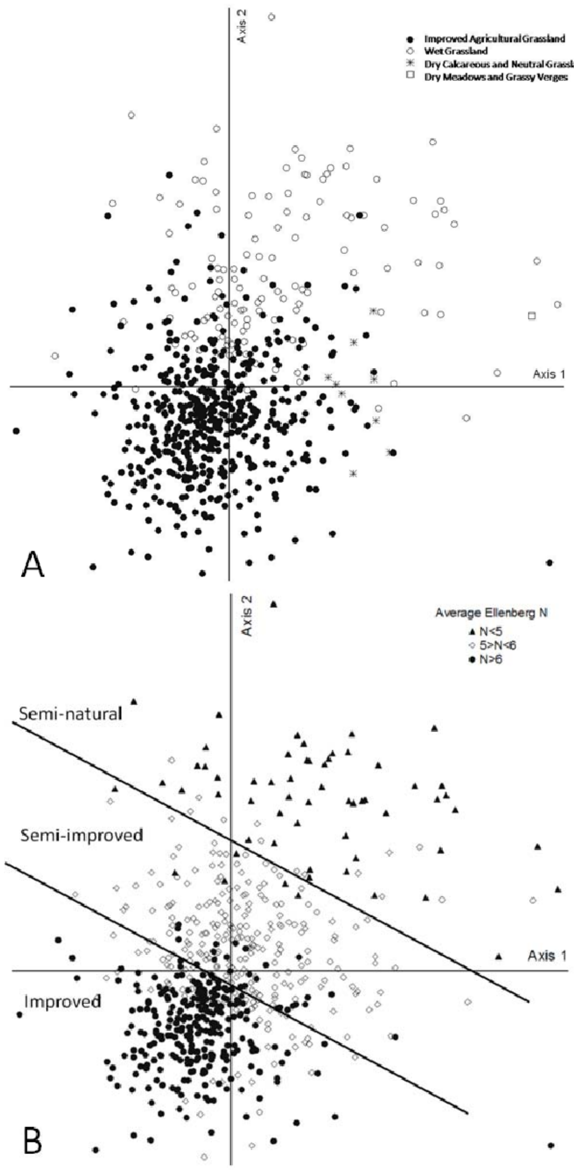

Figure 1. NMS ordination A) with habitat types according to Fossitt (2000) and B) with average Ellenberg N for each field.

Results and Discussion

Axis 1of the NMS ordination explained 33.9% of the variation in the matrix and Axis 2 explained 38.9% (Fig 1). The majority of the fields (>70%) were classified as Improved Agricultural Grassland (*sensu* Fossitt, 2000) (Fig1A). However the ordination indicated a continuum from low species richness to high species richness from the bottom-left to the top-right of the ordination. This continuum was reinforced when the Ellenberg N values were overlain on the ordination (Fig. 1B). An intermediate grassland habitat between semi-natural and improved agricultural grassland (Fig.1) was also evident.

Grasslands with an average Ellenberg N value of 5 are considered semi-improved (Robertson *et al.*, 2002). On this basis, the fields were divided into 3 groups: a semi-natural grassland group (Ellenberg N < 4); a semi-improved grassland group (Ellenberg N = 5) and an improved agricultural grassland group (Ellenberg N ≥ 6). Species richness of the fields in each group differed significantly, $F(2, 600) = 131.776$, $P < 0.0001$.

Semi-improved grassland indicator plant species in Britain include *Rumex acetosa, Ranunculus acris, Trifolium pratense*, *Cardamine pratensis, Prunella vulgaris, Achillea millefolium*, *Phleum pratense* and *Anthoxanthum odoratum* (DEFRA, 2005). The occurrence and abundance of many of these indicators in this study showed that they would be suitable indicators of semi-improved grassland for Irish grasslands (Fig. 2). *Rumex acetosa, Ranunculus acris* and *Trifolium pratens*e, *Cardamine pratensis, Prunella vulgaris, Achillea millefolium, Phleum pratense* and *Anthoxanthum odoratum* consistently occurred in the semi-improved grassland group, but occurred in no more than 10% of the improved grassland group. *Plantago lanceolata, Cardamine pratensis, Prunella vulgaris*, *Leontodon autumnalis, Achillea millefolium* and *Phleum pratense* occurred more frequently in the semi-improved grassland group than in any of the other groups.

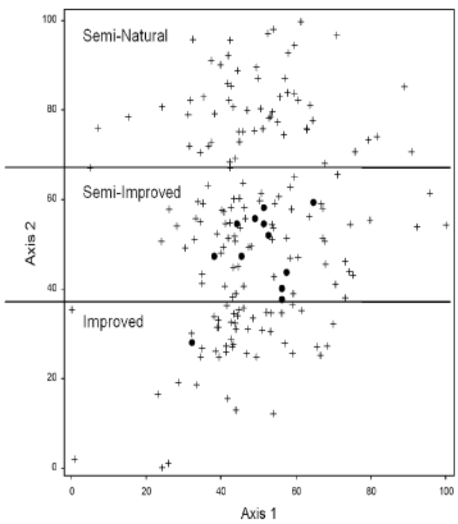

Fig. 2. NMS ordination showing plant species distributions. Black dots represent indicators of semi-improved grassland habitat (DEFRA, 2005).

The evidence supports the inclusion of a 'Semi-Improved Grassland' category in the Irish grassland classification guidelines. The identification of semi-improved grassland areas in Ireland has important conservation implications. Using this refined classification will more accurately quantify grassland biodiversity. For many lowland farms, using this classification acknowledges the higher biodiversity value of these grasslands compared with more intensively farmed fields. On some farms *all* fields previously identified as improved agricultural grassland could now be re-classified as semi-improved grassland fields. This reclassification is important when considering both quantitative measures of agricultural intensification and appropriate targeting of agri-environment schemes. This is because it would provide an important resource for future restoration projects aimed at semi-natural grassland. It would also aid the identification of HNV farmland, particularly at a stage when a farm has already been identified as having HNV farmland potential. At this stage the field-by-field approach would provide the basis for identifying a grassland-based HNV farming system.

Acknowledgements
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High nature value meadows: results from a national grassland survey

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Introduction

A comprehensive study of semi-natural grassland habitats is currently being carried out in Ireland (O'Neill *et al.,* 2009). In addition to classifying all surveyed grasslands within a Fossitt (2000) habitat category, the study is developing a classification for Irish semi-natural grasslands. Meadow systems comprise a significant part of this study, and many can be considered to be of high nature value (HNV) by virtue of their species diversity and structure. A further aim of the study is to assess grassland habitats that correspond to an EU Habitats Directive Annex I habitat; these may be considered as a particularly diverse sub-set of HNV grasslands with specific characteristics in terms of their species composition and structure. The two Annex I meadow habitats recorded in Ireland are the wet meadow habitat *Molinia* meadows (6410) and the dry meadow habitat Lowland hay meadows (6510). Under the EU Directive, Ireland has a responsibility to protect these habitats and maintain them at a favourable conservation status.

Materials and Methods

Field methodology

A 2 m x 2 m relevé was recorded from within each grassland habitat located within a site. Multiple relevés were recorded where there was significant variation in the floral composition within a habitat type. For each relevé, the grid reference, topography, altitude, slope and aspect were recorded and a soil sample was collected for analysis of pH, organic content and total phosphorus. Sward characteristics such as forb to graminoid ratio and sward height were also noted. Cover in vertical projection for each vascular and bryophyte species was recorded on the Domin scale, as were other general parameters such as bare soil, leaf litter, total field layer and total bryophyte cover. For full details of the methodologies used see O'Neill *et al.* (2009).

Vegetation analysis

Outlier analysis was carried out on the 2007-2010 relevé dataset using PC-Ord 5. Relevés outside the remit of the study were omitted and all remaining relevés were analysed using the two complementary statistical techniques of Hierarchical Polythetic Agglomerative Cluster Analysis and Indicator Species Analysis (O'Neill *et al*., 2009).

Management data

From 2010 the recently devised methods for scoring impacts and activities within an Annex I habitat was utilised (Ssymank, 2010).

Results and Discussion

Since 2007, 3,078 relevés have been recorded in 783 sites covering 17,814 ha of semi-natural grassland, much of which is of HNV. The 783 sites are spread over 12 counties and all four provinces of Ireland. A total of 3,024 relevés were analysed to produce a classification of Irish grasslands that recognises 34 grassland vegetation types. The occurrence of the two Annex I meadow communities (6410 and 6510) within the 34 vegetation types was examined. Only those types which had a significant number of relevés classed as Annex I meadows were identified as being important for HNV meadows. In all, 75% (53 of 71 relevés) of relevés of the rarer dry meadow Annex I habitat 6510 were found to occur across four dry grassland types, while 79% (242 of 306 relevés) of relevés of the wet Annex I habitat 6410 were present in seven wet grassland types. These four dry vegetation types (represented by 189 relevés) were therefore taken to include the majority of HNV dry meadow communities and the seven wet types (represented by 735 relevés) to include the majority of HNV wet meadow communities.

The environmental differences between the two meadow types can be largely attributed to edaphic factors. Dry meadows were recorded primarily on well-drained mineral soils (58%) and gleys (26%). Wet meadows were recorded on gleys (61%) and peats (26%). Soils and other parameters are defined for the two types of meadow in Table 1.

Table 1. General relevé data for wet and dry HNV meadows. The main two soil types are shown (WDM=Well-drained mineral) and the mean species richness, grass height (cm), forb height (cm), forb proportion (%) and slope (degrees).

Data type	Dry meadows	Wet meadows
Soils	58% WDM, 26% Gleys	61% Gleys, 26% Peats
Sp. richness	23	23
Grass height	29 cm	41 cm
Forb height	24 cm	25 cm
Forb prop.	47%	31%
Slope	4º	3º

As the data presented show, apart from soil the most pronounced differences between wet and dry meadows are the increased proportion of forbs in dry meadow communities, due to a high incidence of species such as ribwort plantain (*Plantago lanceolata*) and yellow rattle (*Rhinanthus minor*), and the generally taller grass sward in wet meadows, often due to the presence of purple moor-grass (*Molinia caerulea*).

The differences between the Annex I meadow (6410 and 6510) communities and the non-Annex HNV meadows are subtle, with the Annex I meadows tending to have taller forb height and a higher proportion of forbs (Table 2). The species richness of *Molinia* meadows (6410) is noticeably higher than the non-Annex HNV wet meadows.

Table 2. Comparison of wet and dry non-Annex HNV meadows with their corresponding Annex I habitat relevé data. Shown are mean species richness, grass height (cm), forb height (cm), forb proportion (%), and slope (degrees)

Data type	Dry meadows		Wet meadows	
	HNV	6510	HNV	6410
Sp. richness	23	23	22	25
Grass height	29cm	29cm	40cm	43cm
Forb height	22cm	28cm	24cm	28cm
Forb prop.	43%	58%	29%	37%
Slope	5º	2º	3º	3º

Although it was expected that mowing would be the most common management type for HNV meadows, this was not always the case. For Annex I dry meadows (6510) they were always mown, or mown in combination with grazing. However, Annex I wet meadows (6410) were only mown, or mown in combination with grazing in 26% of cases (Table 3). Mowing is more prevalent in all sites than *Molinia* meadows (6410), which does raise issues regarding the future of this important habitat. The fact that 19% of *Molinia* meadows are abandoned is also of some concern as meadows require management to maintain them.

Table 3. Management data for all 2010 grassland sites (n=203), Annex I habitats 6410 (n=31) and 6510 (n=6).

Management	**All sites**	**6510**	**6410**
Mowing only	5%	50%	7%
Grazing only	59%	0%	55%
Mowing & grazing	29%	50%	19%
None recorded	7%	0%	19%

A decline in the cutting of HNV wet meadows has probably occurred over the last 50 years due to increased mechanisation and the difficulty of cutting in wet environments with heavy machinery.

It is generally accepted that many former HNV meadows have been improved over the last 50 years through a combination of drainage, fertiliser application, and the planting of high yielding species such as *Lolium perenne*. The more productive systems that have replaced HNV meadows have a lower species diversity and never equate to the ecologically important Annex I wet and dry meadows. Although HNV meadows are less productive, there is anecdotal evidence that the species-rich hay cut from them fetches a higher price, which would off-set some losses in yield. However, the lower yields of HNV and Annex I meadow systems, compared to improved agricultural swards, necessitates some grant scheme or other incentives for farmers if these important meadow systems are to be maintained.

Conclusions

Our data have shown that there is a diversity of HNV meadow communities in Ireland, with four types of dry meadow and seven types of wet meadow identified. Annex I meadow habitats are rare in Ireland, with only 12% of all relevés recorded between 2007 and 2010 classed as Annex I Lowland hay meadows (6510) or *Molinia* meadows (6410). Dry HNV meadows are even rarer than wet HNV meadows, probably due to the ease with which these meadow systems can be improved. Lack of appropriate management raises concerns about the future prospects of many *Molinia* meadows. Of particular concern is a change in the structure and functions of the habitat which will have negative implications for plant species diversity and fauna, such as the EU Annex II species marsh fritillary.

Acknowledgments

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Identification and distribution of HNV farmland in Germany

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Introduction

In early cartographical estimations of the potential amount of High Nature Value (HNV) farmland within the EU (e.g. EEA 2004), Germany (as well as Northern France, Denmark, and the Low Countries) showed almost no such farmland at all. The data sources available on the EU level for these estimations (e.g. CORINE land cover data) clearly failed to discern potential HNV farmland in these regions, where intensely used agricultural areas are interspersed with relatively small remnants of species-rich, often traditionally used plots. In order to correctly estimate the amount of HNV farmland in Germany, a working group comprising of federal and regional conservation and agricultural authorities and three private environmental consultancies, decided in 2008 on developing a nation-wide sampling programme. This programme was to yield the data necessary to report on the HNV farmland indicator (baseline indicator 18) under the current EU Common Monitoring and Evaluation Framework (CMEF). A first round of surveying took place in 2009 with repeat surveys having taken place in 2010 and being planned for 2011 to 2013.

Materials and Methods

The German HNV farmland survey uses a sample based approach which is structurally similar to the British Countryside Survey (Carey *et al*., 2008). Fieldwork, to locate HNV farmland structures, took place on square sample plots of 1 km² area. Field workers were furnished with a manual, comprising of keys to identify different types of HNV farmland and to evaluate their “nature value” on a three-tier scale.

Sampling design

We used a sample design which had been developed by the Federal Statistical Office in conjunction with the Federal Agency for Nature Conservation for conservation surveys in general and has been used for several years for the German Common Birds Census (GCBC) (Mitschke *et al*., 2005). The sample consists of 1,000 squares of 1km² size and is stratified using 21 so-called ecoregions, i.e. areas defined by a combination of soil, vegetation, climate and elevation characteristics (Schröder and Schmidt, 2001), and six main land use categories to define the strata. Financial constraints forced the removal of 118 squares with more than 95 % non-agricultural use (mainly woodland and settlements) from the sample. On the other hand, two *Länder* decided to increase their samples and use them for other purposes than HNV farmland monitoring as well, resulting in an overall sample of 916 squares for the field season 2009.

Field surveys

Field work in 2009 was commissioned to experienced ecological surveyors in lots comprising 10 – 15 squares each. Most of the field work took place in May to July 2009 with additional field work up to September 2009. The field manual defines 16 types of HNV farmland including: species rich arable, grassland, orchards, vineyards, and fallow land on the one hand, and 10 types of landscape elements such as hedgerows, copses, dykes, reedbeds, sunken lanes, dry stone walls one the other hand. In addition, all habitat types listed on Annex I of the EU Habitats directive are counted as HNV farmland elements, if they are dependent on at least occasional agricultural use (e.g. type 5130 “Juniperus communis formations on heath”).

Two sets of keys were used to identify HNV farmland in the field. For arable, grassland, orchards, vineyards, and fallow land, lists of indicator taxa were used, comprising 12 (vineyards) to 38 (grassland) taxa each. Taxa were either species (e.g. Great Burnet *Sanguisorba officinalis* for grassland), genera (e.g. Poppy *Papaver sp.* for arable) or morphospecies (e.g. “small yellow-flowered clover” for grassland). An area was identified as HNV farmland when at least four of the above indicator taxa were found within 1 m on both sides of a 30 m transect in the area. For landscape elements, a qualitative key was developed using mainly structural criteria such as width and number of woody plant species for hedgerows.

All HNV farmland elements found in the field were sorted in three categories of “moderately high nature value”, “very high nature value” and “extraordinarily high nature value”. This assessment used the criteria mentioned above with e.g. the levels for grassland being defined by 4-5, 6-7 and 8 and more indicator taxa within the 30 m transect.

Field data were digitized as polygons using areal photographs of 1:5,000 scale for boundary definition. HNV type and nature value were stored in a database for each polygon, as were all data on indicator taxa found on each transect.

Results and Discussion

In all squares, 43,370 HNV farmland parcels and elements were found, comprising an area of 13,144.65 hectares. Species rich grassland was the dominant HNV farmland type with 4,328.26 hectares (32.9% of the total), followed by hedgerows (955.90 hectares or 7.3%) and species-rich arable (757.99 hectares or 5.8%).

These raw numbers, however, tell relatively little about the proportion of HNV farmland on all agricultural area. An estimation of the proportion of HNV farmland on agricultural area (AA) has to consider the sample stratification, including the fact that some *Länder* increased the sample size. Taking these factors into account, an estimate of 25,103.90 km² HNV farmland for the whole of Germany was calculated, which translates into 13.0% (with an absolute sampling error of ± 0.4%) of agricultural area. Nature value of HNV farmland is spread unequally with 6.3% ± 0.3% of AA being of "moderately high nature value", 4.5% ± 0.2% of "very high nature value" and the remainder of 2.1% ± 0.1% of "extraordinarily high nature value". The estimates for the different HNV farmland types are collated in Table 1.

Table 1. Proportion of different types of HNV farmland on agricultural area of Germany. Abbreviations: Prop. AA = proportion on agricultural area, a.s.e = absolute sampling error.

HNV farmland type	Prop. AA	a.s.e.
Arable	1.5%	0.1%
Grassland	5.7%	0.3%
Fallow	0.8%	0.1%
Orchards	0.7%	0.1%
Landscape elements	4.3%	0.1%

Most of the HNV landscape elements amount to less than 0.5% of AA, the exceptions being hedgerows with 1.1% ± 0.04% and dykes with 0.5% ± 0.03%. Vineyards could not be adequately sampled in 2009 since field work started only in May, when too many of the geophytes, which are typical for traditionally used and species-rich vineyards, were past flowering.

The estimated amount of HNV farmland differs strongly between the ecoregions used in sample stratification. Highest proportions (20.4 to 23.7%) were found in the higher parts of mountains in southern and central Germany (e.g. Black Forest, Bavarian/Bohemian Forest, Harz) and in the lakes region in north-eastern Germany. Ecoregions with the lowest proportions of 7.0 to 8.4% are situated in the heavily populated Ruhr and Rhein/Main Valleys and in parts of Germany with rich soils and long traditions of large-scale agriculture.

On the level of the ecoregions, the proportion of total HNV farmland is strongly correlated with the proportion of HNV grassland (Spearman's rank correlation test, $\rho = 0.83$, $p<0.001$) which in turn is negatively correlated with the amount of agricultural area on total area of the ecoregion ($\rho = -0.53$, $p<0.05$). On the other hand grassland shows no significant correlations with any of the other HNV farmland types, either singly or grouped together.

Generally, these results confirm some key assumptions about the situation of HNV farmland in Germany. Grassland seems to be the most important factor, since more than 43 % of all HNV farmland is grassland and since grassland tends to be more species rich in areas where there (still) is a lot of it. Also, mountainous regions, with relatively high woodland amounts and a low proportion of agricultural area, tend to have the highest HNV farmland shares.

Conclusions

The sampling programme outlined here allows an estimation of the amount of HNV farmland in regions were such farmland is predominantly found in intensely used areas. These HNV farmland elements contribute decisively to local biodiversity. In the future, the monitoring of the change in their distribution and total amount under increasing pressure from agricultural intensification will be the most important task of the monitoring programme.

Acknowledgments

We wish to thank all representatives of the *Länder* conservation and agriculture authorities who in the introduction of the monitoring programme and especially Rainer Oppermann (IFAB) and Alfons Krismann (ILN) who developed crucial aspects of the methodology with us.

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Habitats in the Irish farmed landscape

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Introduction

It is now widely accepted that the continued existence of many species, including those which are still relatively common, is heavily dependent both on the maintenance of diverse agricultural practices, and the retention of a matrix of semi-natural habitat within the farmed landscape (Donald and Evans, 2006). Agricultural communities are coming under increasing pressure to justify the continuation of direct payments such as the Single Payment Scheme, through the provision of public goods. Farmland habitats and the biodiversity which they support represent one such public good.

However, surprisingly little attention has been afforded to the classification and quantification of habitats at farm scale in Ireland. This study seeks to address this deficiency through the provision of a baseline dataset of farmland habitats against which the relationships between geographical location, farming practice and AE Scheme participation can be assessed. Provision of this baseline data also creates the potential to allow evaluation of the likely influence of future structural changes in Irish agriculture and production systems, ongoing development of agri-environmental measures and potentially the longer-term effects of global warming on Irish farmland habitats.

Materials and Methods

Habitat surveys were undertaken on 118 predominately pastoral farms. Farms were located in three regions i.e. Sligo-Leitrim (n = 39), Offaly-Laois (n = 40), Cork (n = 39). This constitutes a north-south geo-climatic gradient across the country, with increased farm management intensity and a converse decrease in REPS participation. Five 10km2 were randomly selected from each region during 2007 and 2008. The four central 1km squares within each 10km square were identified and a farm, located as close as possible to the middle of each of these central squares was randomly selected.

Sampled farms were classified by REPS participation status, farm system i.e. Dairy, Beef, Suckler and ‘Other’ (which included a miscellany of essentially extensive management types), and stocking rate (LU ha^{-1}).

The type and extent of all habitats was recorded onto farm maps. Classification of habitats principally followed the designations of Fossitt (2000). However, grassland fields on each farm holding were walked and a comprehensive, though not exhaustive visual assessment of component plant species was recorded according to the DAFOR scale. Fields were subsequently assigned to the following classification of agricultural grassland types:

a) Intensively managed grassland (GA1): *Lolium perenne* was ≥ 70% of sward cover.
b) Improved grassland (Grade 1) (GA1): *L. perenne* may have been dominant but a minimum of four other species were also found to occur frequently within the sward.
c) Improved grassland (Grade 2) (GA1): *L. perenne* only of occasional/rare occurrence, if present within the sward. These grasslands typically contained ten to fifteen frequently occurring species.
d) Transitional grassland-scrub (not recognised): Significant incidence of woody species such as: *Prunus spinosa* and *Ulex europaeus.*
e) Species rich wet grasslands (GS4): An abundance of frequently occurring herbs e.g. *Cirsium palustre*, *Lychnis flos-cuculi, Angelica sylvestris* and *Filipendula ulmaria* etc.
f) *Juncus* dominated wet grasslands (GS4).
g) Wet grassland (GS4)- *Juncus* spp frequent but not dominant with a number of grass and herb species. Generally evidence of improvement
h) Callows (seasonally inundated) (GS4)

Farm habitats were digitised onto OSI orthophotographs (2004) and their extent quantified using ArcGIS software. Proportion of the surveyed farm area under different habitat types were computed and categorised as follow:

a) Agriculturally productive
b) Agriculturally marginally productive
c) Non-cropped semi-natural habitat
d) Other

Data analysis

Generalized Linear Model analysis (GLMs) was undertaken to investigate the influence of Region, Farm System and REPS participation status on the area classified under each of the broad habitat categories. Principal Components Analysis (PCA) was used to investigate the relationship between the environmental variables and the proportion of farm area under individual habitat types.

Results and Discussion

Collectively, the 118 farms accounted for 5,673 ha with an average farm size of 48 ha (± 3.03 s.e.). Habitat surveys were undertaken on 3,688 ha with an average area of 31 ha (± 1.88 s.e.) surveyed per farm.

A breakdown of the proportion of farm area classified as a) Agriculturally productive, b) Agriculturally marginally productive, c) Semi-natural and d) Other, across the three study regions, four farming systems according to their REPS participation status, is presented in Fig. 1. This indicates that greatest difference in farm habitat structure was primarily due to the differing ratios of agriculturally productive land to marginally productive land recorded within each of the three study regions, with a greater proportion of marginally productive land recorded in Sligo compared with Cork (Fig. 1). However, this regional effect also incorporates the farm system effects, as farm system was found to show a high regional dependency (Fig. 2). No relationship was found between farm habitat composition and REPS participation status.

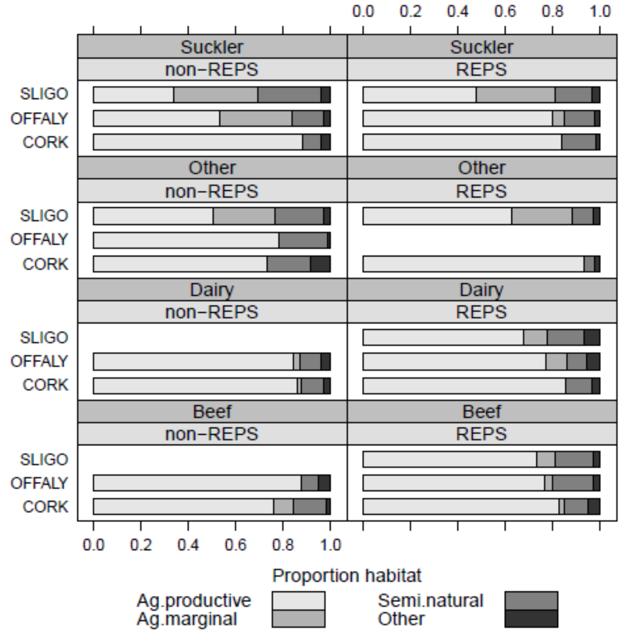

Fig. 1. Habitat type as a proportion of surveyed farm area across region, farm system and REPS participation.

The PCA biplot of habitats and environmental variables is presented in Fig. 2. This shows a close association between dairy, non-REPS, increasing stocking rates, and the Cork region. Intensively managed grassland was the only habitat type whose incidence showed close association with these variables. Most of the natural / semi-natural habitat types were closely associated with each other and with the Sligo region and suckler farming systems, with REPS participation and duration also ordinating in this direction. Additional farm system types such as ‘other’, ‘beef’ and ‘sheep’ ordinate separately from both dairying and suckler systems, indicating that their habitat composition tends to be different. In general these appear to represent a ‘middle ground’ in terms of farm management intensity. Grade 2 grassland was found to ordinate in their general direction.

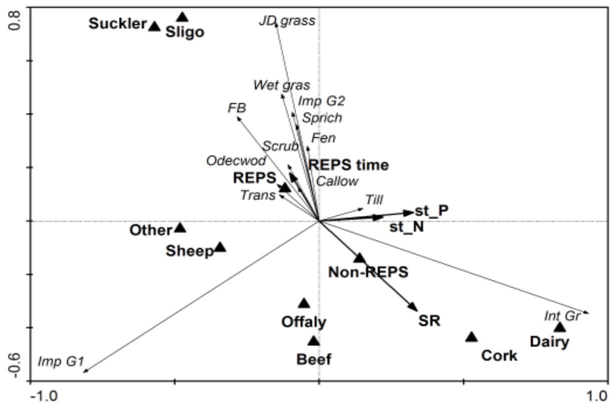

Fig. 2. PCA biplots of farm habitat composition with passive projection of management variables, nominal variables are represented as centroids.

Habitat types: JD grass, *Juncus* Dominated Wet Grassland; Wet gras, Wet Grassland; Imp G2, Improved Grassland Grade 2; Sprich, Species Rich Wet Grassland; FB, Field Boundaries; Trans, Transitional grassland to scrub; Till, Tillage/Arable; Int Gr, Intensive Grassland; Odecwood, Old Deciduous Woodland; Imp G1, Improved Grassland Grade 1; SR, Stocking Rate; st_N, *Standardised N* farm input level; st_P, *Standardised P* farm input level.

Conclusions

These results indicate that the diversity and distribution of farmland habitats is largely dependent on region and farming system. Despite the inseparable nature of these variables, our results indicate the overall need for targeting and customisation during the development of future AE policy in order to ensure maximum ecological effectiveness. Our data also represent a hugely important resource in the justification for continued SPS payments, and indicate that a much higher proportion of ecologically important habitat types have been retained on Irish farmland when compared with many other EU countries (see Manhoudt and de Snoo, 2003). However, these results also indicate the inadequacies of the current habitat classification guide (Fossitt, 2000) and demonstrate the need to address these inadequacies.

Acknowledgments

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Pollinators and pollination networks in Irish farmland: implications for conservation of pollination services

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Introduction

Bees and other flower-visiting insects play an important functional role as pollinators for both crops and wild plants worldwide. Hence they provide a key ecosystem service. However, declines in both the abundance and species richness of pollinating insects have been recorded in Europe, North America and Asia (e.g. Williams and Osborne, 2009). These declines are thought to be primarily due to habitat loss, fragmentation and degradation (Potts *et al*., 2010), often due to agricultural intensification. Changes in agricultural practices, including increased mechanisation, removal of semi-natural features such as hedgerows, simplification of landscapes, widespread use of agrichemicals, increased stocking densities, reliance on a low number of commercial plant strains, frequent reseeding and increased silage cutting, have resulted in loss of forage, nesting and mating sites for pollinating insects (Potts *et al*., 2010). In Ireland, some species of bumblebee (*Bombus* spp.) have declined and shifted westward to the extremity of their ranges (Fitzpatrick *et al*., 2007), most probably because of changes in agricultural practices. However, the effects of land use change on other pollinating taxa, and on the interactions between flower visitors and the plants they pollinate, are not well understood. In particular, the effects of current conventional farming practices compared with alternatives such as organic farming and cultivation of bioenergy crops, are not well understood (Dauber *et al*., 2010; Power and Stout, 2011). In this paper, we compare data from surveys of flower-visiting insects and plants from Irish farmland and semi-natural grasslands across the country, in order to assess pollinator status and to make predictions about potential impacts on pollination services.

Materials and Methods

Surveys of plants and pollinators and their interactions were made in a total of 65 sites across central, southern and eastern Ireland: 25 sites were pastures (10 organic, 15 conventional), 20 were semi-natural grasslands, 10 were tillage crops (winter wheat and oil seed rape), and 10 were energy crops (*Miscanthus*). Surveys were conducted during a two year period (2009-2010), although each site was surveyed in one year only. Flower-visiting insects were sampled using transect walking methods. Flowering plant surveys were conducted using transects and quadrat methods.

Interaction networks

Data matrices of the total number of interactions between plants and flower visiting insects observed in each site were constructed. Bipartite visitation graphs and network descriptors were calculated for each site using the "networklevel" command in the bipartite package (Dormann *et al*., 2009) in R (version 2.11.1, R-Development-Core-Team 2007).

Data analysis

Data were standardised for sampling effort (per unit time for insect observations and per unit area for floral observations) and compared among farming types. Relationships between insect and plant variables were tested using Pearson's Product Moment Correlation Coefficient.

Results and Discussion

Of the 6,723 insects recorded visiting flowers in the sites, 57% were hoverflies (Diptera, Syrphidae), 30% bumblebees (Hymenoptera, Apidae), 4% other bees (Hymenoptera, Apidae) and 8% butterflies (Lepidoptera). Flower visiting insects were more abundant and species rich in *Miscanthus* (M), semi-natural grasslands (SN) and oilseed rape (OSR) sites and least abundant and least species rich in wheat crops (W) (Figure 1a and b). Flower species richness was highest in SN (Figure 1c). Insect and flower species richness were significantly positively correlated with one another across all sites ($p<0.01$).

Insect-flower interaction network parameters did not vary greatly among site types (Table 1). However, low animal-plant ratios (which are typically approximately 4:1 in other networks) suggest that there is little insect redundancy in networks which are therefore less likely to be tolerant to extinction (Memmott *et al*., 2004). Low levels of connectance are typical in plant-pollinator interaction networks, but less well-connected networks are less robust to species loss. Interaction strength asymmetry was highest in SN and pastures (P). This parameter measures the imbalance between interaction strengths of a species pair (Dormann *et al*., 2009), with specialist flower visitors interacting with generalist plants (Bascompte *et al*., 2006). Networks in all sites were quite highly nested (this parameter is measured as departure from perfectly nested matrix = 0), which suggests that less connected species interact with a core of highly connected species.

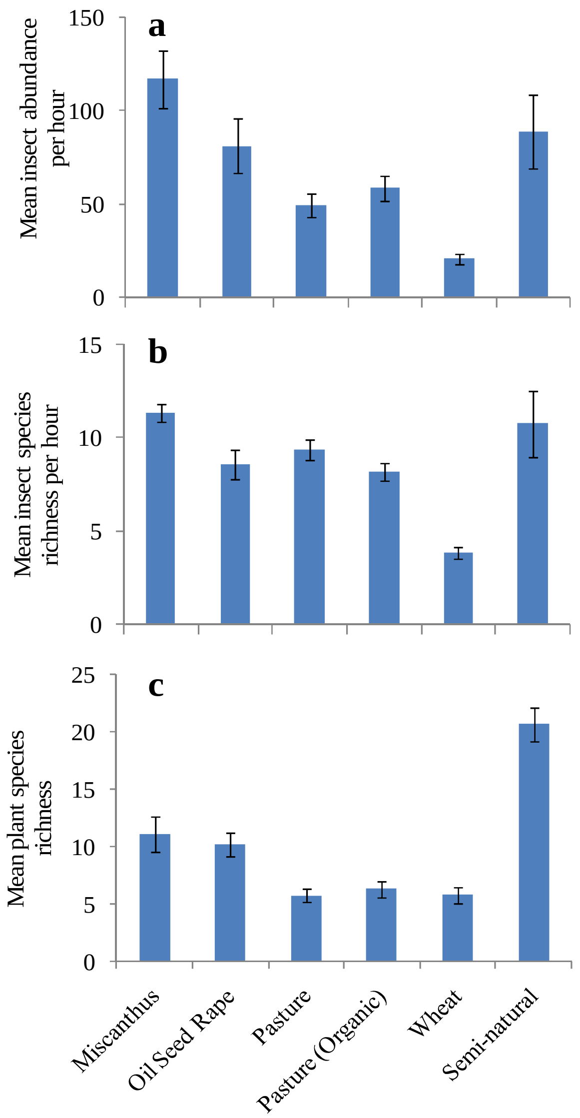

Figure 1. Mean (± SE) insect abundance (a), insect species richness (b), and plant species richness (c) per site type.

Table 1. Mean network parameters (AP = animal plant ratio, QC = quantitative connectance, ISA = interaction strength asymmetry, N = nestedness) per site type (M = *Miscanthus*, OSR = oilseed rape, P = pasture, PO = organic pasture, W = wheat, SN=semi-natural grassland).

Site	AP	QC	ISA	N
M	1.14	0.14	0.03	21.5
OSR	1.29	0.15	0.06	22.9
P	1.51	0.19	0.13	21.2
PO	1.32	0.19	0.10	22.5
W	1.82	0.20	0.04	26.1
SN	1.44	0.11	0.14	20. 5

Conclusions

Wheat crops appear to provide the least resources for pollinating insects, whilst semi-natural sites contain the greatest floral diversity and higher insect diversity and numbers. *Miscanthus* crops appear to be relatively rich in pollinating insects, possibly because of their perennial, low-input nature. However, low insect redundancy and robustness in all networks suggests that insect-flower interaction networks in all sites are vulnerable to insect species extinction, i.e. if insect species are lost from sites, this could have knock-on impacts on the plants they pollinate. Conservation measures to increase both floral resources and nesting opportunities would benefit pollinating insects, and improve community stability. For example, sensitive hedgerow management; reducing/eliminating herbicide usage, especially on uncultivated areas; sowing clover into pastures (and allowing plants to flower); cultivating wild-flower areas; and cutting for hay/silage later in the year after flowering has ceased. Whether these measures will improve pollination services remains to be resolved.

Acknowledgments

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Monitoring of the Agri-environment Programme within the Northern Ireland Rural Development Programme 2007-2013

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Background

Since the introduction of agri-environment (AE) schemes in Northern Ireland, the Department of Agriculture and Rural Development (DARD) has been obliged to monitor scheme performance in relation to environmental objectives. Long-term scientific monitoring of AE schemes has been carried out since 1993 (e.g. McEvoy *et al*., 2006) Previous schemes have now been replaced by the Northern Ireland Countryside Management Scheme (NICMS) which opened in 2008 (DARD, 2008). The NICMS, together with the Organic Farming Scheme (OFS), form the AE programme within the Northern Ireland Rural Development Programme (NIRDP) 2007-2013.

All EU member states are required to monitor RDPs using the Common Evaluation and Monitoring Framework (CMEF). The CMEF specifies the use of common indicators that must be included and monitored. Member states may also establish a limited number of programme specific additional indicators. These should provide information that both identifies the programme efficacy and informs fine tuning and development of measures for future AE programmes. The additional indicators and associated targets for the AE programme in Northern Ireland were developed by DARD in conjunction with stakeholders. A 3-year research and monitoring project based on these indicators commenced in 2010. This paper briefly discusses aspects of current monitoring relating to biodiversity on farmland under AE scheme agreement.

Biodiversity indicators

Farmland birds

Using existing baseline data, farm-scale surveys will measure changes in the abundance of lapwings and seed-eating farmland birds (including yellowhammer) over a 5 year period on AE farms and non-AE farm controls. Field-scale evaluations of the usage of AE options, such as conservation cereal and wild-bird cover, are also being carried out to assess the benefits for seed-eating birds in summer and winter. The survey work commenced in November 2010 and will continue until March 2012.

Irish hare

This study will provide information on how the 'delayed cutting and grazing option' within the NICMS may influence leveret survival. This option provides farmers the opportunity to be compensated for delays in the cutting of silage or grazing of livestock in pastures. This should benefit Irish hares in terms of reduced disturbance during the peak of the breeding season (April-June). The abundance and activity of hare populations will be assessed on a sample of AE farms and suitable controls during spring/summer 2011 and 2012. Juvenile hares will be tagged to enable survival estimates to be calculated and the effectiveness of the option to be assessed.

Invertebrate species

Specific AE scheme options will be sampled in summer 2011 and 2012 to assess the abundance and diversity of particular invertebrate groups compared to suitable controls. This will include pitfall trapping of ground-dwelling invertebrates on ungrazed grass margins and surveys of aquatic macro-invertebrates in waterways associated with enhanced riparian zones. Further research on the utilisation of prescribed AE options by other invertebrate groups such as bumblebees and butterflies may also be undertaken should option uptake be sufficient.

Plant species

Plant monitoring will be based on resurveys of existing AE scheme habitats from which baseline data was recorded in 2002/03 (Flexen et al., 2004). This will involve the sampling of permanent quadrats on species-rich grassland, farm woodland and peatland habitats between May and September 2011/12. Changes in species diversity and vegetation composition due to scheme management over a 9/10 year period will be determined. Habitat condition will also be assessed using specific criteria including vegetation structure and indicator species.

Hedgerows

A survey of hedgerows on a sample of NICMS agreement farms was carried out in summer 2010 (Flexen *et al*., 2011). This included both established hedges and those recently subject to restoration or newly planted. Data were recorded for a number of attributes including dimensions, integrity and woody species composition. The aim of this baseline survey was to provide information on the current management and condition of hedgerows on scheme farms. Condition assessment of established hedges in terms of structure and conservation value was also been undertaken. A future resurvey will assess the effectiveness of

NICMS hedgerow management options and determine if the targets for the length and condition of hedgerows under the scheme have been met.

Conclusions
This research and monitoring project will assess the effectiveness of AE schemes in enhancing farmland biodiversity and delivering on option specific targets in Northern Ireland. The results will be used to recommend how future AE programmes could be refined and improved through modification of existing options or the development of new options.

Given the considerable public expenditure on agri-environment programmes throughout member states, it is important that they are seen to be working and are attaining their targets. This is especially the case as increasingly AE schemes are being identified as a mechanism for assisting with the recovery and management of priority species and habitats.

Currently, approximately 42% of the agricultural land area in Northern Ireland is under AE scheme agreement, with a target of 50% by 2013. This represents a very real opportunity to deliver important benefits to farmland biodiversity through the implementation of programmes and options that can deliver over a large spatial scale and potentially at the population level. The current research and monitoring programme is critical to understanding how current options are working and how future AE policy and options can be defined.

Acknowledgments
The authors wish to thank DARD for funding the AE Monitoring Programme. Farmland bird surveys are being carried out in collaboration with the RSPB.

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Linking catchment activities with conservation status of freshwater pearl mussel populations as an aid to prioritization of rehabilitation measures in Ireland.

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Introduction

The freshwater pearl mussel, *Margaritifera margaritifera*, and the Nore pearl mussel, *Margaritifera durrovensis* are endangered throughout their world ranges and are protected under Irish and European law. High water quality and an absence of fine sediment infiltration is of vital importance in maintaining sustainable *Margaritifera* populations, as clean, stable substrate are required for juvenile mussels to survive. Individuals can live to over 100 years of age, but this longevity can mask long term declines, as most populations in the world now consist only of adult mussels with no sustainable juvenile recruitment occurring to replace the aging adults. Juvenile *Margaritifera* are much more sensitive than adults, as they spend their first five years completely buried in the river bed substrate, where they require high oxygen exchange, a commodity that is lost when river bed substrates become clogged through fine sediment infiltration or eutrophication (Moorkens, 1999).

The Republic of Ireland has carried out wide ranging studies which have led to the development of 27 sub-basin management plans in order to protect and restore the Natura 2000 populations of *Margaritifera* for which it has responsibility under the EU Habitats and Species Directive (the 27 draft Freshwater Pearl Mussel Plans can be downloaded from WFD Ireland[1]). The conservation status varies greatly among the 27 populations, and they are approximately equally divided into 5 different categories. The status categories were correlated with levels of pressures found in the catchment studies in order to establish the likely cause and effects of freshwater pearl mussel decline and determine a strategy for measures to lead towards recovery.

Materials and Methods

The 27 populations that belong to the 19 candidate Special Areas of Conservation (cSAC) for *Margaritifera* cover the species range in the Republic of Ireland (Figure 1).

Surveys for *Margaritifera* included a) an assessment of the distribution of mussels within the designated river systems, b) an estimate of the numbers of adult mussels and their densities within each population, c) an estimate of recruitment success from size profiles measured from 0.5m x 0.5m quadrats at various locations of potential juvenile habitat within the population and d) adult mussel counts from permanent repeatable transects used in the ongoing monitoring of these populations. Methods followed Moorkens (2011). Redox potential differences were measured between the open water and the water within the substrate 5cm below the river bed surface according to the methodology of Geist and Auerswald (2007).

The sub-basin plans utilised Geographical Information Systems (GIS) datasets, generated through the various elements and Programmes of Measures Studies (PoMs) of the Water Framework Directive. Water quality data was obtained from the local authorities together with the EPA, and CORINE land cover maps were provided to the River Basin District Projects under licence agreement from the EPA. Livestock Unit Density maps were provided by the Department of Agriculture, Fisheries and Food (DAFF) to the River Basin District Projects, to facilitate preparation of the RBD characterisation reports. It is based on the CSO data from 2002 and provides the average LU densities on a DED basis. Whilst this data set is nine years old, it provides a general guide to the level of livestock unit density in each sub basin catchment rather than absolute values on a field by field basis. Forestry coverage details were made available through the Western RBD[2] Forestry and Acidification PoMs. Finally, locations and numbers of on-site waste water systems were assessed for % cover in each of the 27 *Margaritifera* SAC catchments again from the Western RBD PoMs.

Results

Populations were ranked following the *Margaritifera* surveys into 5 categories with roughly even numbers of populations in each category (Table 1). Catchment characteristics and catchment land use were analysed by status category. The best remaining populations are associated with small catchments, with low intensity land use and with lakes upstream (Table 2).

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[1] http://www.wfdireland.ie/docs/5_FreshwaterPearlMusselPlans/Freshwater%20Pearl%20Mussel%20Plans%20March%202010/

[2] http://www.wrbd.ie/index.htm

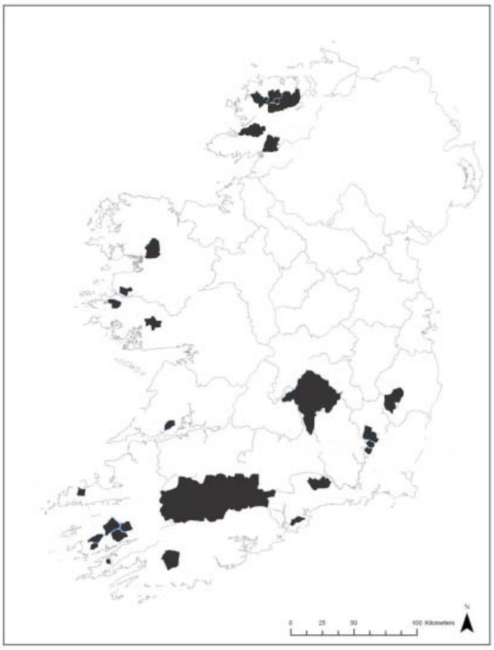

Figure 1. Map of Ireland showing locations of *Margaritifera* cSAC Catchments.

Table 1. Ranking system used to divide *Margaritifera* SAC Catchments into status groups from 1 (best) to 5 (worst).

Ranking	Definition	Number of catchments (% of catchments)
1	Very large populations of adults (200,000+), all ages of juveniles, some juveniles in more than one area	5 (18.5%)
2	Large widespread populations of adults, or smaller numbers in good but restricted habitat, some juveniles in more than one area	5 (18.5%)
3	Large numbers of adults, some decline from larger numbers evident, few juveniles	6 (22.2%)
4	Small numbers adults from historical evidence (<20,000), very few juveniles	5 (18.5%)
5	Very poor population of adults (<10,000), few or no juveniles	6 (22.2%)

The average sizes of the poorest status catchments are on average eight times larger than those of the best status catchments. Low intensity land use cover was estimated from the CORINE database, and in Ireland this includes peat bogs, natural grassland, moors and heathland, broad-leaved forests, transitional woodland scrub, inland marshes, bare rock and sparsely vegetated areas.

The average percentage of these combined categories within a catchment for the highest status populations was 91.85%, compared with only 33.85% total for these combined categories in SACs in the worst status category.

Table 2. Status of *Margaritifera* population compared with size of catchment (km²), land use in catchment and presence or absence of a lake upstream (* = significant at 0.05; ** = significant at 0.01 by status compared with expected mean of all rivers).

Rank of popn. status	No. of catchments	Average size of catch-ment (km²)	Average % extensive land cover (CORINE)	Number (%) of catchments with lakes upstream
1	5	72	91.85%	5 (100%)
2	5	117	80.85%	5 (100%)
3	6	86	77.47%	5 (83%)
4	5	158	33.6%	1 (20%)
5	6	613	33.85%	1 (17%)
Total (mean)	27	(206)	(48.31%)	(37%)
Sign.		**	**	*

The corollary values of 8.15% (for the best status catchments) and 66.15% (worst status) were found for intensive land use categories, which included urban land uses, arable and intensive pastures, and coniferous forestry plantations. The top 14 best status catchments all have lakes upstream of *Margaritifera* habitat.

These results demonstrate that the species is particularly sensitive to cumulative effects that lead to stepwise increases in fine sediment and/or nutrients. Further analyses of individual pressures confirm that this is so. Table 3 demonstrates that as individual pressures intensify, pearl mussel status drops. The exception is for coniferous forestry, particularly on peat, which is a pressure in the best pearl mussel catchments as well as the poorest. There is some discrepancy between the CORINE data and the forestry data, suggesting that the CORINE dataset may be interpreting some coniferous plantations as broad-leaved forestry.

Table 3. Status of *Margaritifera* population compared with numbers of licensed outfalls, numbers of on-site septic systems, % of catchment with >1.5 livestock units per hectare size and % of catchment (km²) under commercial forestry (* = significant at 0.05; ** = significant at 0.01 by status compared with expected mean of all rivers).

Rank of pop. status	No. of on-site septic systems per km²	Average % of catchment with >1.5 livestock units per hectare	% of catchment (km²) under commercial forestry	% of catchment (km²) with commercial forestry planted on peat
1	2.01	0	8.7	5.63
2	3.4	0	10.6	3.71
3	7	0.04	10.5	4.84
4	9.5	26.1	18.9	2.57
5	8.2	50.2	11.8	3.02
Total (mean)	(6.02)	(15.27%)	(37%)	(3.95)
Sign.	**	**	*	

As the pressures are acting on the river bed substrate quality, two important parameters can be used to assess risk from nutrients and from fine sediment. These are orthophosphate (measured as unfiltered molybdate reactive phosphorus), which is normally the limiting factor in filamentous algal growth and thus the most important nutrient in the assessment of eutrophication, and redox potential loss, which is a proxy measure of the loss of oxygen between the open water and the interstitial habitat where juvenile mussels live. Table 4 shows the results of the analysis of these parameters by mussel population status. Orthophosphate levels rarely exceed the detection limit in the best status mussel populations, whereas there are detectable and sometimes high levels of phosphorus in the poorer status rivers. Similarly, loss of redox potential gets higher as mussel status declines.

Table 4. Status of *Margaritifera* population compared with mean orthophosphate levels (Source; Local Authorities) for 2005 for rivers measured (n rivers=18, n samples =361), and loss of redox potential at 5cm (%) (n rivers =16).

Rank of population status	Mean ortho-phosphate (mg/l P)	Mean loss of redox potential (%)
1	<.005	20.8
2	<.005	22
3	0.007	31.8
4	0.03	31.3
5	0.03	43

Discussion

As the main mechanism for managing catchment protection in Ireland is the River Basin District level under the Water Framework Directive, 27 sub-basin plans have been prepared using the resources and approach of the larger River Basin Catchment Plans. Using the datasets available, and from survey work and walk-over studies, the pressures within each catchment that are negatively affecting the pearl mussel populations, or would negatively affect their return to favourable conservation status, can be assessed, and then measures outlined that need to be taken in order to remove these pressures. In order for the measures to be implemented, they need to be clear in nature, specific in their locations, and the responsibility for their implementation identified.

To build on the information distilled during the sub-basin plan project, the specific pressures and their extent in catchments, along with the likely measures needed to rehabilitate river water and river bed quality, the estimated timescale of rehabilitation and the likely timescale of the extinction of the mussel population were all assessed in order to produce a strategy for prioritisation of effort in *Margaritifera* conservation for Ireland (Moorkens, 2010). The strategy recognised that there is high cost involved in the rehabilitation of sustainable *Margaritifera* habitat. The required result is that rivers are consistently at close to reference level, with no significant loads of nutrients or fine sediments entering the river. For this to be achieved, measures will need to be taken to stop the pressures at source, through de-intensification, or along the pathway between the source and the river, for example through drain blockage, fencing and management of buffer zones. Both types of measures are expensive to undertake, and resources to carry them out are limited.

The strategic approach identified eight catchments that would be likely to provide the best return for investment in terms of current mussel numbers protected, and the ability to return populations to sustainable reproduction levels. A further two catchments were added to cover the Irish range. If strong efforts were made to restore function in the top eight catchments alone, an estimated 2 million mussels could be saved from net loss over the next ten years. While the top eight catchments comprise less that 10% in area of the 27 sub-basins populations, a total of 92% of the Irish *Margaritifera* resource (mussel numbers) live there, so there is immense value to be gained by concentrating the conservation resource in these areas. However, only one of these eight catchments is currently in favourable conservation status. These catchments are highly sensitive to any form of intensification, so very careful management of all activities together with restoration measures will be required in all eight on an ongoing basis.

The future situation may be somewhat worse than predicted, as evidenced by the large areas of coniferous plantation already present in the populations that are currently at the highest status, particularly forestry on peat soils. Many of these areas were planted at a time before water quality precautions were considered, and are approaching the stage where they are ready for their first clear felling. Unless this can be done in a manner that can mitigate negative effects of phosphorus and sediment release, severe damage to these populations will result.

In the case of the conservation of an IUCN endangered species such as the FPM, the value is the value of its conservation (Unpublished Report, 2010). High value conservation areas have economic value that can be directly attributed to their ecological features, both in terms of the emotional value of knowing that a catchment is operating in a sustainable manner, and in the wider ecosystem services that non-intensively managed land and clean rivers provide. Because of the high sensitivity of the freshwater pearl mussel, diluting conservation effort over small pockets of land in large catchments would provide negligible conservation return. The desired results can only be attained through co-operative catchment-wide effort. Socio-economic models have been described that suit high nature value farming over a landscape scale, but they must benefit both profit and biodiversity (Polasky *et al*., 2005; Cooke *et al.*, 2009). Polasky (2006) concludes that conservationists have soft hearts, but that effective conservation also requires hard heads. It is difficult for conservationists to accept that a population of a rare species cannot be saved through lack of resources, but resources are essential to allow a return to sustainable low intensity land use in these most important catchments. Assessing the international conservation value of the FPM would appear to be an acceptable mechanism for valuation, as these values are based on the idea of rarity and the need for protection internationally, rather than just the benefits of the FPM to Ireland. (Unpublished Report, 2010)

Protection for the freshwater pearl mussel has a strong legal basis, and not fulfilling European requirements under the Habitat's Directive would result in severe penalties in the form of fines, thus the cost of not restoring sustainable high quality river habitats for *Margaritifera* is much higher than ecosystem service loss alone. The field-by-field methodologies of removing risk from juvenile mussels and their habitat has yet to be fully developed, but the analysis of studies on the mussel populations themselves and the nature of their pressures as described in this paper have provided welcome clarity to guide the conservation efforts that need to be taken.

Acknowledgments
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The role of habitat creation in the recovery of the Irish grey partridge *Perdix perdix*

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Introduction

The grey partridge (*Perdix perdix*) is a farmland bird species which has declined to one remaining naturally occurring population in the Irish Republic. It is a red listed species in Ireland (Lynas *et al*., 2007). The Irish population is now confined to post industrial peatlands in Boora, Co. Offaly. Management of the species in this landscape creates suitable habitats for grey partridge, including, nesting, brood-rearing and overwinter cover. This habitat creation involves planting of 4 meter wide linear strips which included kale, lucerne, triticale mixes, unsprayed cereal, wildflower strips and LINNET plots. Incorporating these habitats into modern agriculture is the key to the future survival of the grey partridge as a naturally occurring species in Ireland. This paper documents the role that habitat creation had in increasing the population from 17 in 1991 to 317 in 2010. In addition, we discuss the viability and requirements for range expansion of the species population beyond the nucleus in Boora.

Materials and Methods

Since 1991 the last remaining grey partridge population in ROI has been studied on a 150ha site at Boora, a cutaway peatland. This habitat is not ideally suited to grey partridge since this species is typically a lowland farmland bird and classified as a lowland Farmland Indicator species (Gregory *et al*., 2004).

Conservation measures

The dynamics of post industrial peatland are not ideally suited to the management of an iconic farmland bird like the grey partridge. However, sufficient areas of habitat, including nesting cover in the form of tussocky grass strips, beetle banks, and kale based brood rearing strips were introduced in 1999. Habitats to benefit the species included 100m x 4m wide linear strips of kale, lucernes, triticale mixes, unsprayed cereal headlands, wildflower strips and LINNET plots. To date a total of 120ha of combined nesting cover and over-wintering cover have been created in Boora, combined with nearly 2km of beetle banks.

A consistent predator management programme has been implemented since 1996; predator counts corresponding to total number of predators eliminated. Population augmentation was carried out from 2002, but these data are not included here.

Data analysis

Autumn population, spring pairs and chick survival rates (Potts 1986) were analysed using generalised additive models that accounted for temporal correlations and non-linear effects of annual rainfall. Effects of different habitats on population variables were assessed in models that also included log transformed predator counts. Akaike Information Criterion, with a correction factor for a finite samples size (AICc), was used to assess the effects of management variables on population variables following Zuur *et al.*,(2009).

Results and Discussion

Partridge autumn population and spring pairs increased over time (Figure 1; $P < 0.001$). An increase in predator counts was significantly associated with a decrease in partridge autumn counts ($P < 0.01$), and chick survival ($P < 0.001$).

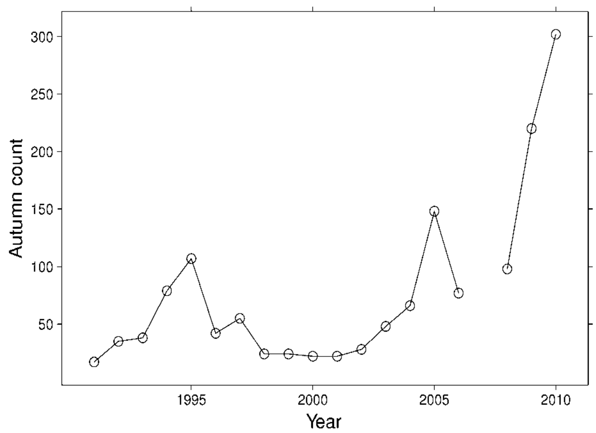

Figure 1. Autumn populations of grey partridge over 20 years. (No data in 2007.)

Cover creation appeared to be the only significant habitat variable associated with autumn counts. However, overall habitat management may have also contributed to the increase in partridge population through its effects on chick survival (Table 1).

Table 1. Effects of habitat management variables on partridge population variables. *P* values are given corresponding to AICc comparisons between models with and without each habitat type.

	Beetle bank	**Nesting**	**Cover**
Autumn pop.	0.17	0.10	0.05
Spring pairs	0.92	0.69	0.29
Chick survival	0.03	0.10	0.09

Conclusions

Grey partridge population recovery was achieved through the multiple influences of predator management and habitat creation in atypical habitats for this species. Although multiple factors helped reverse the decline of grey partridges at the study site, appropriate habitat management was important. This indicates that habitat management for grey partridges would be suitable in a targeted agri-environment scheme in order to facilitate a range expansion within Irish agricultural ecosystems.

It must be stated that single species measures have limited longevity and success as part of an agri-environment schemes. Therefore, ongoing investigations regarding the benefits of specific habitat measures for partridges on the site in Boora are required to demonstrate, where possible, how other important elements of farmland biodiversity may also thrive. There is ongoing collection of data on granivorous passerines which appear to benefit for the habitat creation measures for the partridge. Granivorous passerines have generally declined across Europe in recent years (Donald et al., 2006).

The implementation of an agri-environment measure that would facilitate the expansion of grey partridges from Boora needs to be highly targeted in terms of region, i.e. in the west Offaly area, and in terms of providing habitat that would benefit the species such as linear strips of kale based mixed crops and beetle banks. The measures implemented could potentially benefit a wide range of farmland biodiversity including granivorous passerines and other Red Listed species of conservation concern such as the barn owl (*Tyto alba*). In addition to this, a range of invertebrate species could potentially benefit from the structure of the habitats created and it is these populations of invertebrates that could provide a vital food source for partridge chicks that would increase survival rate (Potts, 1986).

In conclusion, the results from the Boora project have been impressive and have answered the question as to whether the Irish population of grey partridges can be saved (Kavanagh, 1998). However, in many respects this is only the end of the beginning in terms of saving the species in Ireland. It would appear that modern agriculture has driven the species out of its traditional farmland habitats in Ireland and for a real conservation success we must endeavour to return it to its natural habitat. A specific, targeted agri-environmental scheme is the logical approach to facilitate this decolonisation of Irish farmland. There appears to be sound rationale behind such a measure as numerous other components of biodiversity could also benefit, as outlined above.

This approach is in agreement with previous research (e.g. Whittingham *et al.*,2007) which highlights the fact that targeted agri-environment measures are more likely to yield beneficial results for biodiversity than those applied uniformly in national schemes.

Acknowledgments

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REPS and farmland bird populations: results and recommendations from the Farmland Birds Project

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Introduction

The joint BirdWatch Ireland - University College Cork *Farmland Birds Project* was established to evaluate the impacts on farmland bird populations (as indicators of biodiversity in the wider countryside) of the Rural Environmental Protection Scheme (REPS) and offer evidence-based recommendations to improve REPS as a tool for the conservation of birds in farmed landscapes. This study also aimed to develop an ecological (bird/habitat) monitoring methodology for REPS. This paper summarises the results from this project (full details can be found in Copland (2009)).

Methods

Bird and habitat data were collected during three summers (April – June, 2003 – 2005) on 122 farms (61 REPS farms paired with 61 non-REPS farms, pairs were based upon farm location and enterprise) distributed across North-west, Midlands and South-east, which generally reflect a gradient of farming intensity in Ireland from extensive farms in the North-west to intensive farms in the South-east (see Figure 1). In winter (mid-November – mid-February, 2003/04 and 2004/05), 41 farm pairs (a subset of the 61 pairs surveyed in the summer) were surveyed.

Figure 1. Locations of study sites.

REPS impacts on bird populations

An assessment of the current impacts of REPS was undertaken for both breeding and wintering bird species. Only the eleven basic measures of REPS were tested. Due to a lack of baseline biodiversity data, comparative assessments of breeding and wintering bird populations were made using the bird and habitat data. Further analyses of the data were undertaken at the farm level to identify key habitat predictors of bird occurrence, and these were then used to suggest outlines for future agri-environment measures for bird conservation in the wider countryside.

An agri-environment evaluation method

For the study reported here, key farmland habitat types are identified (five basic habitat types were used: improved grassland, other grassland, tillage, built and woody habitat; derived from habitat data collected during fieldwork). Determination of a biodiversity value for each habitat based on key indicators (the example used is based on the collected bird data) that incorporates both the ability of the habitat to support individuals as well as different species was developed, and these were applied at the farm scale.

Results and Recommendations

The three seasons of summer fieldwork surveyed a total of 3,240.05 hectares across the 122 farms. On these, some 31,357 individual birds were recorded from 72 different species. In the two winter periods, a total of 2,178.26 hectares on 82 farms were surveyed. During winter fieldwork there was a total of 38,810 individual birds recorded from 66 species. The sample size of farms, and number of birds included in the analyses reported here represent the largest for any study undertaken to date on the impacts of farming activities on bird populations in Ireland.

REPS impacts on bird populations

Overall bird species diversity, and individual species densities and numbers showed no differences between REPS and non-REPS farms. There was one exception of Magpie *Pica pica* during winter (which occurred at higher densities on non-REPS farms). The best predictors of bird occurrence at the farm level in both summer and winter were the area of grasslands, field size and amount of fence-lines (typically negatively associated with bird numbers), and the amount of hedgerows with trees, which were positively associated with bird numbers. In summer, the amount of non-cropped (woody, wet and built) habitat was also a good (positive) predictor of bird occurrences. Farm enterprise type was also a significant predictor, as was geographical region.

Increasing both hedgerow densities and the areas of non-cropped habitats would likely benefit overall bird biodiversity, but measures aiming to achieve this should take cognisance of potential negative impacts on certain key species. Also, the regional targeting of agri-environment measures, particularly in Ireland where there are clear geographical differences in farm habitats and enterprise types, should be considered to maximise the potential of agri-environment schemes. More information on the summer data can be found in Copland and O'Halloran (2010b) and for the winter data in Copland (2009).

An agri-environment evaluation method
A model for simple and rapid biodiversity assessments (SARBAS) was developed (Figure 2).

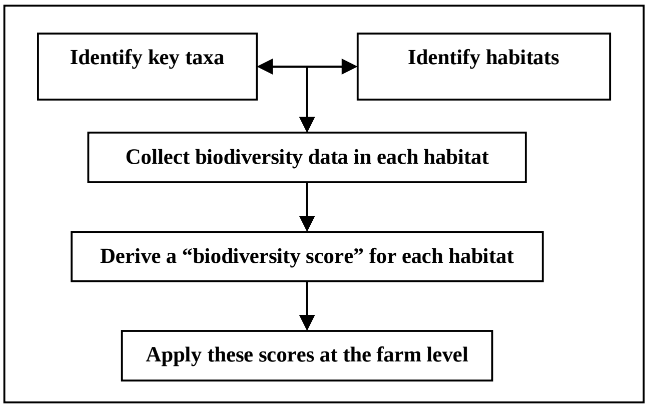

Figure 2. Method to construct SARBAS model.

The identification of the broad habitat categories is the only requirement to produce the farm level 'biodiversity score', and it is intended that this could be undertaken by non-biodiversity/taxa specialists (such as agricultural planners involved in producing agri-environment plans). The method outlined here is designed to be best suited to horizontal (or broad and shallow) agri-environment schemes such as REPS. Within such schemes, all agri-environment plans produced could incorporate this biodiversity score, and all plans should state that this score should be maintained over the term of the agri-environment agreement. Full details on this evaluation method can be found in Copland and O'Halloran, 2010a)

Conclusions

It is clear from this and other similar studies (e.g. Flynn, 2002), that REPS failed to halt the declines of bird populations on farmland. Furthermore, the basic eleven measures within REPS failed to have any impact on bird populations using farmland habitats. It is also clear that an integrated monitoring and evaluation framework for agri-environment schemes such as REPS is also required. However, REPS and Ireland are not alone in this regard, with many other agri-environment schemes throughout the EU failing on similar objectives (Kleijn and Sutherland, 2003).

Had REPS continued, a re-survey of the bird populations and habitat composition of the farms studied here would have provided very valuable data on the continuing impacts of the scheme. Nevertheless, the data here indicate a direction for the operation of successful agri-environment in Ireland if broad conservation objectives are to be met. While such measures would struggle to meet conservation targets for many species listed as Birds of Conservation Concern in Ireland (Lynas *et al.*, 2007), there might be opportunities to address conservation issues in relation to wider countryside species. However, a properly resourced and integrated monitoring and evaluation programme is essential to maximise any future impacts.

Acknowledgements

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Posters

Learning to improve agri-environmental schemes: using experts' judgements to assess the environmental effectiveness of the Rural Environmental Protection Scheme

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Introduction

Agri-environment schemes (AES) in the EU offer payments to farmers in return for undertaking management practices (measures) that maintain, enhance or restore the rural environment. In Ireland just over €3.1 billion was spent on REPS between 1994 and 2009, with 62,000 farmers participating in the scheme when REPS 4 was closed in 2009 (DAFF, 2009). These payments are for the delivery of environmental benefits, but the assessment of the environmental effectiveness (EE) of AES such as REPS has proven difficult. Such assessment is increasingly required to satisfy EU agri-environmental legislation, to demonstrate value-for-money for taxpayers, and to avoid accusations of trade distortion. Due to the absence of quantitative, national-scale, environmental monitoring data on the performance of REPS, experts' judgements were used in this study to learn about the strengths of the REPS and identify opportunities for improving the delivery of environmental benefits.

Materials and Methods

Clear objectives, verifiable targets, and the collection of appropriate baseline and monitoring data are fundamental to assessing how well a scheme is designed and performing. Due to the lack of this information in Ireland to date (Bartolini *et al*., 2005), a methodology was devised to estimate the EE of REPS. The methodology combines; a reduction of complex scheme structure into assessable elements; experts' judgement of the performance of these elements, and; the production of aggregated judgements on the contribution of single or multiple measures to single or multiple environmental objectives.

Table 1 outlines the hierarchical set of environmental objectives derived from evaluation criteria in the Common Evaluation Questionnaire of the European Commission used in this study (European Commission, 2000). We identified the basic measures in REPS 2 (RDR 1257/1999) that contributed to these objectives, and each measure-objective (M-O) pair was the unit of assessment.

Table 1. Summary of environmental objectives.

Environ. Category	Objective Description
Soil quality	**1.1** Reduction of soil erosion **1.2** Prevention & reduction of chemical contamination of soils
Water quality	**2.1** Reduction of agricultural inputs potentially contaminating water **2.2** Impeding the transport mechanisms (from field surface or root zone to aquifers) for chemicals (leaching, run-off, erosion)
Species diversity	**4.1** Reduction of agricultural inputs to achieve benefits for flora & fauna
Habitat quality	**5.1** Conservation of high nature-value habitats on farmed land **5.2** Protection/ enhancement of ecological infrastructure, including field boundaries/ non-cultivated farmland with habitat function **5.3** Protection of valuable wetland or aquatic habitats from leeching, run-off or sediments originating from adjacent farmland
Genetic diversity	**6.1** Conservation of endangered breeds/varieties
Landscape quality	**7.1** Maintain or enhance perceptive/cognitive coherence between the farmland and the natural/biophysical characteristics of the zone **7.2** Maintain or enhance perceptive/cognitive differentiation (homogeneity/diversity) of farmland

Each M-O pair was assessed by the following five criteria: strength of cause-and-effect relationship, quality of institutional implementation, farmer compliance, extent of participation, and degree of spatial targeting (Table 2). Seven Irish agri-environment experts conducted the assessment in a one-day group meeting in which assessment scores were explained and justified and experts discussed differences among their judgements. The environmental performance of each M-O pair was estimated using the geometric mean (*n*th root of product of scores) of the assessment scores from each of the criteria, reflecting dependent relationships among factors in achieving environmental effectiveness (Finn *et al*., 2007, 2009).

Table 2: Requirements for highest score (5) to be allocated to the assessment criteria for a M-O pair.

Criterion	Interpretation of criteria performance
Cause-and-effect	If a measure, or group of measures, would be expected to make a major contribution towards achieving the environmental objective. The management prescriptions are wholly or almost wholly appropriate to achieve the agri-environmental objective.
Implementation by institutions	The quality of implementation by the institution is high
Implementation by farmers	The measure is implemented wholly or almost wholly in accordance with the management prescriptions
Participation	Participation exceeds the level required to achieve the expected environmental effects of the stated M-O pair.
Targeting	Participation in the measure wholly or almost wholly matches the distribution of the relevant environmental pressure

Results and Discussion

Thirty eight M-O pairs were assessed by the experts. As an overall estimate of environmental effectiveness of each M-O pair, the geometric mean of the criteria was calculated and categorised (aggregated) according to individual measures (Table 3) and environmental objectives (Table 4). The average criteria scores for each REPS measure showed that institutional implementation and causality showed greatest variation (Table 3). For example, M2 and SM3 were given maximum scores for the causality criterion while M3 and M9 were assigned low scores. Farmer compliance consistently received high scores (4.5), and was judged by the experts to least affect the environmental effectiveness of the scheme. The targeting criterion consistently received lower scores.

Table 3. Average criteria scores for different measures in REPS 2 (maximum score for high effectiveness = 5). The final column indicates the geometric mean of the five criteria.

REPS Measure	Causality	Implementation		Targeting	Participation	Geometric mean
		Instit.	Farm			
M 1	4.7	5.0	4.5	2.3	2.9	3.5
M 2	5.0	3.7	4.7	2.3	2.8	3.4
M 3	1.0	5.0	4.5	2.1	2.8	2.3
M 4	4.0	1.0	4.5	2.3	3.0	2.9
M 5	3.0	5.0	4.5	2.6	3.3	3.1
M 6	0.9	5.0	4.5	2.3	2.7	2.3
M 7	5.0	4.0	4.5	2.8	2.6	3.5
M 8	3.0	5.0	4.5	2.7	2.9	3.1
M 9	1.0	5.0	4.5	2.6	2.0	2.2
M A	4.0	1.8	4.5	2.7	2.9	3.1
SM 3	5.0	5.0	4.5	2.6	3.1	3.7
SM 4	4.4	5.0	4.5	2.6	2.1	3.3
SM 6	5.0	5.0	4.5	2.5	2.2	3.4

The effectiveness of REPS 2 measures in meeting environmental objectives is outlined in Table 4. Relatively low scores for participation and targeting reflect the experts' belief that the scheme could not achieve its environmental objectives without increased participation by larger, more intensive farms. The scheme targeted smaller farms by having a per hectare payment that only paid for the first 40 ha. Overall, the basic scheme (Measures 1 to 11) adopts a one-size-fits-all approach, and incorporates little (if any) regional differentiation. Participation scores for water and soil quality were slightly lower than those for biodiversity, probably reflecting the greater difficulty in achieving widespread improvements in water and soil quality. Scores for causality and institutional implementation showed much greater variation, and this reflected specific reasons (deficiencies and good performance) at the level of individual M-O pairs (Table 3).

Table 4. Average criteria scores for different EU environmental objectives in Ireland's agri-environment. Data are based on high priority M-O pairs (standard deviation in parentheses).

Environ. Obj.	Causality	Implementation		Targeting	Participation	n
		Instit.	Farm			
Soil quality	4.0 (2.0)	3.0 (2.3)	4.6 (0.3)	2.4 (0.1)	2.6 (0.2)	4
Water quality	3.1 (1.9)	5.0 (0.0)	4.5 (0.0)	2.4 (0.1)	2.6 (0.4)	10
Species diversity	2.4 (1.9)	4.2 (1.8)	4.5 (0.0)	2.4 (0.2)	2.6 (0.5)	5
Habitat quality	3.3 (2.1)	3.5 (1.9)	4.5 (0.0)	2.5 (0.4)	2.8 (0.4)	14
Genetic diversity	5.0 (0.0)	5.0 (0.0)	4.5 (0.0)	2.6 (0.0)	3.1 (0.0)	1
Landscape	4.0 (2.0)	4.8 (0.5)	4.5 (0.0)	2.7 (0.1)	2.9 (0.2)	4
Mean	**3.3 (1.9)**	**4.1 (1.6)**	**4.5 (0.1)**	**2.5 (0.3)**	**2.7 (0.4)**	**38**

Conclusions

The use of experts' judgements can contribute to learning how to improve the environmental effectiveness of agri-environment schemes. This approach can help identify specific reasons for the ineffectiveness of individual measures. It is clear that verifiable targets, specific to the scheme objectives, along with relevant monitoring data, are also required to assess the environmental effectiveness of REPS. The experts' scores highlighted many positives in the Irish agri-environment scheme; however, they also identified where improvements can be targeted to help increase environmental delivery.

Acknowledgements

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Halting biodiversity loss: the potential of High Nature Value farming in north-west Ireland

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Introduction

High Nature Value (HNV) farming is low intensity farming associated with a high diversity of semi-natural habitats and species. Despite the fact that the majority of biodiversity throughout Ireland and the European Union (EU) is formed and managed by agricultural practices, there have been very few actions taken to protect this important resource.

A number of projects carried out on an EU scale have attempted to identify land use and changes in land use (Billeter *et al.,* 2008; Doxa *et al.,* 2010). Most notably, the CORINE project (Bossard *et al*, 2000) has identified an increase of 35% in 'arable land' in Ireland between 1990 and 2000; this includes land used for grass-based silage production. This suggests that potential areas of HNV farmland continue to be lost as farming practices intensify. HNV farming is also threatened by land abandonment, as farming no longer appeals to younger generations or as low-intensity farming becomes uneconomical.

Apart from CORINE, which has recognised scale-related limitations, there has been very little effort directed towards identification of the extent or quality of HNV in Ireland (Sullivan *et al.,* 2010). This project aims to remedy this by developing a methodology which can be used to identify the extent and quality of HNV in the North West of Ireland, with potential for utilisation throughout Ireland.

The project is composed of two individual studies, the results of which will be amalgamated to provide a suite of indicators that can be used by agricultural planners, farmers and other interested parties for the identification and monitoring of the extent and quality of HNV farmland in Ireland. Management recommendations for HNV farming will also be produced which may be used to contribute towards increasing overall biodiversity of farms.

Materials and Methods

This project will study HNV farming on two levels; field scale and landscape scale. It is hoped that by incorporating the results from both strands that a standardised methodology for identification and monitoring of HNV will be produced. Both study scales are linked strongly by keeping the farmer and the current farming practices as a constant consideration throughout. Owners of study farms will be provided with a questionnaire to gather details about land use, fertiliser inputs, livestock units and other factors which may impact farmland biodiversity. These details will be considered on both the field scale and landscape scale to gain a greater understanding of what management techniques create and maintain HNV farmland in Ireland.

Landscape scale

Landscape scale identification of HNV farming will be focused primarily on the use of remote sensing techniques. The project hopes to construct a GIS model which can be used with aerial photographs, as these are the most accessible imagery available for agricultural planners, etc who may use the system in future. This will be ground truthed by carrying out plant community analysis on selected farms as per Sullivan *et al.* (2010).

In addition to this, it is envisaged that butterfly and bird data will be collected at a farm level and will be incorporated into a suite of indicators, which can be utilised for the identification of HNV farmland.

Field scale

The focus of the work at field level centres on an investigation of the terrestrial invertebrates of HNV farmland, in landscape ecosystems with diverse habitats that are typical of the West of Ireland. Diptera and Carabidae will be sampled extensively on selected sites during the sampling season of 2011. Data will be analysed to determine how HNV farming practices influence terrestrial invertebrate and associated plant communities. The second year of sampling will involve the testing of additional sites using selected indicator species and the third year of the study will see the more broad application of use of indicators in other regions of the country.

Site Selection

In order to select a suitable study area for investigation in year one, a number of factors were considered. Previous studies have shown the importance of soil diversity and land use intensity on the presence/absence of HNV farmland (Sullivan *et al.,* 2010). For this reason, a number of databases were consulted to select a suitable area (Table 1).

Table 1. Databases used for site selection.

Source	Information obtained
CSO	DED, size, location, farmed area statistics, etc
GSI	Geology
EPA	Soils, CORINE land cover and land use change
NPWS	Designated Areas
OSI	Aerial photos, contour maps, Discovery series maps

Progress to date

The study area for year one has been selected within Co. Mayo (Fig. 1) (Table 2). This area was chosen after consideration of the databases gathered (Table 1) and is representative of a variety of agricultural systems in North West Ireland. The area incorporates a variety of ecosystem types e.g. upland and coastal areas which will provide results which are representative and usable throughout the North West region of Ireland.

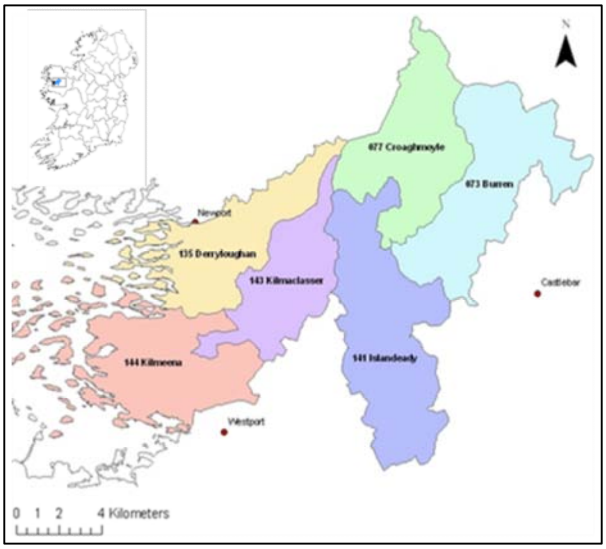

Fig. 1. Study area, Co. Mayo (year 1).

Table 2. Agricultural statistics of study area (from CSO, 2000).

Electoral Division	Population (persons)	Total Area (ha)	Area farmed (ha)	Total no. Farms
Croaghmoyle	162	3149	873	31
Burren	292	3717	1105	54
Kilmaclasser	534	2353	1916	72
Derryloughan	579	2846	2022	84
Kilmeena	1445	3613	2644	113
Islandeady	1000	4202	2271	119
Total	4012	19880	10831	473

Future work

Year one will focus on gathering baseline data at field, farm and landscape levels which will be analysed by the end of the first year. This will allow us to develop and test possible identification techniques and models on a wider scale in year two and build on gathered data again in year three.

It is hoped that by the end of this project that the first steps towards an easily understood, accessible HNV farmland identification tool or key will have been developed and tested. This can then be used by agricultural planners and farmers alike, who will then be able to easily identify and manage areas of biodiversity importance.

The role of HNV farmland will become increasingly important as the focus of the Common Agricultural Policy shifts towards ‘green’ payments. Ireland has great potential to benefit from this refocusing. It is therefore essential that adequate identification and monitoring methodologies are established by the time the new policies are implemented to maximise the gains. This project will build towards advancing the status of HNV farmland in Ireland, which seems to have generally remained static in recent years. This will contribute to putting Ireland to the fore in terms of sustainable agriculture within Europe.

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Upland commonages in Connemara – can biodiversity be used to inform sustainable agri-environmental policy?

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Introduction

While the Connemara landscape has been heavily influenced by agriculture for some time, the effects of modern farming practices in recent decades have been much more rapid and intense. The European Less Favoured Areas rural development policy introduced headage payments in the early '90s which contributed to overgrazing of upland commonages. To address environmental problems, several policy initiatives were introduced. These included the EU policy of decoupling, the Irish Rural Environmental Protection Scheme which is an Irish interpretation of EU policy and the Commonage Framework Plans which are a national policy. The effects of these measures on biodiversity in the uplands have not been studied in any great detail. This research investigates the biodiversity value of upland commonages in Connemara, with particular reference to vegetation and ground beetle (Carabidae) communities as indicators of habitat condition. This study, which forms an intrinsic part of an extensive socio-economic investigation of Connemara, will contribute to the development of agri-environmental policy in supporting the provision of agrobiodiversity on farms in the uplands.

Materials and Methods

Habitat maps of 16 upland commonages in Connemara were produced using Fossitt (2000). A habitat condition score (good, moderate and poor condition) was also given to each distinct peatland habitat, based on guidelines produced by the NPWS - then called Duchás (Anon 1999). In 2010, thirteen wet heath habitat sites of different habitat condition were selected from six of these commonages. Sampling was done in wet heath as it was one of the dominant habitat types in the region and it showed the greatest variation in condition of all habitats. Data were collected from 6 poor, 4 moderate and 3 good condition sites. Eight 1m^2 vegetation relevés were recorded at each of these sites giving a total sample of 104 relevés. Each plant species was recorded and its abundance measured as percentage cover. As well as collecting data on ground flora, physical environmental data such as vegetation height and percentage cover of bare ground, slope and aspect were also recorded. In addition, 3 pitfall traps were set to capture ground beetles at each site from May until October 2010, giving a total of 39 traps. These were arranged in a triangle 1.5m apart and collected fortnightly, giving a total of 390 samples.

Results and Discussion

NMS (Non-metric Multidimensional Scaling) is a non-parametric ordination which does not assume linear relationships between data (Mc Cune and Grace 2005). The angles and length of the radiating lines indicate the direction and strength of relationships of the variables with the ordination scores. The sites in poor condition lie at the top and right-hand side of the ordination (Fig. 1), those in good to the bottom of axis 3 and those in moderate condition sites in roughly an intermediate position. Using the Sørensen index as a distance measure, axis 3 represents 52% of the variation in the matrix while axis 1 and axis 2 (axis 2 not shown) represent 23% and 11% respectively. Percentage bare ground is positively correlated with Axis 1 (r = 0.750) whereas percentage shrub cover is negatively correlated with this axis (r = -0.760). Average vegetation height is negatively correlated with axis 3 (r = -0.496).

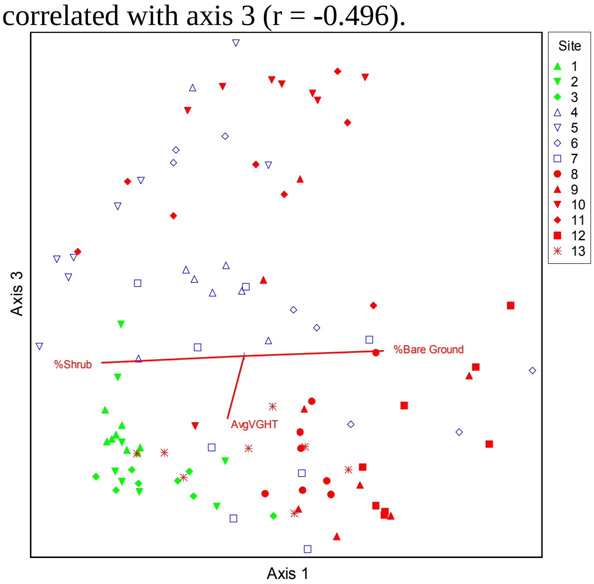

Fig. 1. NMS ordination showing good (green), moderate (blue) and poor (red) condition of sites with numbers representing each of the 13 sites.

Ground beetle assemblages also differ according to habitat condition (Fig. 2). Sites in poor condition plotted to the left (along with % bare ground), while the sites in good condition plotted to the right and bottom along with average vegetation height, % forbs and %bryophyte cover. Axis 2 represents 33% of the variation in the matrix while axis 3 and axis 1 (axis 1 not shown) represent 25% and 22% respectively. Percentage bare ground is negatively correlated with axis 2 (r = -0.657). Percentage forb (r = 0.569) and bryophyte cover (r = 0.499) were positively correlated with axis 2.

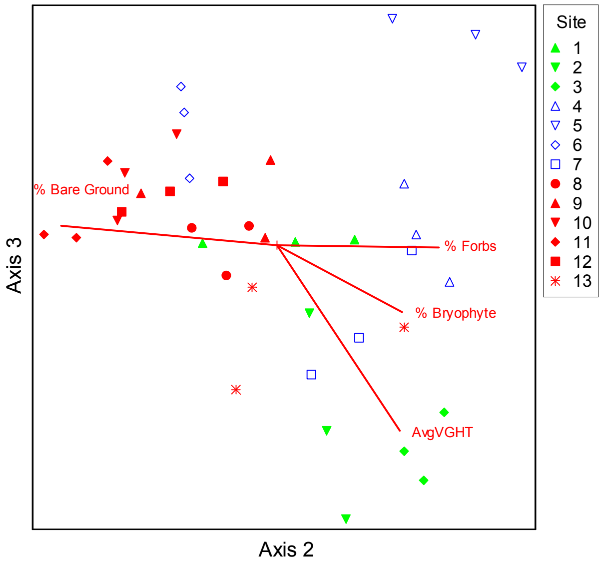

Fig. 2. NMS ordination of Carabidae showing good (green), moderate (blue) and poor (red) condition sites with numbers representing each of the 13 sites.

Average vegetation height is negatively correlated with axis 3 (r = -0.610).There were very significant differences between % bare ground, % shrub cover and average vegetation height across all three site conditions (Table 1). This means that they may be useful as indicators of site condition. Percentage forb and % bryophyte cover showed significant differences between good and poor, and moderate and poor condition sites, but no significant difference between good and moderate condition sites.

Table 1. Comparison of sites in different condition status: good and poor (G-P), good and moderate (G-M) and moderate and poor condition (M-P). Significant differences (Mann-Whitney test) are highlighted in bold.

	%Bare Ground	%Forbs	%Shrub	% Bryophytes	Avg Veghgt
G-P	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
G-M	**<0.001**	0.479	**0.003**	0.134	**0.005**
M-P	**<0.001**	**<0.001**	**0.001**	**<0.001**	**0.003**

Carabus clatratus is a species of ground beetle in decline in western Europe as its preferred habitats (natural bogs, swamps and mires) are increasingly disappearing due to drainage (http://www.habitas.org.uk/groundbeetles/).
Ireland is one of the last strongholds for this species and as such, it is a species of conservation concern. Greater numbers of *C. clatratus* were found on poor condition sites (Fig. 3). This suggests that agri-environmental policy solely designed to improve the condition of upland commonages may have a negative impact on this important species.

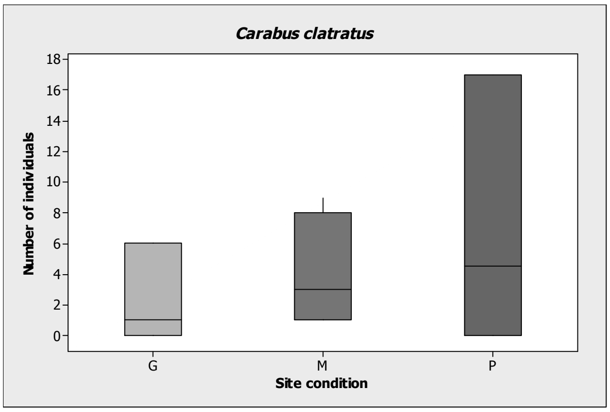

Fig. 3. Boxplot of *C. clatratus* abundance in sites in different condition status (G= good, M = medium, P = poor). The median value is shown as a thick black line while the box covers the interquartile range.

Conclusions

The plant and ground beetle communities are influenced by differences in the condition of upland commonages. The vegetation and ground beetle community data show a clear response to habitat condition, but the ground beetle community data responded to different environmental variables. Hence, it seems that looking at vegetation alone in assessing habitat condition is insufficient.
There is evidence of degradation throughout much of the upland commonages of Connemara which must be addressed through agri-environmental policy. However, it would seem that even the most degraded of sites may have some ecological value for invertebrates, which is an important consideration to have when designing agri-environmental policies.

Acknowledgments

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Probability of pollinator occurrence increases with duration of AES participation and floral diversity.

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Introduction

Agricultural intensification and specialisation has been implicated in the loss of habitat and floral resources, resulting in the considerable decline in hymenopteran pollinators over the last sixty years (Goulson *et al*., 2008). In view of the principal role that these organisms play in providing pollination services, this trend is alarming. In response to agricultural impacts on biodiversity, the Rural Environment Protection Scheme (REPS) has been implemented in Ireland in various forms since 1994. One particular aspect of this Agri-Environment Scheme (AES) focuses on safeguarding grassland margins from the effects of pasture management and nutrient enrichment. The prescribed exclusion of an area within 1.5m of the margin from grazing cattle, slurry application and synthetic fertiliser application is expected to improve floral diversity. However, the positive repercussions of these measures on field margin flora is likely to take time because soil to plant processes that regulate response to nutrient loading generally operate at medium time scales (Musters *et al*., 2009). The resulting increase in floral diversity may consequently improve both the habitat and the food resource necessary to maintain/improve arthropod biodiversity and ecosystem services, and specifically, pollinator communities (Isaacs *et al*., 2009). Here we present data from 119 farms surveyed for pollinators using pan traps along field margins also surveyed for plant.

Materials and Methods

Pastoral farms from thirty distinct 16 km^2 squares of identical soil type were surveyed in 2007 and 2008 across three regions (Sligo-Leitrim, Offaly, Cork). Four farms were sampled from each square. They were managed for either dairy (36), beef (32), suckler (44) or mixed (7) production.

Sampling protocol

Three pan traps per farm were placed 1m above ground along a field margin and collected after 48 hours during July–August 2007 (60 sites) and 2008 (59 sites). All collected pollinators were sorted and identified to species level. Plant communities were surveyed in four quadrats each in the margin, within 1m of margin and 20m in field, using Braun Blanquet cover system. The species richness of flowering plants was used as a measure of potential floral resources.

Data analysis

We used GLMMs to assess the relationship between pollinator presence/absence (ie binary response variable assessing for the presence of any pollinator), abundance and richness, and REPS participation, farm management, and floral plant richness. Random effects for square were specified to account for potential correlation between farms in the same 16km^2 square. We also ran the analysis excluding squares that did not contain any REPS participating farms (4) or only REPS participating farms (5). Results did not qualitatively differ, so we present data collected from all farms.

Table 1. Likelihood ratio test p-values. The effects of region (Cork, Offaly-Laois, Sligo Leitrim), length of time individual farms have been a REPS participant (Time in REPS, in years) and plant species richness (Plant richness) on pollinator presence-absence (Pre/abs), pollinator richness (Richness) and pollinator abundance (Abundance) were assessed by likelihood ratio test.

Response	Region (2df)	Time in REPS (1df)	Floral plant richness (1df)
Pre/abs	<0.01	0.03	0.04
Richness	<0.01	0.54	0.01
Abundance	<0.01	0.54	0.09

Results and Discussion

A total of 367 pollinating Hymenoptera (Aculeata) in 42 species were collected. Although no relationship was found between pollinators and farming system or whether a farm was in the REPS or not ($p > 0.1$), the probability of pollinator occurrence was positively correlated with the duration of REPS participation and richness and abundance with floral resources (Table 1 and Figure 1).

Conclusions

It may take considerable time for passive AES to have the desired positive effects on specific elements of biodiversity. Although non-target organisms can benefit from general non-targeted measures such as those implemented in the REPS, this may be due more to chance than design. The improvement of biodiversity status in field margins may be greatly enhanced through more active approaches. Indeed, pollinators would be more likely to respond positively to targeted measures that specifically provide the required habitat and food resource, as has been found in arable landscapes (Pywell *et al*., 2006). These effects are not only relevant to the conservation of pollinators but also to the wider range of arthropod-mediated ecosystem services, including pest control and food resources for higher trophic levels. By providing pollen and nectar resources, such targeted measures improve the chances of maintaining sustainable populations of the organisms that provide these services. The livelihood of rural communities is increasingly dependent on production-decoupled subsidy. Delivery of the expected benefits from AES therefore depends on their design.

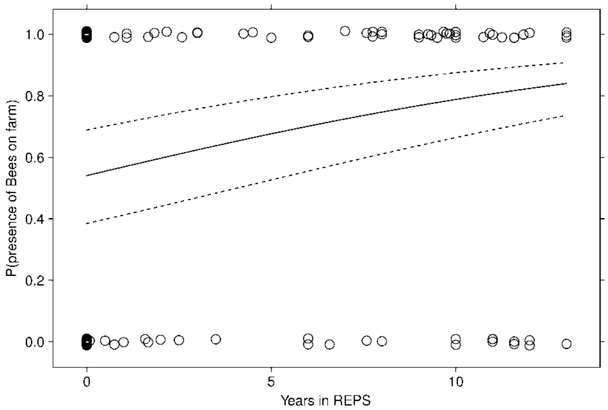

Fig. 1. Probability of bee presence in relation to length of time in REPS. Average probability across farms and 95% confidence intervals are given.

Although the analysis of pollinator populations was limited by sampling methodology, we give qualitative indication of pollinator distributions on Irish pastoral farms and implicate floral resources as the link between farm management and pollinator diversity.

Acknowledgments
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Positive effects of sown evenness on sward biomass across three years, nitrogen application and cutting intensity.

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Introduction

Environmental, economic and legal constraints are putting increasing pressure on agricultural systems to reduce inputs while maintaining or increasing productivity. This study is concerned with the effects of diversity of two grass and two clover species on biomass production, in mixed grassland systems, under two different levels of nitrogen (N) addition and two levels of cutting height over three years.

Materials and Methods

Experimental design

A split-plot field experiment was established in 2006 at Teagasc Johnstown Castle research centre. The main plot treatment involved varying plant diversity and the split-plot treatment was a two-way factorial of low and high levels of N addition (~50 kg ha^{-1} y^{-1} and ~200 kg ha^{-1} y^{-1}) and cutting intensity (~2 cm and ~7 cm). Seed biomass proportions of *Lolium perenne*, *Phleum pratense*, *Trifolium pratense* and *Trifolium repens* were systematically manipulated to vary evenness (E, a measure of relative abundance distribution) according to a simplex design (Kirwan *et al*., 2007). The design consisted of four monocultures (E = 0), six two-species mixtures (E = 0.67) and 18 four-species mixtures dominated in turn by each species (88:4:4:4, E = 0.29 and 70:10:10:10, E = 0.64), by pairs of species (40:40:10:10, E = 0.88) and equally represented at the centroid (25:25:25:25, E = 1). The design was repeated at two levels of overall initial abundance giving a total of 56 main plots and 224 split-plots. Plots were harvested three times in 2007, twice in 2008 and three times in 2009.

Data analysis

Total yield and unsown species were analysed as a function of species identity, evenness and treatment factors (Kirwan *et al*., 2009) using linear mixed models to account for the split-plot random effects and repeated measures over three years.

Results and Discussion

Over three years, both evenness and N addition positively affected total yield (Fig. 1, Table 1), while cutting decreased total yield.

Table 1. Predicted yields (t/ha) (s.e.) of monocultures, and effects of evenness, N and cutting (cut) over 3 years. Figures in bold are significant at $p < 0.01$.

Model terms	2007 t/ha	2008 t/ha	2009 t/ha
Monocultures:			
L. perenne	7.73	9.02	9.32
P. pratense	8.67	11.7	10.5
T. pratense	9.68	8.6	9.55
T. repens	7.83	8.46	11.1
s.e	0.68	0.67	0.7
Treatments			
Sowing density	-0.34 (0.17)	-0.06 (0.17)	-0.23 (0.18)
Cutting	**-1.11 (0.47)**	-0.39 (0.46)	**-1.48 (0.51)**
Grass x N	**2.47 (0.53)**	**1.63 (0.53)**	**2.46 (0.53)**
Legume x N	0.73 (0.53)	0.33 (0.53)	**1.94 (0.58)**
Mixture effects:			
Evenness	**2.49 (0.67)**	**1.72 (0.67)**	0.81 (0.70)
Evenness x cut	-0.47 (0.68)	0.64 (0.67)	-0.4 (0.74)
Evenness x N	-0.88 (0.68)	-0.47 (0.67)	0.38 (0.74)
Evenness x N x cut	0.66 (0.96)	0.25 (0.95)	0.01 (1.05)

In the first two years, yield of dry matter was linearly related to evenness at both N levels and cutting (no evenness by treatment interactions), and was maximum at the centroid (overyielding of 1.67 t/ha^{-1} averaged over 3 years, and Table 1). Over the three years, centroid mixtures produced 23% and 14% more biomass than the average monocultures, when fertilised with 50 or 200 kg ha^{-1} y^{-1} of N, respectively.

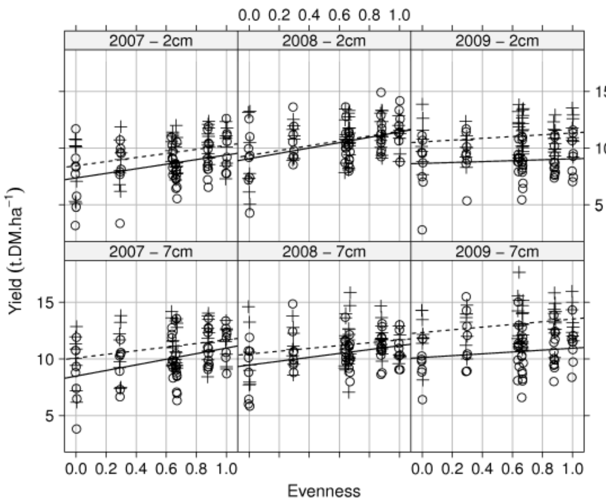

Fig. 1. Total yield as function of evenness across three years, two cutting heights and two levels of N. Regression lines indicate overyielding, while the intercept indicates average monoculture yields. Dashed regression lines and crosses for the higher level of nitrogen; solid lines and circles for lower level.

Due to overyielding, mixture yields at low levels of N were comparable to the yields of the best-performing monoculture at high levels of N (*L. perenne* in 2007, *P. pratense* in 2008 and *T. repens* in 2009). Overyielding at both high and low N suggests that the diversity effect was not solely due to symbiotic N-fixation.

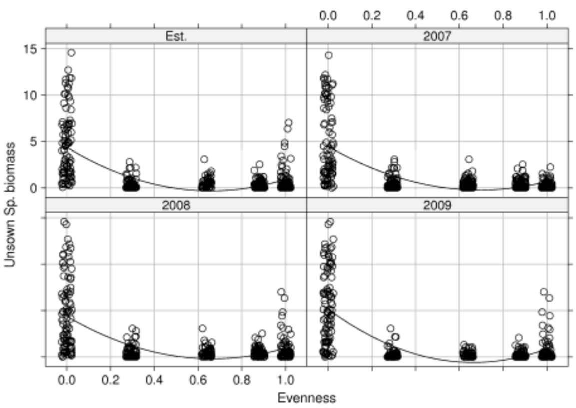

Fig. 2. Unsown species (weed) biomass as function of evenness. Regression line shows the quadratic underyielding in mixtures compared to average monocultures (intercept of regression line). Data were log transformed in analysis.

Biomass of unsown species (weeds) was significantly lower in mixtures than monocultures (Table 2 and Fig. 2). Although averaged over three years there were no significant differences in unsown species biomass between monocultures of different species (Table 2), year by year significant differences were evident. *P. pratense* had the most resistance to unsown species incidence over all three years, while both clover monocultures had high incidence of unsown species, particularly in 2009 where *T. repens* monocultures were composed in some cases of up to 99% unsown species.

Table 2. Model fitting for total biomass and unsown species biomass averaged over three years. Likelihood ratio tests were used to assess the significance of all effects. Significant effects ($p < 0.05$) are in bold.

Effect tested	df	Total biomass	Unsown sp. biomass		
		χ^2_{df}	$P(>\chi^2_{df})$	χ^2_{df}	$P(>\chi^2_{df})$
Sowing density	1	1.41	0.23	0.02	0.88
Monocultures	3	**8.41**	**0.04**	5.42	0.14
Evenness	1	**9.95**	**<0.01**	**11.1**	**<0.01**
N	1	**58.5**	**<0.01**	0.23	0.63
N x mono.	3	7.55	0.06	0.86	0.83
N x evenness	1	0.15	0.7	0.98	0.32
Cutting	1	**88.6**	**<0.01**	1.8	0.18
Cut x mono.	3	1.33	0.72	0.42	0.94
Cut x evenness	1	0.05	0.83	0.77	0.38

Conclusions

Four-species mixtures consistently produced more biomass than the average of the constituent species monocultures. The extent of overyielding declined in the final year, most likely due to severe deterioration of sown proportions and the very high incidence of unsown species in monocultures, particularly in the clover monocultures (highest yielding monoculture in 2009 was that of *T. repens*: this was in fact 99% unsown species).

The addition of nitrogen had a positive effect on grass yields (and clover in final year – again probably on unsown species as opposed to clover) and cutting had an overall negative effect on biomass. Thus, overall, evenness effects were unaffected (no interactions between either of the treatment levels and evenness, which suggests that the positive effects of mixtures were relatively robust.

Acknowledgments

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Conserving Ireland's farmland birds: performance and prospects of agri-environment schemes

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Introduction
Under the EU Rural Development Regulation (European Union, 2005), Member States are required to operate agri-environmental schemes (AES). The stated aim of AES is the "*protection and improvement of the environment*", of which biodiversity is identified as a key issue. The Rural Environment Protection Scheme (REPS) was Ireland's AES, operated between 1995 and 2009. The Agri-Environment Options Scheme (AEOS) was launched in 2010 to replace REPS. This paper summarises the current status of farmland bird populations and the impacts of AES on these in Ireland, using data from recent studies. It explores the potential of AEOS in meeting biodiversity objectives. Bird populations are used as indicators of biodiversity since they satisfy many of the criteria of effective indicators, and have been widely used within agricultural ecosystems (Gregory *et al.* 2005; Purvis *et al.*, 2005).

Farmland Birds in Ireland - Current Status
Analysis of data from the Countryside Bird Survey (CBS) between 1998 and 2008 (Crowe *et al.* 2010) indicated that agricultural intensification was most likely responsible for continued declines in some farmland bird species. Of three species that showed significant declines over the assessment period, the declines of two (Kestrel *Falco tinnunculus* and Skylark *Alauda arvensis*) were directly attributed to changes in agricultural practices. The analysis also suggested that land abandonment, with consequent decline in farming activity, will impact on grassland specialists, including several of conservation concern.

An assessment of the conservation status of all birds in Ireland in 2007 (Lynas *et al.*, 2007) highlighted a 90% decline in Yellowhammer *Emberiza citrinella* over the last two decades and stated that this species represented the fortunes of many other lowland farmland birds that have declined in Ireland and across Europe. The assessment recommended that targeted habitat management for these species, for example through agri-environment schemes, should give them the best chance of recovering. Of the 19 species listed on the Red List of the Birds of Conservation Concern in Ireland (BoCCI) due to breeding population concerns, nine (Grey Partridge *Perdix perdix*, Quail *Coturnix coturnix*, Corncrake *Crex crex*, Lapwing *Vanellus vanellus*, Curlew *Numenius arquata*, Redshank *Tringa totanus*, Barn Owl *Tyto alba*, Twite *Carduelis flavirostris* and Yellowhammer) are dependent upon farmland habitats at some point during the course of the year. In addition to this, several other bird species that are dependent upon agricultural habitats appear on the BoCCI Amber List. The only two species (Corncrake and Curlew) on the IUCN Red List (species of global conservation concern) breeding in Ireland are both species associated with lowland farmland (IUCN, 2010). Also, the most recent regular breeding species to become extinct in Ireland, Corn Bunting *Emberiza calandra*, was a specialist lowland farmland bird, with breeding last recorded in 1992 (Taylor and O'Halloran, 2002).

Impacts of REPS on farmland bird populations
Several studies (e.g. Flynn, 2002; Copland, 2009) concluded that REPS had little or no demonstrable effect on bird populations. Although there is a lack of baseline data against which to compare the impact of REPS, comparative studies of both breeding and wintering bird populations have failed to show any significant differences between bird population on farms undertaking REPS measures and those not participating in the scheme. Given the nature of REPS, with its 'broad and shallow' approach, the lack of any impact on biodiversity is to be expected (Vickery *et al.*, 2004). Other benefits, such as improvements to water quality or landscape, are not considered here.

Species-specific AES in Ireland
In addition to REPS, two agri-environment schemes have operated in Ireland over a similar time-frame. These are the Corncrake Grant Scheme (CGS) in core Corncrake areas since the early 1990s (Donaghy, 2007), and Grey Partridge conservation at Boora, Co. Offaly since 1991 (Copland and Buckley, 2010). The high level of input to both projects by specialist staff has resulted in a stabilisation of Corncrake populations in Ireland (against a background of huge declines from a national population of thousands as recently as the 1970s (Donaghy, 2007)), and an increase in the Grey Partridge population at the only remaining core site (see Figure 1) (see also contribution by Buckley *et al*.). Additionally, both projects have delivered benefits for non-target species. Together, these two schemes demonstrate

that an agri-environment approach can work to conserve farmland birds in Ireland.

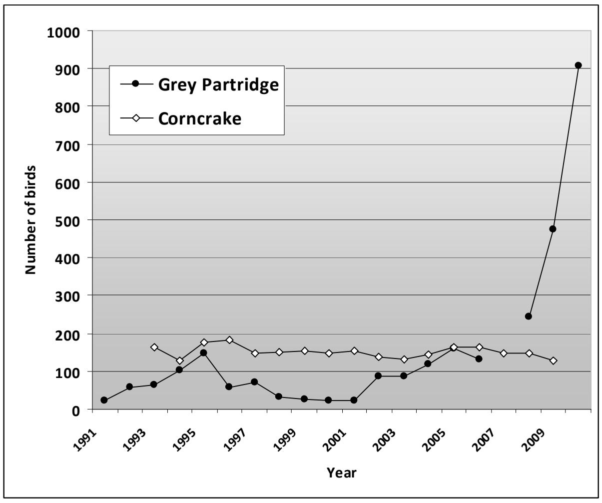

Fig. 1. Number of singing male Corncrakes and autumn Grey Partridge population estimates in Ireland, 1991-2010.

Potential impacts of AEOS on biodiversity

As with the two projects above, it has been shown that AES that set objectives that are focused on delivering for target species can deliver conservation benefits (Aebischer *et al.*, 2000). Although at present the objectives within AEOS are likely too broad to deliver demonstrable conservation benefits, the overall architecture of the scheme (setting an objective for each applicant who then selects a range of options to meet that objective) provides AEOS with the potential to address the decline of farmland bird populations in Ireland.

In addition to expanding the existing Corncrake and Grey Partridge programmes, other potential options within AEOS could target breeding wader species on lowland wet grasslands habitats across Ireland, Twite breeding and/or wintering in the north-west of Ireland or Chough *Pyrrhocorax pyrrhocorax* on coastal grasslands. Non-avian species that might benefit from such targeted measures could include Natterjack Toad *Bufo calamita* (building upon the existing NPWS scheme in Co. Kerry) or Great Yellow Bumblebee *Bombus distinguendus*.

If AEOS is to fully realise this potential, more focused objectives are required. These need to allow species targeting, both geographically within Ireland and for specific habitat types. The current Bird Atlas (2007-2011) will soon be completed, and an update on the distribution of all bird species in Ireland will be available. Concurrently, work is ongoing to map the distribution of many non-avian taxa that are likely to be of conservation concern. An opportunity now exists for Irish AES to deliver on reversing declines in biodiversity in the wider Irish countryside as well as the populations of many species of conservation concern, such as farmland birds.

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The food versus fuel debate – what effect will replacing traditional crops with *Miscanthus x giganteus* have on farmland biodiversity?

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Introduction

The adoption of the Kyoto Protocol of the UN Framework Convention on Climate Change has stimulated the search for methods to reduce net CO_2 emissions to the atmosphere. The urgency for mitigation actions in response to this has stimulated policy makers to encourage the rapid expansion of the bioenergy sector, resulting in major land-use changes over short timescales. Despite the potential impacts on biodiversity and the environment, scientific concerns about large-scale bioenergy production have only recently been given adequate attention (Dauber *et al*., 2010). The SIMBIOSYS (www.simbiosys.ie) project was set up to investigate the impacts of a range of sectors on biodiversity and ecosystem services, with part of the project's focus on those measures that may help mitigate the effects of climate change. In this paper we therefore aim to assess the impact of growing *Miscanthus x giganteus* on former grassland and tillage crops on plant, pollinator and carabid beetle diversity and abundance and the composition of their communities.

Materials and Methods

Fifty sites were selected across the south east of Ireland, consisting of 10 replicates of 5 treatments (crop types): *Miscanthus* planted on former tillage (MT), *Miscanthus* planted on former grassland (MG), Oilseed rape (OS), Tillage control (winter wheat) (CT) and Grassland control (CG) (Figure 1). Plants, pollinators (syrphids, bumblebees, solitary bees) and carabid beetles were surveyed at the margin, edge and centre of each site on two occasions during the summer of 2009. Plants were surveyed with 1m x 1m quadrats using the percentage cover abundance scale. Pollinator diversity and abundance was measured using blue, white and yellow coloured UV pan traps. Carabid beetle diversity and abundance was measured using pitfall traps. Generalised linear models (with either a poisson error distribution or log10 transformation where data were not normal) were used to examine the effect of crop type on species richness and abundance. A generalised least square model was used where variance was not homogenous. The effect of crop type on community composition was assessed using a PERMANOVA analysis using a Bray Curtis Similarity matrix. *A posteriori* pairwise tests were performed between crop types. All statistics were performed using R (R Development Core Team, 2008) and PRIMER v6 (Clarke & Gorley, 2006).

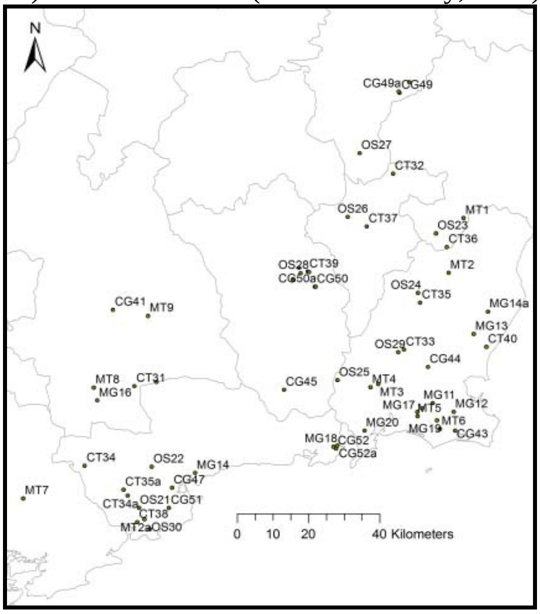

Figure 1. Location of the 50 sites across the south east of Ireland.

Results and Discussion

Figure 2 shows the effect of crop types on the species richness (SR) and abundance of the carabids, pollinators and plants. For the carabids, SR and abundance in the CT and OS were shown to be significantly higher than the other crop types. A similar pattern was shown for pollinator SR where the annual crops (OS and CT) were significantly higher than the perennial crop types (MG, MT, CG). For pollinator abundance, there was only a significant difference found between OS and the other crop types. In contrast, for the plants, SR in CT was shown to be significantly lower than all other crops types. Clear differences in SR and abundance emerge between the annual and perennial crop types where more resources available in the annual crops appear to favour both carabid and pollinator SR and abundances. On the other hand plant diversity and abundance is favoured by stability of perennial crops. Crop effects on the composition of the carabid, pollinator and plant communities are shown in the ordinations outlined in Figure 3. All plant communities were significantly different from each other ($p<0.001$) except those in MT and MG. For the carabids, no significant differences were found between the communities of the OS and CT, and between MG, MT and CG, but significant differences were shown between the communities in the annual crops (OS and CT) and those of the perennial crops (MG, MT and CG) ($p<0.001$). For the pollinators, the OS communities were shown to be significantly different from the communities of all other crops ($p<0.011$), while no significant differences were found between the communities of all other crops. In general, *Miscanthus* was shown to be most similar to other perennial crops, and most dissimilar to the annual tillage crops, i.e. the replacement of traditional crop types with *Miscanthus* did not result in novel communities except for the plants. Overall, this study showed that growing *Miscanthus* did not have an obvious negative impact on biodiversity as measured using carabids, pollinators and plants at field scale. However, it is important to note that replacing tillage crops with *Miscanthus*, thereby reducing overall landscape heterogeneity, may result in biodiversity losses at the landscape scale.

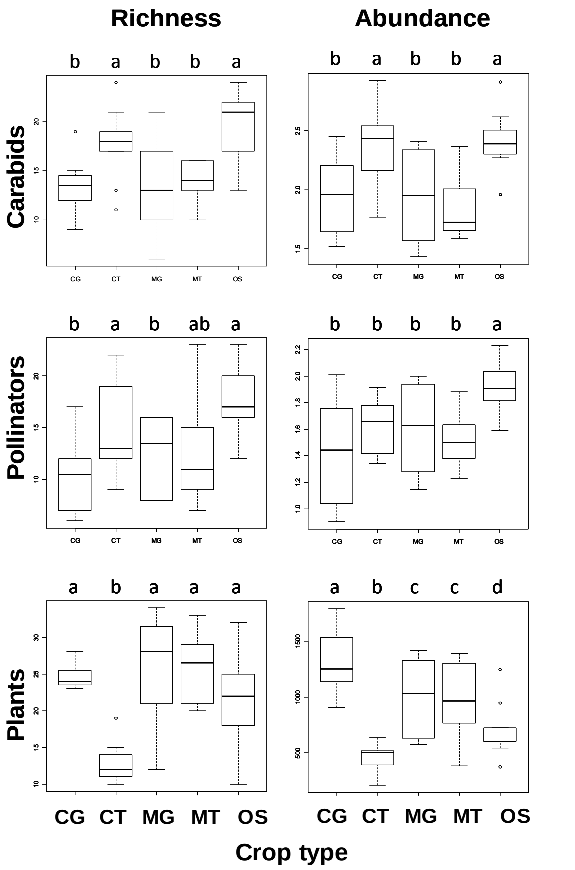

Figure 2. Boxplots highlighting the relationships between carabid, pollinator, and plant species richness and abundance and crop type (CG, Ct, MG, MT, OS). Significantly different crop types are shown by the letters (a, b, c, d) at the top of each graph.

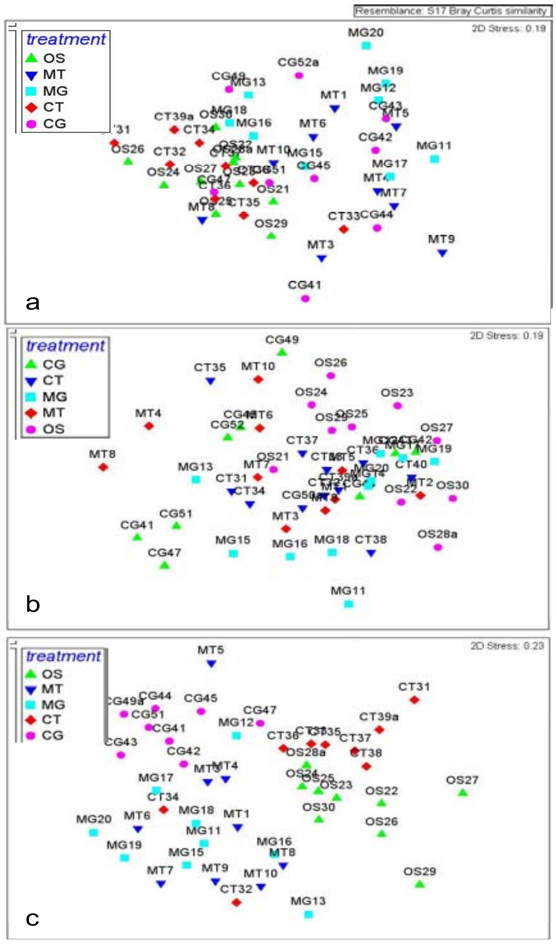

Figure 3. MDS ordination of the carabid (a), pollinator (b), and plant (c) communities in relation to crop type. Similarities based on Bray Curtis.

Conclusions

In this study, the impact of growing *Miscanthus* on former grassland and tillage crops did not negatively affect alpha-diversity. Future large-scale replacement of these crops with *Miscanthus* may however affect gamma-diversity in agricultural landscapes. Maintaining land-use diversity in these landscapes must be a priority to ensure climate change mitigation measures such as bioenergy crops do not negatively impact farmland biodiversity.

Acknowledgements

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How to measure the environmental effectiveness of the Rural Environmental Protection Scheme?

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Introduction
Agri-environment schemes in the EU are now one of the most important policy mechanisms for the protection of public goods, and offer payments to farmers in return for undertaking management practices (measures) that are intended to maintain, enhance or restore the rural environment. The Rural Environment Protection Scheme (REPS) has become a widely adopted scheme (over 54,000 participants in 2009), and provides an important financial contribution to farm incomes in Ireland (e.g. DAFF, 2008; Connolly *et al*., 2009). Since 1994, REPS has paid a total of over €3.1 billion to Irish farmers, and paid over €330 million in 2009. In return for these payments, participating farmers undertake a variety of prescribed measures that are intended to benefit water quality, soil quality, nutrient management, grassland management and biodiversity.

Since its inception in 1994, there has been strong demand for evidence of the environmental effectiveness of the REPS. A number of different forces are aligning that will likely result in various pressures on agri-environment schemes. These include an increase in the number of EU Member States that will receive funding from the Common Agricultural Policy and Rural Development Programme, increased pressure on EU budgets, and increased pressure on the ability of individual member States to provide co-financing. In addition, the EU Court of Auditors is due to report its audit of the effectiveness of EU agri-environment schemes. The World Trade Organisation also requires that the environmental benefits of agri-payments are clearly demonstrated, to prove that such payments are not disguised trade subsidies. At the same time, there are strong suggestions of an increased provision of public goods in the post-2013 CAP, and agri-environment schemes will be an important policy instrument to achieve this (as well as others).

To date, there has not been a national-scale, comprehensive monitoring programme to measure the environmental impacts of REPS. There will be increasingly demanding requirements to demonstrate the environmental effectiveness (and especially biodiversity benefits) of agri-environment schemes. This desk study aimed to support decision-making about the appropriate design and implementation of an environmental monitoring programme for Irish agri-environment schemes.

Materials and Methods
A desk study reviewed available publications that are relevant to the environmental effectiveness of REPS. The distribution of payments, across the different environmental objectives of REPS1 and REPS 4, was examined to assess the extent to which payments were allocated to specific environmental objectives (e.g. water, biodiversity, soil). A number of REPS options and measures were selected as priorities for inclusion in an environmental assessment programme, and were usually those with highest participation (as these generally involved greatest expenditure). Broad aims were suggested for the sampling of each of the selected measures and options. Estimates of the number of field surveys and staff requirements were used to estimate the total cost of an environmental monitoring programme.

Results and Discussion
There has been a significant increase in the relative proportion of expenditure on basic measures for biodiversity-related objectives between REPS 1 (~57%) and REPS 4 (~79%) (Finn, 2010; Finn and Ó hUallacháin, in press). This is not surprising given that most of the measures associated with the original priority objective of REPS to protect water quality (largely through improved nutrient management) have since become part of the standards associated with cross-compliance, which are not paid for. This clearly indicates that the majority of REPS 4 payments is now associated with biodiversity objectives. In addition, supplementary measures and options are dominated by biodiversity issues. Thus, measurement of the effectiveness of biodiversity measures and options should be a priority for environmental monitoring.

Note that Table 1 generally includes measures with highest participation. It omits several elements of REPS that: have insufficient participation to have an environmental effect; have insufficient existing information available with which to assess performance, or; require field experiments rather than monitoring.

Overall, the monitoring of selected REPS measures, supplementary measures, biodiversity options and Measure A was estimated to cost about €3.4 million over a four-year period (Finn, 2010). The monitoring programme would need to recruit 18 different staff (eight of which would be part-time).

For the whole programme, there would need to be at least 1500 different field surveys. Note that there is very different spatial distribution of different REPS measures, supplementary measures and options. Privileged access to the Department of Agriculture, Fisheries and Food (DAFF) REPS database and e-REPS would be necessary to help quickly identify the location and contact details of randomly selected farms that contain specific measures or groups of measures. The effectiveness and cost of the monitoring programme would be very dependent on such privileged access. Privileged access to the REPS database will be necessary for the design and implementation of an effective and cost-efficient monitoring programme. Without such access, the costs would increase considerably.

Conclusions

The average annual budget for the proposed monitoring programme (~€0.86m) would be less than 0.25% of the recent annual expenditure on REPS (>€360m in 2009).

There is considerable overlap and similarity between the existing REPS measures and options, and those included in the new Agri-Environment Options Scheme (AEOS) that will replace REPS.

Thus, an assessment of the environmental impacts of REPS could be used to more quickly assess the probable environmental effectiveness of similar measures that are implemented in the AEOS. The cost of measuring the environmental performance of REPS should be viewed as an investment in securing the future of agri-environment schemes in Ireland. This would provide necessary information to confirm the environmental benefits of effective measures, and to implement any required improvements to other measures. In the long term, such an approach would ensure that these schemes and the participant farmers get appropriate credit for their successes.

Acknowledgements

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Table 1. Suggested priorities for assessment in REPS 4 and indicative workload (no. of farm visits) fieldwork associated with sampling of selected REPS measures and options. Estimates are for environmental sampling only and assume independent visits to farms for each measure or option (which could be reduced, see text for details).

REPS 4 measures and options	No. of Reps farms	No. of non-REPS farms
Measure A (Natura 2000 and other priority sites)	250	0
Measure 3 Watercourses and wells	90	30
Measure 4: Farmland habitats	240	60
SM2 Traditional Irish orchards	-	-
SM5 LINNET	50	0
SM8 Traditional grazing systems	70	40
SM9 Clover swards	100	0
SM10 Mixed grazing	100	25
2A Traditional hay meadow	50	20
2B Species-rich grassland	100	0
2E Control of invasive species	35	25
4A Creation of new habitat	70	0
4B Broadleaved tree planting	80	0
4C Nature corridor	70	0
4D Farm Woodland establishment	28	0
5C/5A New hedgerow establishment	70	40
5D Stone wall maintenance	60	35
9B Environmental management of setaside	60	30

Landscape aesthetics: assessing the general publics' preferences for rural landscapes

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Introduction

At a broad level, the general public can be characterised as nature friendly, that is, individuals largely acknowledge the intrinsic value of nature and its subsequent right to exist irrespective of its functions for mankind. Individuals regard their interactions with what can be termed as natural landscapes as more positive than their experiences with landscapes that have been shaped to a large degree by human interaction. This finding has been interpreted as supporting an evolutionary theory of landscape preferences, whereby it is assumed that similarities in responses to natural scenes outweigh the differences across cultures or smaller groups of individuals (Ulrich, 1993). There has, however, been widespread disagreement as to the validity of this consensus assumption. Specifically, much research has found substantial individual and inter group differences in landscape preferences (Van Den Berg *et al*., 1998). With this in mind, the central aim of this study was to gain greater insights into the individual characteristics that affect preferences for a variety of landscape settings.

Materials and Methods

A survey of 430 individuals living in Ireland was conducted in the summer of 2010. The respondents were asked to indicate their preferences for rural landscapes by rating 47 landscape images on a scale from 1 (not very highly) to 6 (highly). The photographs themselves were selected with the aim of representing a broad geographic and thematic representation of rural landscapes in Ireland. Environmental value orientations were measured by including a series of attitudinal statements conveying two pro-environmental values - ecocentrism, anthropocentrism - and environmental apathy. The statements relating to ecocentrism were devised to capture the importance of nature and the amenity as well as visual value of the landscape whereas the anthropocentric statements refer to a more functional view of the landscape - one that emphasises the importance of using the landscape for agricultural production.

Data analysis

A factor analysis (principal component analysis with varimax rotation) was employed on the attitudinal statements designed to capture environmental value orientations and also on respondents mean scores of the landscape images. As expected, the factor analysis of the attitudinal statements resulted in three factors with an eigenvalue > 1, together explaining 61 percent of the variance. The statements relating to ecocentrism loaded highly on the first factor and as such this factor was termed 'ecocentric value'. The statements relating to environmental apathy loaded highly on the second factor and finally the statements relating to anthropocentrism loaded highly on the third factor. Therefore these individual factors were labelled as 'environmental apathy' and 'anthropocentic value' respectively. These individual factor variables were utlised in an OLS regression model in order to examine their relative influence on preferences towards a variety of landscape types.

A factor analysis was also employed on respondents mean ratings of the 47 landscape images. A five factor solution proved to give the best solution. The derived factors represent individuals' distinct preferences towards different features of the landscape. Based on an analysis of the factor loadings, the factor variables were labelled as 'intensive agriculture', 'extensive agriculture', 'wild nature scenes', 'cultural landscapes' and 'water related landscapes'. Individual factor scores for each category of landscape were used as a dependent variable in separate regression models designed to examine if they were any socially differentiating factors affecting individual landscape preferences. Factor scores representing respondents' different environmental value orientations were also ultilised as explanatory variables in the following analysis to examine if these along with background socio-demographic factors influenced the general publics' landscape preferences.

Results and Discussion

Water-related landscapes attracted the highest mean scores by respondents. Cultural-related landscapes are also highly regarded by respondents as all of the images in this category also attracted relatively high mean scores. In relation to the agricultural landscapes, respondents rated all of these quite highly as all the mean scores were at the upper end of the six-point scale. The agricultural landscapes that respondents appeared to like least, however, were the more intensive farming landscapes. This supports findings in a variety of other studies which suggest that modern intensive farming landscapes are less attractive to the general public due mainly to the homogeneity of this type of landscape.

Multivariate regression analysis was used to examine what factors influenced respondents' preferences for each of the landscape types derived from the factor analysis. The dependent variable was individuals' factor scores for each of the derived 5 perceptual categories of landscape. The results from each of the 5 regression models are presented in table 1. Age was the socioeconomic variable that was perhaps the strongest predictor of preferences in that it was statistically significant in determining preferences for three of the landscape categories (intensive and extensive farming and water related landscapes). The positive relationship between age and both agricultural landscapes could be reflective of generational differences in culture and upbringing with relatively elderly respondents more likely to be familiar with agricultural landscapes. Age had a negative association with water-related landscapes and this could be attributable to older people's greater vulnerability to the dangers of this type of landscape.

Environmental value orientations were perhaps the most significant determinant of landscape preferences as these were found to strongly affect preferences for each of the landscape types examined. Environmental value orientations are defined as individual or societal beliefs about the importance of the natural environment and in particular how the natural world should be viewed and treated by humans (Reser and Bentrupperbaumer, 2005). An ecocentric value was found to have a positive impact on all the landscape types examined (extensive farming landscapes, cultural landscapes, wild nature scenes and water related landscapes) with the exception of intensive farm landscapes where it was not found to have a statistically significant impact. These landscape types may be preferred over intensive farming landscapes by respondents with a strong ecocentric value because of their strong amenity, ecosystem or wildlife aspects. An anthropcentric value orientation and environmental apathy were found to have a negative effect on preferences for 'wild nature scenes'. It could be that the relatively unproductive nature of this type of landscape makes it unattractive for respondents with either of these types of value orientations. Finally, environmental apathy was also related to preferences for intensive farming landscapes as respondents who were indifferent to environmental issues were more likely to rate this type of landscape in terms of beauty highly

Table 1. OLS regression model examining factors influencing landscape preferences (statistically significant variables highlighted in bold).

Coefficient	Intensive	Extensive	Wild nature scenes	Cultural	Water related landscapes'
Age	**0.03***	**0.04*****	0.01	0.002	**-0.04****
Females	0.08	**0.37*****	-0.13	-0.12	0.07
Social class	0.11	**-0.19****	**0.27*****	0.02	0.06
Rural	**0.30****	**0.31*****	0.08	-0.09	**0.21***
Town	**0.35*****	-0.03	-0.09	0.05	0.07
Farming background	0.13	**0.35*****	-0.10	-0.11	-0.12
Ecocentric value	0.03	**0.26*****	**0.21*****	**0.20*****	**0.13*****
Anthropocentric value	-0.04	**0.10****	**0.13*****	0.03	0.020
Environmental apathy	**0.09***	0.06	**0.19*****	**-0.19*****	**-0.20*****

* significant at 10 percent level, **significant at 5 percent level, ***significant at 1 percent level

Conclusions

The landscape can be viewed as an economic resource and as a local public good in that it provides amenities and supports recreational as well as productive activities. Policy perceptions of rural landscapes have changed over time from sites of mass agricultural commodity production to areas of socio-cultural, economic and ecological diversity in which a range of goods are both produced and consumed. Land use policy can be improved if decision makers in both the environmental and agricultural sectors are better informed about the landscape preferences and attitudes toward the environment among various user groups. The results presented here suggest that there are distinct differences in terms of landscape preferences between different demographic groupings and also depending on individuals' environmental value orientations. Accordingly, in studying landscape preferences in particular areas it will be necessary to consider the personal characteristics of the population as well as the physical aspects of the landscape. Moreover in terms of land use policy, given the diversity of preferences a one-size-fits-all approach will not meet the general publics' needs and desires.

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Cessation of grazing - the effects on land snail communities in farmed grassland, scrub and woodland habitats in the Burren region in the west of Ireland

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Introduction

The Burren is famous for its flora and fauna. Its impressive biodiversity is indebted in no small way to the agricultural traditions of the area (Dunford, 2002). The limestone pavements and the species-rich grasslands are among the most remarkable aspects of the Burren. These habitats are now set in a changing landscape. Many areas are being taken over by encroaching hazel scrub which threatens some aspects of the biodiversity of the Burren (The Heritage Council, 2006). The scrub also interferes with farming by blocking trackways used by stock and taking over valuable farmland.

One of the main theories about why this is happening is because of changes in farming. A combination of factors such as the use of less-hardy animal breeds, farmers often needing to work off-farm and the changeover from beef cattle to suckler cows has resulted in a general decrease in the grazing pressure on some of the most valuable Burren habitats (Dunford and Feehan, 2001; Dunford, 2002; Williams *et al.*, 2009).

The current study investigates the effects that the cessation of grazing might have on biodiversity, focussing on vascular plants and land snails. Very few studies have used grazing exclosures in order to investigate the effects of changes in land management practices on molluscan communities. Of two such studies, higher densities of snails were found in ungrazed areas of boreal forests in Fennoscandia, compared to plots grazed by moose and/or reindeer (Suominen, 1999), and negative impacts of cattle grazing on mollusc densities were found in fens in the UK (Ausden *et al.*, 2005).

Materials and Methods

A network of twelve fenced exclosures (each 20 x 20m) was set up across the Burren region in 2006. The fences prevent access by large grazers (mainly cattle and goats) and were placed in three types of habitat: rough grasslands, areas with low or scattered hazel scrub, and hazel woodlands. Beside each fenced area is an unfenced plot of similar size which acts as a control. Plants and snails (and other aspects of biodiversity) have been monitored since the set-up in both the fenced and control plots.

Molluscs were sampled in both 2006 and 2008 using 25cm x 25cm quadrats, five in each plot. All low-growing vegetation, litter (dead plant material) and loose soil were removed, dried and sieved into different size fractions. The molluscs were removed and identified. Slugs were not included in this study.

Results and Discussion

Summary of vegetation findings

The strongest changes recorded in the vegetation came from the grassland sites, where there was a significant decrease in both plant richness and diversity, and a significant increase in the amount of litter. The cessation of grazing appears to have had a negative effect on grassland plant communities, at least in the short term. The woodlands showed an increase in diversity. Results are more complex for the scrub habitat, and longer-term study is needed.

Findings on snail diversity

No mollusc species were lost or gained between the two sampling periods, although many species exhibited changes in abundance. The mean number of snails collected per quadrat increased by almost 50% inside the fenced plots between the first and second sampling periods (i.e. between 2006 and 2008), and there was only a very small change in the control plot numbers (a decrease of 3%).

The largest and most consistent changes were seen in the grassland sites, with significant increases in the numbers of snails collected across all quadrats ($p=0.03$, one-tailed paired t-test) (Fig. 1). The species which showed the greatest change was *Columella aspera*. It appeared for the first time in three of the grasslands sites in 2008. This is a species of ‘rough’ habitats generally, such as uncultivated grasslands (Kerney, 1999). The general trend was for an increase in mollusc numbers and species across most grassland sites.

Multivariate analysis using NMS (non-metric multidimensional scaling) showed a definite shift in the species composition of the mollusc communities over the two-year period. In the resulting ordination, quadrats sampled in 2006 tended to separate from those sampled in 2008 (Fig. 2). The main factors associated with this shift were found to be cover of litter and vegetation height, both of which increased substantially in the absence of grazing.

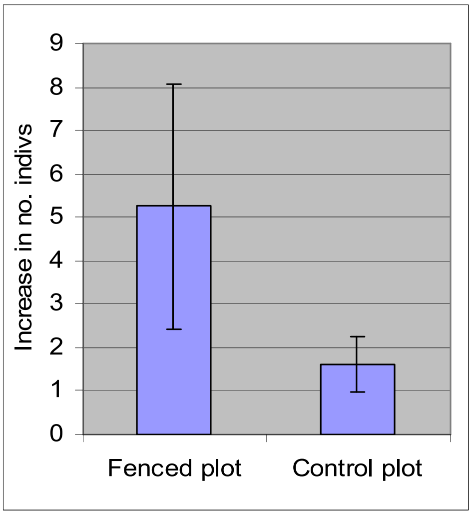

Figure 1. Average changes in numbers of individuals recorded in the grasslands (±s.e.).

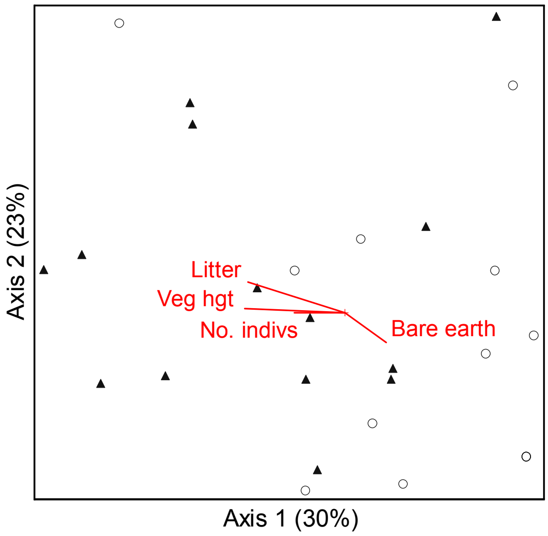

Figure 2. NMS ordination of mollusc data from fenced grassland plots. Each point corresponds to a quadrat. Figures in brackets on axis labels are the percentage of the variation in the distance matrix which is explained by this axis. The most influential variables are overlaid. Open circles, 2006; closed triangles, 2008.

Conclusions

When grazing was removed experimentally from grassland habitats in the Burren, the snails seemed to benefit from the longer vegetation and denser litter which resulted. It is likely that the litter provides extra food, shelter and moisture for the snails, and thus conditions have improved (at least for certain species) within the fenced exclosures at the grassland sites.

These findings contrast with the decreases in vascular plant richness and diversity which were seen in the grasslands, and thus they highlight the importance of assessing a suite of taxa when investigating the effects of changes in management practices on biodiversity. If we compare these findings (from grasslands) with those of Ausden *et al.* (2005) (from fens), we can see that the effects of the removal of grazing on mollusc communities may also be habitat-specific. This again points to the importance of broad-scale studies, particularly when landscape-scale changes are in question.

The exclosures set up during this study provide a valuable tool for monitoring long-term vegetation and landscape change in the Burren into future decades. It is hoped that this work will be continued into the longer term.

Acknowledgments

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Development and application of the Agri-environmental Footprint Index (AFI)

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Introduction

The Common Monitoring and Evaluation Framework (CMEF) developed by the European Commission provides a unified framework for monitoring and evaluation of all rural development interventions for the programming period 2007-2013. Given the many customised implementations of the EU rural development instrument (Rural Development Regulation (EC) 1698/2005, amended by Council Regulation (EC) 74/2009) in the interests of subsidiarity and effectiveness, it is envisaged that the CMEF will need to be supplemented, as specific contextual factors in different regions call for locally-adapted, context-specific indicators and evaluation (e.g. due to variable geology and soils, topography, climate, farming type and tradition). The Agri-environmental Footprint Index (AFI) was developed as the primary output of an FP6-funded project, to provide exactly this flexibility, whilst using a common conceptual evaluation structure and harmonised process (see Purvis *et al.*, 2009).

Materials and Methods

The methodology developed in the AE-FOOTPRINT project involves the construction of an AFI, allowing the combination of various indicators reflecting the environmental performance of a particular farm. The approach employs components of multi-criteria analysis techniques to provide a means of combining indicators corresponding to a variety of farm management activities and relating to a range of environmental objectives. The methodology incorporates the participation of stakeholders and technical advisors in designing a customised form of the AFI relevant for each particular application. In the methodology, stakeholders validate the assessment criteria and provide a series of weights allowing combination of different components of environmental performance. Such input of specific, technical and local knowledge ensures the evaluation is appropriate to the local agri-environmental context. The participatory process is described at length by Mortimer *et al*. (2009) in an AFI User's Manual.

The AFI also relies on a matrix structure comprised of three major environmental issues (Fig. 1) crossed with three management strategies or management domains (crop and animal husbandry, physical farm infrastructure, and natural and cultural heritage). Through a participatory process, this universal matrix structure can be customised to any agri-environmental context. The resulting nine-dimensional matrix accommodates two essential building blocks of the AFI: an assessment criteria matrix (ACM) and an indicator matrix (IM). The ACM gives a context-specific description of the assessment to be made; the IM defines the means to make the assessment. (For details, see Purvis *et al*., 2009; Mortimer *et al*., 2009).

AFI applications in Ireland

One of the case study areas was in Ireland, where the AFI methodology was tested by evaluating the effectiveness of a broad, multi-objective agri-environmental scheme (AES), the Irish Rural Environment Protection Scheme (REPS). We report two contrasting farming situations: relatively intensive dairy farming in County Cork, and comparatively extensive dry-stock (beef/sheep) farming in County Sligo. The customised AFI was created through an interactive process with stakeholders, and was similar for both applications. Stakeholders consisted of a group of environmental, agricultural, natural/cultural heritage, production and agri-environmental policy specialists, along with agricultural advisors and farmers. Assessment criteria were largely defined based on the REPS objectives and associated obligations, as REPS provided the evaluation background for the presented applications.

This scheme is very holistic and addressed all nine dimensions of the AFI matrix structure. Indicators were selected based on the agreed assessment criteria. Transformation functions were developed to map all indicator values onto a common scoring scale (0 to 10). However, as some ACM dimensions contained up to 14 criteria, it was necessary to devise more complex multi-metric indicators in order to evaluate all identified concerns, whilst still meeting the desired target of using no more than a maximum of five to six indicators per matrix dimension. This allowed 'real world' interactions and relationships between multiple agri-environmental concerns and farming practices to be aggregated into a single indicator score. Technical specialists were regularly asked for their feedback to secure a sensible and coherent structure for the transformation functions. Stakeholders weighted issues, management strategies and the underlying aspects of indicators individually. These weights are perceptions of relative importance when policy priorities are not or not sufficiently defined. Where possible, a consensus of final issue and management strategy weights was reached among the stakeholders; in other cases the mean of the individual weights was chosen. The AFI was quantified by multiplying scores with weights (weighted sum), subsequently at the three levels of indicators, management strategies and issues. In both contexts, the AFI was calculated for a small sample of farms of which half had a REPS agreement. As a proof-of-concept application, data were collected for indicators relevant to the ACM for REPS and non-REPS farms in Sligo and Cork. The environmental criteria that were used went beyond those based on REPS, to measure wider environmental impacts of the scheme.

Results and Discussion

In Cork, data were collected from eight REPS dairy farms and eight non-REPS dairy farms. In the Sligo region, indicator data were collected on ten REPS dry-stock farms and ten non-REPS dry-stock farms. In the application of the AFI in Cork, the mean AFI scores of the REPS farms (4.72) was significantly greater than the mean AFI score (3.78) of the non-REPS farms (Fig. 1). In Sligo, the mean AFI score of the REPS farms (5.74) was significantly ($p=0.05$) higher than that of the non-REPS farms (5.00). At the level of individual issues, the REPS farms in the sample consistently outperformed the non-REPS farms. Note that all the farms in the Cork case study area scored substantially lower than the livestock farms in the Sligo case study area. This interpretation requires some care, due to the low sample sizes, and due to the two slightly different forms of the AFI used (weighting and a small number of indicators differed).

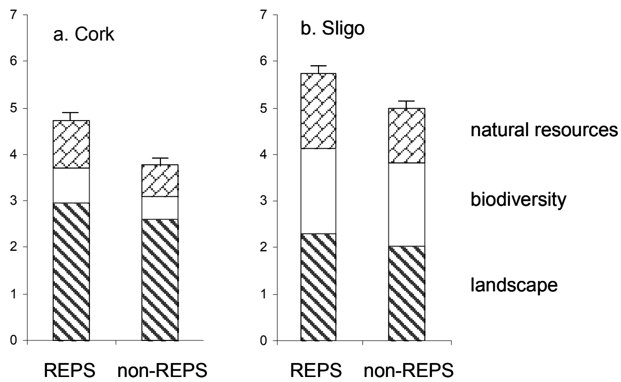

Fig. 1. Comparison of AFI scores (illustrating performance among three different environmental issues) in participating REPS farms and non-participating farms in the Cork and Sligo regions of Ireland

Overall, these results have to be treated with caution, as the sample size of up to 20 farms is very limited, and is not representative of the national-scale application of REPS (which has about 50,000 participants). The AFI approach was applied in six other EU member states, and these results are representative of the outcomes.

Conclusions

REPS farms attained higher AFI scores than non-REPS farms in both applications of the methodology in Ireland. Note that the sample size in this study was too small to be a nationally representative comparison of REPS and non-REPS farms. There may also be biased participation of farms with higher levels of environmental quality. Nevertheless, this work demonstrates the feasibility of constructing an AFI for the evaluation of an AES with multiple environmental objectives. The weighting process also permits prioritisation of environmental objectives that may differ among farming systems, among regions, and among different AESs.

Overall, the AFI methodology developed by the AE-Footprint project has a number of features that have the potential to contribute to the aims of agri-environmental evaluation. The method also offers the advantage of being quantitative and transparent. Importantly, the participatory approach can also help increase the quality of policy dialogue among policymakers, stakeholders and farmers.

Acknowledgments

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Can current Irish riparian management practices enhance ground beetle diversity?

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Introduction

Riparian zones have high levels of biodiversity and play an important role in the abundance, diversity and functioning of floral and faunal communities in agri-ecosystems. The nature of riparian vegetation in agricultural settings is largely a function of management practices. The Rural Environment Protection Scheme (REPS) in Ireland includes measures to exclude grazing stock from riparian areas through fencing (1.5m from the edge of the stream), but prescriptions for riparian management within these fenced zones are varied. Farmers may plant trees within the fenced area, but they can also cut back vegetation within the fenced area. The impact of this management on biodiversity is uncertain, given the lack of specific biodiversity aims, representative target species or standardised monitoring system to identify any impacts.

Carabid ground beetles are widely considered to be suitable indicators of conditions in riparian habitats due to the sensitive and quick reaction of many species to environmental change. Species assemblages can reflect differences in both fluvial hydrology and micro-habitat conditions.

The aims of this study were to assess the impacts of vegetation type on riparian carabid beetle communities in grassland agricultural catchments. The results will inform policy makers on the relative success for biodiversity enhancement of the current riparian management guidelines.

Materials and Methods

Study sites

Ten farms in SE Ireland, managed under the REPS scheme, were selected for sampling. Each farm had a 1st or 2nd order stream within its boundaries, along which were present three riparian vegetation types. These were classified as grass (low herbaceous vegetation), scrub (vegetation dominated by bramble and/or gorse) and woodland (dominated by mature trees such as alder and willow). Each stream within all 10 farms possessed all three vegetation types.

Carabid and Botanical sampling

Pitfall traps were used to sample carabids within each of the three vegetation types along each stream, during 2-week periods in both June and September, 2008. Seven pitfalls traps were placed parallel to each stream, within 1m of the bank edge and with 2m between each trap. Beetle data for each site was combined from both collection periods. Ground vegetation for each site was sampled with ten 0.25m^2 quadrats, randomly located parallel to (and within 1.5m of) each watercourse bank edge. Upper-storey vegetation was given Braun Blanquet values for the entire 20m plot.

Data analysis

Carabid abundances were standardised to trap mean per site to correct for lost samples. Species richness (SR) was calculated using rarefaction (ECOSIM software, Gotelli & Entsminger 2001), which eliminated variation in SR due to differences in sample size and sampling effort. This method repeatedly resamples a pool of samples at random, to produce both abundance curves (abundance of individuals per trap) and diversity curves (SR per trap). Rarefaction curves plotted 'expected' SR across all levels of sampled abundance and number of samples, allowing for a standardized comparison of richness among habitats. Analysis of similarity, ANOSIM, was used to determine if there were significant differences in assemblages between habitat types for carabid and floral communities. ANOSIM produces an R-value statistic, which if approaching 1 indicates strongly distinct assemblages, and if close to zero indicates that the assemblages are very similar. Two-way ANOVA or non-parametric Friedman test with Tukey *post hoc* tests were used to examine differences in SR and abundance.

Results and Discussion

A total of 1943 beetles, from 51 species (approximately 24% of the Irish carabid fauna), were identified. The most abundant species were *Pterostichus melanarius* (38%) and *P. madidus* (17%), both habitat generalists. Only three species were riparian specialists, all occurring on 50% or fewer of the study farms (Table 1). Furthermore, no habitat appeared to be more 'riparian' in character than any other (Table 1). The streamside habitats in our study clearly did not represent true riparian habitats for carabid beetles. This may be due to the highly modified nature of the streamside habitats, their very small spatial scale, or their isolated and fragmented nature. Anderson (1996) has suggested that the riverine riparian carabid fauna in Ireland are disjointed and scattered due to arterial drainage schemes across large areas.

Although 19 carabid species were confined to a single habitat type, 14 of these were singletons, 16 were found on only one farm and none showed an association with a habitat after analysis with Indicator Species Analysis, indicating that this may be a site effect, rather than a more general habitat effect. Other studies have shown that different riparian habitats can contain very distinct communities (Cole *et. al.*, 2008; Plachter and Reich, 1998; Eyre et al., 2001). The low beta species diversity in our study reflects the dominance by eurytopic species which may be due to the highly modified nature of the streamside habitats in these agricultural catchments.

Table 1. Abundance and frequency of occurrence of carabid beetles that are riparian specialists among farms and habitat types. (habitats: G, grass; S, scrub, W, woodland).

Species	Total Number of Individuals	Total Number of Farms	Abundance in each habitat G,S,W	% of Total Carabid Catch
Paranchus albipes	14	5	2, 3, 9	0.7
Pterostichus nigrita	8	2	2, 1, 1	0.4
Trechoblemus micros	8	5	3, 1, 2	0.4

Among habitats, carabid abundance was highest in grassland and richness highest in scrubland (Table 2). Grassy field margins have been found to have both low (Cole *et al.*, 2008) and high densities of carabids (Kromp and Steinberger, 1992) when compared to infield habitats. Our results indicate that the managed grassy habitats within fenced riparian zones, although not as speciose as other habitats, may provide highly suitable habitat for generalist agricultural species. When sites from all farms within each vegetation type were combined, scrub cover provided the highest expected species richness per number of individuals, whereas grass and wood were not significantly different from each other e.g. 400 individuals have an expected SR of 36 in scrub habitats, 25 in grass habitats, and 24 in wood habitats.

Table 2 Impact of vegetation type on carabid abundance (mean ± SD per trap) and species richness (plot mean after rarefaction by sample). Values sharing letters are not significantly different.

	Grass	Scrub	Wood	ANOVA
Abundance	7.1 ± 5	3.8 ± 2	5.1 ± 3.3	P=0.063
Species richness	5.5 ± 1.9ab	6.6 ± 1.6a	4.7 ± 0.9b	P<0.05

The ANOSIM analysis confirmed the marked floristic differences between grassland, scrub and woodland riparian habitats (R-value of 0.86). However, this was not reflected in the carabid assemblages, which showed very little difference between habitats (R-value of 0.119). The three vegetation types along study streams, although floristically distinct, clearly did not provide for differentiation among carabid beetle communities.

Conclusions

The managed streamside habitats in our study contained very few riparian carabid specialists. There was also little difference in the carabid communities between the three vegetation types, despite distinct floristic differences. Together, these results likely reflect the highly modified nature of streamside habitats in many agricultural catchments.

The management practice of fencing agricultural streams at this scale is unlikely to significantly enhance riparian carabid diversity at the farm, or the regional scale. Removing the disturbance of cattle by fencing is unlikely to enhance the numbers or diversity of riparian specialists, because the colonisation of riparian habitats by specialists is hindered by the low carabid diversity in adjacent areas. Although fencing (with no subsequent management) will likely lead to streamsides being dominated by woody and scrubby vegetation, rather than grassy (grazed) vegetation, it seems unlikely that this would cause a significant reduction in the number of grassland specialist species.

Acknowledgments

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Do cattle drinking points contribute to stream pollution levels in Ireland?

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Introduction

The Water Framework Directive (WFD) (2000/60/EEC (Council of the European Union 2000)) requires that water quality be managed and monitored within river basins by a coordinated effort inclusive of all public authorities. The Directive aims to achieve at least a 'good status' in all waters by 2015. In Ireland, the Rural Environment Protection Scheme (REPS) has been the main agri-environment scheme over the past 17 years (Department of Agriculture, Food and Forestry 2007) and so can be considered an important vehicle for the protection of waterbodies. Within REPS and the Agri-environmental Options Scheme (AEOS, the current replacement scheme for REPS) farmers are required to prevent unrestricted cattle access to watercourses, but they are allowed to provide a single drinking access point within each field. There are many additional water protection measures required when participating in REPS, such as effective nutrient management, all of which can contribute to reducing the pollution load to surface waters. Anthropogenic effects on receiving waters can range from the catchment scale (e.g. intensive catchment agriculture) to the stretch scale (e.g. local livestock access). At present however, there is little published data on the effects of cattle drinking access points (CDAPs) as pollution pathways and sources to headwater streams.

The aim of this study was to quantify the extent to which CDAPs impact water quality in agricultural headwater streams. We investigated macroinvertebrate communities and water chemistry parameters both upstream and downstream from CDAPs on streams running through grassland farms in south-east Ireland. We sampled macroinvertebrates, because they are widely used as indicators of stream and river health, are considered good indicators of water quality, and play an important role in the food web of streams and rivers. They are relatively immobile, easy to sample, relatively long lived, respond to a wide variety of pollutants, and can reflect long and short term trends (Chadd & Extence, 2004).

Materials and Methods

Study sites

Forty streams in the southeast of Ireland were selected for sampling. The average annual rainfall total in the southeast has been lower than the rest of the country over the past 50 years and farming practices are relatively intensive when compared to western regions. The study was carried out on first- and second-order streams. These streams, which are expected to be more impacted by intermediate pollution sources such as CDAPs, typically account for >95% of the total processing and transportation of materials (Maitland, 1979). The majority of streams were located on individual farms, and sampling points were over 500m apart.

Water chemistry and macroinvertebrate sampling

Sampling was carried out from July-September 2009. At each site, area of bare ground, adjacent land-use variables, stream physical attributes, and riparian vegetation was recorded. Water chemistry (total phosphorus, total nitrogen, reactive phosphorus, ammonium, nitrate, dissolved oxygen, conductivity and temperature), sediment characteristics and macroinvertebrate communities were sampled at a single site upstream and downstream from the drinking points at locations where stream flow and riparian vegetation were similar. Macroinvertebrates were sampled at the next riffle point downstream of the CDAP, usually at a distance of 5-7 times the width of the stream, and immediately upstream where substrate and riparian habitat were most similar to the downstream sampling location. Macroinvertebrates were sampled using a 5-minute kick-sampling technique, covering approximately 3m^2 of riffle habitat.

Data analysis

The Small Stream Risk Score (SSRS) and Q-values are commonly used biotic indices of water quality in Ireland and each was assigned to macroinvertebrate communities at all sampling locations. Up- and down-stream samples were compared using t-tests of the water and macroinvertebrate data. Because multiple t-tests were conducted, all comparisons of differences between upstream and downstream data sets were only accepted as significant if $p < 0.01$.

Results and Discussion

Forty CDAPs were sampled with a mean individual area of bare or poached ground of 14.6m^2 (±10.9 SD), ranging from 0 to 50m^2. There were no significant differences between upstream and downstream in any water chemistry parameter, sediment or macroinvertebrate parameter (Table 1). Longer-term continual sampling of water chemistry or sampling over the duration of a high rainfall event may be needed to detect any inputs from CDAPs.

Table 1. Mean (± s.e.) water nutrient parameters (mg/l), both upstream and downstream of CDAPs. No parameters showed a significant effect, p<0.01.

	Upstream	**Downstream**
N-NH4	0.04 ± 0.008	0.04 ± 0.01
N-NO2	0.01 ± 0.003	0.01 ± 0.003
RP	0.02 ± 0.004	0.02 ± 0.005
TN	5 ± 0.55	5 ± 0.54
TON	4.2 ± 0.53	4.1 ± 0.53
TP	0.04 ± 0.007	0.05 ± 0.01

The majority of sampled streams returned a Q-value below 4, indicating poor water quality. 10% of streams produced good water quality scores (Q4) (Fig. 1). There were few clear differences between sites that were upstream of drinking points, and those that were downstream. This was also the case for those streams with higher water quality (Q4).

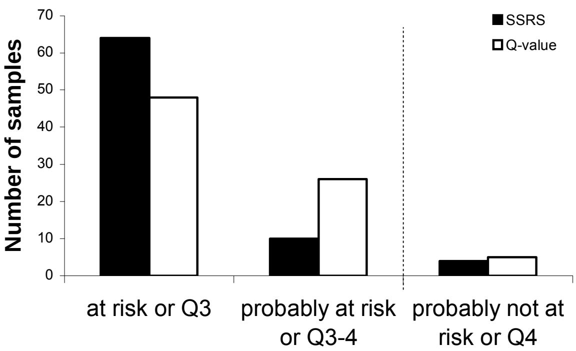

Fig. 1. (A) Number of samples (n=80) assigned to each Q-value and SSRS category. The broken line indicates a boundary between high and lower quality streams.

As highlighted by Q-values, SSRS scores showed that water quality was generally low in the majority of the sampled streams. Again, only 10% of streams were within the 'probably not at risk' category, with two streams showing a decrease in water quality downstream and two streams showing an increase in water quality downstream.

Conclusions

There was no significant impact of CDAPs on stream water quality and biological communities in this sample of study streams. However, a majority of these small streams in our sample were of relatively low water quality, irrespective of the presence of cattle drinking points. These data indicate that cattle drinking access points were unlikely to further impact negatively on water quality in streams of water quality of Q3 or less. Complete exclusion of cattle from watercourses might not be cost- or environmentally effective in some intensive agricultural grassland systems where water quality is already at low levels (≤ Q3).

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Hay meadow plant communities on the Shannon Callows: responses to summer flooding and changes in management

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Introduction

Floodplain grasslands are composed of mosaics of plant communities, the species diversity and composition of which are determined primarily by the hydrological regime (Grevillot *et al.*, 1998). Agricultural practices are the next most influential factor affecting plant communities (Grevillot *et al.*, 1998). The Shannon Callow hay meadows have been managed in the same way for centuries and farmers have valued the annual hay cut as a nutrient-rich food source for their livestock. The annual flooding has restricted agricultural intensification but the waters and sediments bring nutrients to the meadows each winter. Each summer the meadows are cut for hay and this annual removal of biomass plays an essential role in maintaining the nutrient balance on the meadows and promoting floristic diversity. Recent summer floods have brought additional nutrients and prevented farmers from cutting the meadows. Here, we investigate the effects that a combination of both summer flooding and lack of cutting have had on the plant communities.

Materials and Methods

Study area

The Shannon Callow SAC covers 5,788 ha of wet meadows and pastures. The designated area includes two Priority Annex 1 habitats: *Molinia* meadows and lowland hay meadows. The callows comprise the most extensive river meadows in Ireland and support bird species and populations of both national and international importance.

Methodology

Eight hay meadows were selected between Athlone and Banagher. Forty-one relevés were recorded in 2007 across 15 sample areas (each chosen to comprise a homogenous plant community and to reflect the range of zones in relation to flood duration). Each relevé was recorded within a 2m x 2m quadrat and repeated in 2010. The elevation of each quadrat was recorded using a differential global positioning system. The elevation readings combined with twenty years of river level data (1990-2009) was used to calculate a variety of flood variables. Landowners completed questionnaires to ascertain details regarding management on the meadows.

Results and Discussion

Table 1 summarises the flood and management variables for each of the sample areas (listed 1-15 in order of increasing hydroperiod). The annual hydroperiod here refers to the total number of days a sample area was submerged in a year and the mean was calculated for 1990-2009. The summer hydroperiod indicates the number of days a sample area was submerged from May to September (inclusive), calculated for 1990-2009. The mean hydroperiod for recent summers (2006-2009, incl.) was also calculated to highlight the recent increased duration of hydroperiods.

Table 1. Summary of variables for each of the 15 sample sites. The mean refers to the arithmetic mean in each case. ’90-’09 = 1990-2009; ’06-’09 = 2006-2009.

Site	’90-‘09 mean annual hydroperiod (days)	’90-‘09 mean summer hydroperiod (days)	’06-‘09 mean summer hydroperiod (days)	No. of years not cut
1	21.0	0.0	0.0	1
2	40.7	0.0	0.0	2
3	51.3	0.3	0.8	3
4	72.9	2.5	7.3	2
5	74.8	2.4	7.1	3
6	85.2	3.7	10.5	2
7	103.4	5.8	16.5	3
8	119.0	4.3	21.7	0
9	137.2	10.7	26.3	1
10	146.0	15.5	39.0	1
11	148.6	13.6	33.8	3
12	151.9	14.3	35.7	2
13	159.7	16.9	41.9	0
14	163.6	17.1	42.9	3
15	168.7	18.5	43.8	1

Over half the sample areas were flooded for more than 100 days *per annum*. Recent summer floods lasted over twice as long as the long term average. The last column on Table 1 shows the number of years each sample area was left uncut during 2006-2009, i.e. number of recent summer cuts missed. These meadows were not cut either because the meadow was flooded or, as was the case for sample areas 1 & 2, the area was inaccessible due to the surrounding floods. For other sample areas (e.g. 8 & 13), summer flooding occurred, but the farmer did cut hay when meadows were unflooded.

For most sample areas, a significant decrease in plant species richness was observed in 2010 when compared with 2007 (Fig. 1). The greatest drop in species richness was observed for sample areas 2 - 6 inclusive. These areas have annual hydroperiods of less than 100 days and were left uncut for at least two years. Those meadows which normally experience longer flood duration comprise wetter plant communities which are adapted to tolerate flooding and thus reacted less dramatically to the summer flooding.

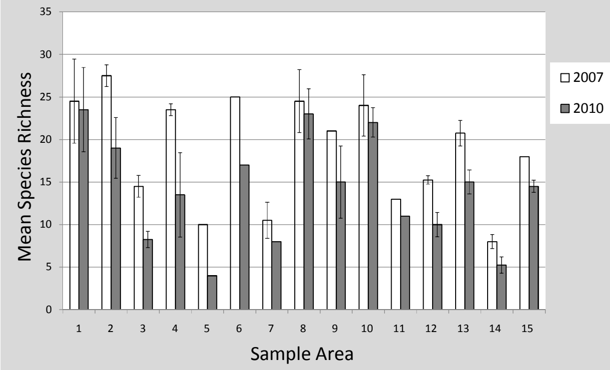

Fig. 1. Mean plant species richness in 2007 and in 2010 for sample areas 1-15. Error bars indicate SD.

A significant drop in β-diversity, as measured by the Shannon Diversity Index (Fig. 2), was also observed for the relevés sampled in 2010 when compared to relevés from 2007. This drop in β-diversity occurred across all sample areas, whether they were only flooded in the summers, only left uncut (& not flooded) or both flooded in the summers and not cut.

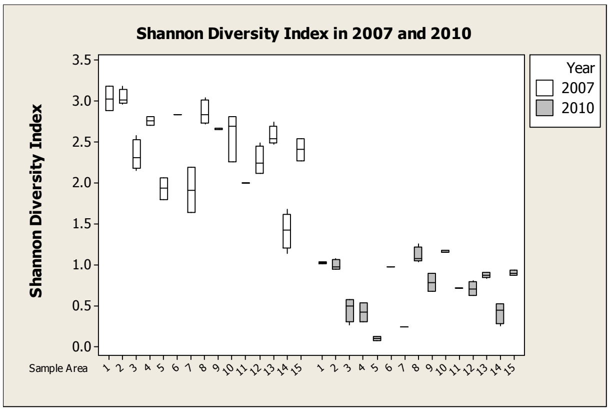

Fig. 2: Shannon Diversity Index for the 15 plant communities in 2007 and 2010.

The drop in β-diversity (Fig. 1) is more significant than the drop in species richness (Fig. 2). This reflects the fact that many species recorded in 2007 although still present in 2010 were present in much lower abundances. A contrasting increase in the abundance of faster-growing species was also observed. In particular, meadowsweet *Filipendula ulmaria*, which grew to over 1.5 metres in height on some meadows, out-competed smaller forbs and even vigorous grasses.

A non-metric multidimensional scaling (NMS) ordination of the relevés recorded in 2007 and 2010 (Fig. 3) shows that relevés taken in 2010 clustered to the top right of the graph and relevés recorded in 2007 to the bottom left. Mean hydroperiod is strongly positively correlated with Axis 1 where as species richness and the diversity indices are strongly negatively correlated with this axis. Number of years since the meadow was cut is strongly positively correlated with Axis 2. Thus, whereas the 2007 relevés are correlated with species richness and diversity the 2010 relevés are correlated with longer flood duration and lack of cutting.

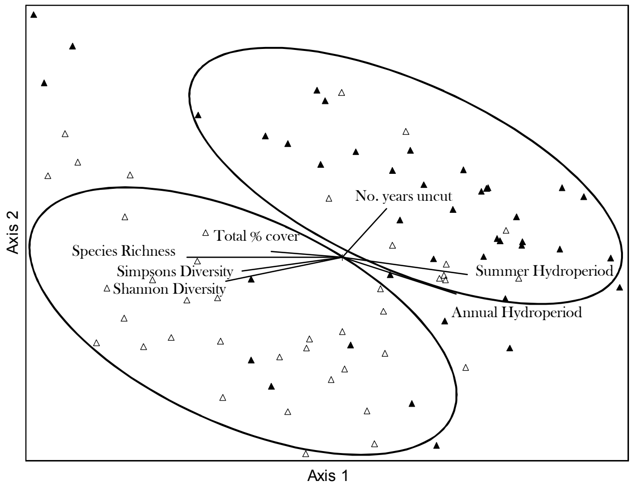

Fig. 3. NMS Ordination of relevés taken in 2007 open triangles) and 2010 (closed triangles). Axis 1 explains 37.6% and Axis 2 explains 33.5% of the variance in the data.

Conclusions

It appears that a combination of consecutive summer floods and lack of hay cutting has significantly reduced the plant species richness and diversity on the callows. The summer floods have facilitated the growth of a few dominant species while retarding the growth of other species. The plant communities which were not flooded during the summers of 2006-2009 also showed a significant drop in diversity corresponding to a lack of cutting. This highlights the need for an annual hay-cut on the meadows both as a means of removing nutrients and controlling fast-growing species. The annual cutting on hay meadows is essential not only for the meadow plant communities but also to maintain the vegetation structure favoured by ground nesting birds, most notably, the corncrake. Although delaying hay cutting until after the breeding season for ground nesting birds is preferable, to ensure habitat quality it is not advisable to delay cutting beyond July or August (with timing depending on the hydrology of the meadow).

Acknowledgments

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Development and design of locally targeted HNV programmes in Ireland-The Aran Islands Case Study

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Introduction
The three islands of Aran, Inis Mór, Inis Meáin and Inis Oírr are a geological extension of the karstic limestone region of the Burren in north Co. Clare. Agriculture is and has been an important part of the islands economy and the agricultural practises have created a High Nature Value (HNV) system. The area contains a mixture of rare Irish and European habitat types including orchid-rich grassland/calcareous grassland, lowland hay meadows, limestone pavement (Plate 1) and machair. Over 75% of the total land area is designated as a Special Area of Conservation (SAC) under the EU Habitats Directive. Some of these priority habitats are now in bad condition (NPWS 2008) (Plate1).


Plate 1. Calcareous grasslands on Inis Mór showing scrub encroachment due to changes in traditional agricultural practices.

The BurrenLIFE project has shown that by working closely with farmers it is possible to improve the condition of priority habitats through locally targeted solutions. This model could be extended to other HNV areas such as the Aran Islands.

Background
The principal farming enterprises on the Aran Islands are single suckling production and sheep. Most of the cattle are sold as stores to cattle dealers on the mainland. In 2000, the area farmed was recorded as 3,025ha across 224 farmers on the three islands, indicating an average size of approximately 13.5ha, significantly below the national average of 31.4ha (CSO, 2000). Kelly (2008) analysed the structure of farms under agreement in the Rural Environmental Protection Scheme (REPS). Whilst the average farm size in REPS was 17ha, 29% were less than 10ha and only 5% of the farms exceeded 40ha. 79% of the farms were less than 20ha. Stocking rates were low with 60% of the farmers having a stocking rate of less than 0.6 livestock units/ha. Many farms are very fragmented with some spread over 12 separate plots of land (Smith *et al*., 2010). The small fragmented farms coupled with low stocking rates means the farms are on a poor economic footing. Resulting changes in the islands traditional agricultural system is affecting the condition of many habitats leading to a potential overall loss in biodiversity.

To date the main policy instrument for targeting biodiversity on individual farms within Europe has been agri-environment schemes, which in Ireland has been implemented through REPS and more recently the Agri-Environment Option Scheme (AEOS). Kelly (2008) carried out a study of REPS on the Aran Islands. He concluded that overall, REPS had been a beneficial scheme to the islands, with 88% of the farmers participating. The study found that REPS had improved knowledge of the environment within the farming community and had helped in the maintenance of stonewalls that are so characteristic of the islands landscape. However, the study exposed some important limitations in the context of the Aran Islands. There was a lack of positive management with some specific conservation issues that the REPS scheme did not address. He concluded that a higher-tiered agri-environment scheme or measure is required to focus on the specific habitat, species and cultural conservation issues, which should complement rather than replace the work being done by the REPS. REPS has benefited the islands through the provision of economic support to farmers, but it has failed to adequately address a number of conservation issues, such as declines in cereal and vegetable tillage and associated rare arable plants and scrub encroachment on priority habitats designated under the EU Habitats Directive (Smith *et al*., 2010). Some of these shortcomings arose from the fact that REPS was a national-scale scheme and although adaptable to some regional-specific issues, Smith *at al*. (2010) found that it was not ideally suited to meeting all ecological and agricultural needs in the Aran Islands.

The Burren approach
Farmers and researchers managing similar limestone grasslands in the Burren, Co Clare also found that the generic farm management prescriptions under REPS were not particularly effective at conserving unique features of the

Burren landscape. This shortfall led to the BurrenLIFE initiative, an EU funded LIFE program that undertook work based on “on farm” research with 20 local farmers. It combined local farming knowledge with best scientific practices to develop a regionally targeted farming for conservation programme. A variety of management options for grazing, feeding and scrub control were researched. This combined with monitoring, education and awareness raising programmes resulted in successful measures being expanded to the wider farming community. The result has been a locally targeted agri-environment scheme for a High Nature Value (HNV) area now known as the Burren Farming for Conservation Programme (BFCP).

Extending the BFCP to the Aran Islands.

The similarities between the Burren and the Aran islands means much of research outcomes could be transferred to the Aran Islands, with some changes to reflect the differences in the two areas. A number of Aran farmers took part in a study tour to the BurrenLIFE project in 2008. The Aran Islands were also included as a case study area in a recent Heritage Council Study on High Nature Value farmland in Ireland (Smith *et al*., 2010), part of which included a series of public consultation meetings. The Heritage Council then teamed up with the European Forum on Nature Conservation and Pastoralism (EFNCP) to employ a HNV officer for Ireland who would further the HNV work on the Aran islands and other areas. The work began with a series of workshops held on each of the three islands in August 2010. These workshops explored the HNV concept and aimed to initiate community participation. The BFCP was discussed, identifying areas where it may be directly transferable or where possible amendments were required. A total of 48 islanders attended the workshops with 17 people volunteering as contact points to assist with the future developments of the project. One of the main differences highlighted between the Aran Islands and the Burren was farm structure with smaller farm sizes and fragmented holdings on the islands. Overall the local community saw merit in exploring the BurrenLIFE model in further detail. A further series of meetings were held in late September 2010 in conjunction with REPS training courses to present the combined results from the August meetings and collect any additional information or other views. The meetings also offered an opportunity to highlight the importance of the islands for nature conservation and the importance of agriculture in maintaining these areas. Some of the farmers requested an additional study tour to the BFCP, which took place in November 2010.

From the workshops, feedback from the additional meetings and farm visits, the project team in consultation with local farmers drew up a list of issues, proposed solutions and initial costings. The framework for an Aran Farming for Conservation Programme based on the BFCP model was produced. Through the farmer representative group, a further series of meetings was held on each island and the programme was explained with knowledge gaps identified. On-going work involves the gathering of management details from the farmers so best practices can be documented and the identification of trial sites for necessary management works. The next step in the process is to identify suitable funding sources to implement the plans either through LIFE programs or through future changes in the Common Agricultural Policy (CAP) reform.

Discussion

Whilst the Aran Islands and the Burren are similar landscapes, the approach can be followed in a range of HNV landscapes to produce targeted programmes that meet the needs of the community and improve the status of many priority habitats. To be successful they require not only sufficient funding but relevant research, dedicated individuals within the farming community and an understanding of the important environmental services that their farming area offers as well as the production of quality food. Enhancement of environmental quality and sustaining the ecosystem services provided by HNV areas can only be achieved through the active involvement of local communities. These communities are committed to the development of their areas. Through support from and engagement with other stakeholder much progress can be made in developing and implementing targeted programmes for the maintenance and enhancement of HNV landscapes.

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Conserving Twite *Carduelis flavirostris* in Ireland

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Introduction
The Twite *Carduelis flavirostris* is a member of the finch family that breeds and winters in Ireland. Although never common here, 100 years ago it was believed to breed in all coastal counties. In the past thirty years a considerable decline in populations has been observed and the latest estimate is less than 100 breeding pairs (McLoughlin & Cotton 2008). This population breeds in only five of the 32 counties on the island of Ireland with over 85% of these occurring in north Co. Mayo and west Co. Donegal. The national winter population is estimated at between 650 – 1100 birds. Consequently, the Twite is one of only three passerine species on the Red List of Birds of Conservation Concern in Ireland (Lynas *et al.*, 2007). Breeding Twite can be categorised as being 'Endangered' using the International Union for the Conservation of Nature (IUCN) criteria for the categorisation of Red List species and are thus considered to be facing a 'very high risk of extinction in the wild' in Ireland.

This paper presents an overview of the main elements of the Twite's ecology in Ireland with a summary of the primary actions required to conserve Twite as a breeding species in Ireland.

Methods
Movement patterns
Data on the movement patterns of Twite in the two breeding strongholds was generated by monitoring colour-ringed birds in the breeding and winter seasons. Radio tracking was also used to analyse home-range size and dynamics. This is presented in McLoughlin *et al.* (2010).

Habitat requirements
Habitat selection studies focused on the breeding populations in north Mayo and west Donegal. Walkover surveys and radio tracking were used to determine habitat preferences of Twite within 2 km of their breeding colonies. Habitats were classified using the Fossitt (2000) classification. Results were analysed using compositional analysis (McLoughlin 2009). The assessment of habitat requirements during the winter season was based largely on evidence from similar studies in Scotland and England e.g. RSPB Twite Recovery Project (Gowthorpe 2009).

Results and Discussion
Movement patterns
In the course of this study, 492 birds were ringed of which 480 were caught outside the breeding season; 57 (12%) were resighted on their breeding grounds. The breeding birds spent most of the winter season within 28 km of their breeding areas. Two birds ringed in the study areas during the winter season were subsequently resighted during the breeding season on Islay and Mull of Kintyre respectively. These results suggest that Irish breeding Twite are mainly sedentary and that populations appear to be augmented by Scottish breeding birds during the winter months.

Breeding season foraging and nesting areas
Foraging Twite selected lower saltmarsh habitats in west Donegal and dry-humid acid grassland habitats in north Mayo, where lower saltmarsh did not occur. Wildflowers along tracks and roads were important in both areas in April and early May. The sward height in most of the foraging areas tended to be <100 mm, which, depending on the target plant, allows access for birds to feed on the seed of shorter plants, e.g. Pearlwort *Sagina nodosa*. This shows the importance of grazing in the foraging habitat during the breeding season to maintain suitable sward height and to prevent a dominance of a rank sward.

Of 72 nest sites found between 2005 and 2011 in Donegal and Mayo, 68 occurred in long Heather *Calluna vulgaris* with only four using patches of Bracken *Pteridium aquilinum*. Twite strongly depend on long heather with a heterogeneous mix of moorland vegetation for roosting and nesting. This highlights the importance of maintaining and increasing the extent of long heather adjacent to breeding colonies. It should be noted that at the Mayo study area this vegetation type constituted approximately 1% of their home range. These nesting areas should ideally be <2.5 km from low intensity agricultural lands where the Twite forage.

Targeted food plants
The target food plants of Twite throughout the breeding season comprise solely of common plants that produce relatively small seeds including Dandelion *Taraxacum* agg., Chickweed *Stellaria media*, Sea Plantain *Plantago maritima*, Thistle *Circium spp.*, and Autumn Hawkbit *Leontodon autumnalis.*

Winter season
Although the winter ecology of Twite has not been studied in Ireland, it is thought that there may be a bottleneck in the availability of suitable seed towards the end of the winter season (Raine 2006).

Based on successful projects in Scotland, McLoughlin (2011) suggests several options that would provide suitable seed, including Radish *Raphanus sativus* and Turnip *Brassica rapa*, throughout the winter season. Seed prescriptions for current wild bird plots (e.g. LINNET plots in REPS) tend to be too large for Twite.

Conservation implications and recommendations

The implementation of successful conservation plans for bird species can often be complicated by the large areas the species may cover between winter and summer seasons. In the case of twite however, due to the sedentary nature of our population, conservation action plans focused in the areas they occur have the potential to be highly successful for breeding and wintering populations.

A document giving guidance on the enhancement of Twite habitat through suitable land management has been prepared (McLoughlin 2011) and is currently available to land managers and their advisors in areas where Twite occur.

Table 1. Summary of suggested actions for farmland conservation of Twite

Primary suggested actions (April-October)
1. Maintain, or create, a heterogeneous mix of moorland vegetation, particularly long Heather.
2. Maintain bracken stands but prevent them from increasing in dominance on dwarf shrubs.
3. Prevent afforestation of potential breeding areas by careful consideration of the location of proposed plantations.
4. Avoid topping of Thistles and Sorrel *Rumex acetosa* in potential feeding areas.
5. Avoid the chemical spraying of wildflowers.
6. Avoid agricultural 'improvement' of enclosed fields within a 3km radius of breeding areas.
7. Maintain meadows with seeding wildflowers throughout the breeding season.
8. Restoration of improved, flower-poor fields to traditionally managed hay meadows.

Conclusions

In the years prior to this project, a serious lack of knowledge of the ecology of Twite in Ireland was a major barrier to designing and implementing conservation measures to secure their future as a breeding species. Today however, we have a detailed knowledge of many aspects of their ecological requirements and we have a comprehensive plan (McLoughlin 2011) to address the issue of their possible extinction here.

Due to the precarious situation regarding the Twite breeding population in Ireland, it is vital that land management prescriptions and species policy now focus on their conservation. As Twite are not Annexed species under the EU Birds Directive, they have not been included in any previous agri-environment schemes.

It is crucial that we incorporate species such as Twite in future agri-environment policy by targeting specific measures on a bio-geographical basis (e.g. High Nature Value farmland policy). Implementation of these measures would also benefit a host of other flora and fauna in these areas e.g. Red Grouse *Lagopus lagopus*. Without such measures it is most likely that Twite will follow the fate of Corn Bunting *Emberiza calandra*, another farmland bird which became extinct in Ireland in the early 1990s.

Acknowledgments

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How does animal stocking rate influence agricultural grassland biodiversity when measured at different scales?

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Introduction
Individual biological taxa operate at different scales within agricultural ecosystems. As a result there is currently no consensus as to what is the optimal scale to implement effective agri-environment policy (Gabriel *et al*., 2010). In order for indicators to be used to their fullest advantage, it is necessary to understand the ecological relationships between the chosen indicator group(s) and wider community structure, as well as the particular ecological influences they reflect (Paoletti 1999). In this study, plants, parasitoids, birds and habitats were utilised as response indicators to animal stocking rate as each of these indicators operate at different scales within agricultural ecosystems. The nature of the response of these indicators provides important information as to the targeting of different biological taxa within agri-environment schemes.

Materials and Methods
Plants, parasitoid and farmscale bird surveys were carried out on 119 grass-based farms located in three regions in the Republic of Ireland during two field seasons (2007-08 and 2008-09).

Plants were sampled using quadrats at the field margin and in the field. Parasitoids were collected from field swards were sampled using a Vortis Insect Suction Sampler (Burkard Manufacturing Co Ltd, Rickmansworth, Hertfordshire, UK) (Arnold 1994). Standard yellow pan traps with a window interceptor were used to collect mobile flying parasitoid populations. Bird surveys were conducted using standardise techniques (Bibby *et al.,* 2000; McMahon *et al*., 2008). In addition, habitats on each farm and within the surrounding landscape were also classified and quantified. Animal stocking rates, calculated as livestock units per hectare (LU/ha) were used as an indicator measure of agricultural intensity.

Analyses
Animal stocking rate, calculated as standardised livestock units per ha (LU/ha), was calculated as a measure of overall agricultural intensity on the surveyed farms, following the methodology of the Irish National Farm Survey (Anon. 2009). Generalized Linear Mixed Models were used to quantify the relationship between animal stocking rate and each of the indicators.

Results and Discussion
The field scale indicators of plant species richness, parasitoid taxon richness and abundance were negatively associated with animal stocking rate (Table 1). There was a positive relationship between stocking rate and total winter bird species richness and abundance, and the species richness and abundance of winter Farmland Bird Indicator species (Gregory *et al*. 2004). However, the overall relationship was quadratic, indicating that above an upper limit intensity has a negative influence (Table 1). All other indicators showed no response to animal stocking rate.

Table 1. Summary of likelihood ratio tests (χ^2) with the effect of stocking rate on the selected indicators.

Indicator	Stocking Rate (χ^2, *P* value)	Effect of stocking rate
Field plant species richness	5.55, 0.019	Negative
Field parasitoid taxon richness	5.15, 0.023	Negative
Field parasitoid abundance	3.36, 0.067	Negative
Winter birds species richness	4.56, 0.033	Quadratic
Winter bird abundance	15.85, <0.001	Quadratic
Winter Farmland Indicators species richness	8.55, 0.003	Quadratic
Winter Farmland Indicators abundance	16.23, <0.001	Quadratic

Conclusions
The lack of a consistent response from the indicators to variations in stocking rate indicates that maximising biodiversity within agricultural ecosystems requires taxa to be targeted at their appropriate operational scale. A variation in taxa response to farm system has also been reported in a previous study (McMahon *et al*., 2010). It is not surprising that our data revealed a significantly negative influence of stocking rate on sward species richness in the centre of surveyed fields and the abundance and diversity of parasitoid within the sward; the latter group being particularly good indicators of taxon richness of wider arthropod populations within agricultural

grasslands (Anderson *et al*., 2011). The explanation for this is that increased nutrient input levels can have a marked influence on both sward plant and arthropod communities in grasslands, with a generally negative effect on species richness.

The positive effect of stocking rate (and by inference a positive influence of overall management intensity within managed grassland fields) on winter bird populations is counter-intuitive and contradicts any assumption that grassland management intensity has a necessarily negative impact on all aspects of farmland biodiversity. A partial explanation for winter bird populations, including Farmland Indicator species, occurring in greater numbers on intensively managed fields is that soil invertebrates, especially earthworms can be significantly more abundant (if not more diverse) under conditions of greater nutrient input levels (Curry *et al*., 2008).

The results of this study provide two important insights that should inform agri-environment policy in the future, within Ireland but also throughout the EU.

Firstly, for development of optimally customised agri-environment schemes where the aim is the protection or enhancement of biodiversity, the scale of implementation is vital and should depend on the taxa that are targeted. The results of this study and Gabriel *et al*. (2010) provide substantial evidence to support this perspective.

Secondly, the presence of relatively intensive grassland management has a place in agriculture and may present an opportunity so long as it is not coupled with widespread removal of non-cropped habitat.

Recognition of these is essential to facilitate the effective implementation of agri-environment measures to maximise biodiversity within Irish and EU farmland.

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Lethal and sub-lethal effects of ivermectin on two common species of dung beetle in a laboratory experiment

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Introduction

Dung decomposition is an important ecosystem service in grazed grasslands and underpins efficient nutrient cycling. Dung beetles play an important role in dung decomposition. In addition, dung beetles constitute part of the diet of several vertebrate wildlife species, including bats and birds of priority conservation interest.

Ivermectin is an anthelmintic veterinary medicine, and is excreted in the dung of treated livestock in a mainly unmetabolised form. Ivermectin is known to have toxic effects on dung beetles, but most studies to date have been conducted on tropical and sub-tropical species. Relatively few laboratory studies have focused on the specific effects of ivermectin on survival and development of north temperate dung beetles.

Susceptibility of dung beetles to the lethal and sub-lethal effects of ivermectin (and other related compounds) in dung is of particular concern, because of the potential for reduced dung beetle biodiversity, impaired dung decomposition and reduced prey resources for wildlife. Current wildlife management guidelines of conservation authorities (e.g. Natural England, Joint Nature Conservation Committee) recommend livestock husbandry practices that at least limit the use of anthelmintics such as ivermectin in order to eliminate potential ecotoxicological risks for wildlife. Nevertheless, further evidence is desirable to support such recommendations.

We investigated the lethal and sub-lethal effects of ivermectin on different life history stages of two widely distributed and abundant north temperate beetle species. In this study, a series of bioassays were conducted using two species that are abundant and have a widespread distribution in north temperate areas i.e. *Aphodius ater* (de Geer) and *A. rufipes* (L.). We investigated the effect of ivermectin concentration on:

a) survival of adult beetles,
b) oviposition by adults,
c) larval development rates and
d) survival of larvae.

Materials and Methods

Cattle were divided into four groups: an untreated control group and three treatment groups in which animals received a subcutaneous dose of ivermectin (Qualimec™) by injection (0.2 mg/kg body weight). Following subcutaneous injection, ivermectin concentrations in dung typically reach a peak at 3-5 days post-treatment, and thereafter decline to low detection limits. Thus, to vary the ivermectin concentration in dung, the treatment groups were dosed on different days (i.e. at 7, 5 and 3 days prior to dung collection) but dung was collected from all four groups (including a control group) on the same day to eliminate any differences in dung quality (e.g. dung moisture content) which might arise if dung was collected on different days. Dung was collected separately from all groups.

Four bioassays were carried out for each beetle species using two dung types (cattle and calf), giving eight bioassays in total (Table 1). Groups of adult beetles were initially added to replicate dung pats from each experimental group. Adult survival and oviposition were measured, and replicates were repeatedly inspected to determine larval development and survival of the eggs laid by the adults. (See O'Hea *et al*. (2010) for details).

Generalised linear mixed models (GLMMs) were used to assess the effect of ivermectin concentration on beetle survival and development. In each analysis (a-e), fixed effects of concentration, dung type (calf/cattle dung), beetle species (*A. ater*/*A. rufipes*) and their interactions were fitted. A random effect was incorporated to account for variation among bioassays. The number of surviving adults (a), number of eggs laid by *A. rufipes* females (b), and number of individuals surviving at the end of the bioassay (e) were all modelled using Poisson regression (GLMM with a Poisson distribution and log link function). The effect of ivermectin concentration, dung type, beetle species (*A. ater*/*A. rufipes*) and their interactions on the probability of reaching a particular life stage by a certain time (analysis c) were assessed using an ordinal model (GLMM with a multinomial distribution and a cumulative logit link function). The proportional survival of larvae (d) was modelled using logistic regression with binomial distribution and logit link. All analyses were fitted using the GLIMMIX procedure in SAS.

Results and Discussion

There was a highly significant and negative overall effect of ivermectin on larval development (e.g. Fig. 1). For example, the predicted probability of a larval individual developing beyond instar III was significantly affected by ivermectin for both species. The largest effects occurred in the bioassays with *A. ater* in cattle dung. These indicated an 80% probability of *A. ater* larvae having developed beyond larval instar III after 4 weeks in the dung without ivermectin, whereas this probability dropped to about 15% in dung with 0.2 mg of ivermectin per kg (wet weight of dung) (Fig. 1). There can be strong pressures on larvae to complete their development before conditions in the dung pat become unsuitable, and additional delays to larval development by ivermectin may increase larval mortality.

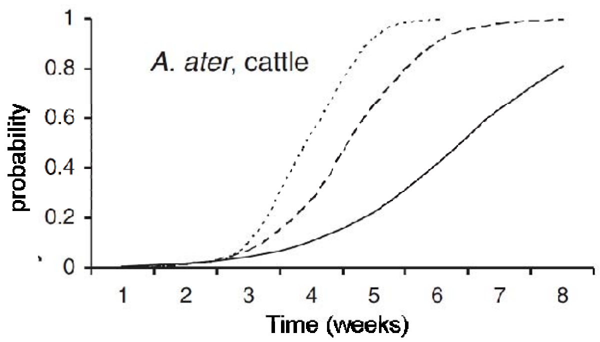

Fig. 1. Example of effects of ivermectin on larval development times of *Aphodius ater*. Ivermectin levels of 0, 0.1 and 0.2 mg kg^{-1} are shown as short-dashed, long-dashed and continuous lines, respectively.

Increased ivermectin concentration consistently had a highly significant negative effect on the abundance of surviving individuals at the end of the bioassays. Highest mean numbers of surviving newly emerged adults (*A. ater*) or prepupae (*A. rufipes*) were found in the control dung pats with no ivermectin. In the majority of cases, there were few, if any, survivors at the end of the study in the dung pats with highest ivermectin levels (Fig. 2).

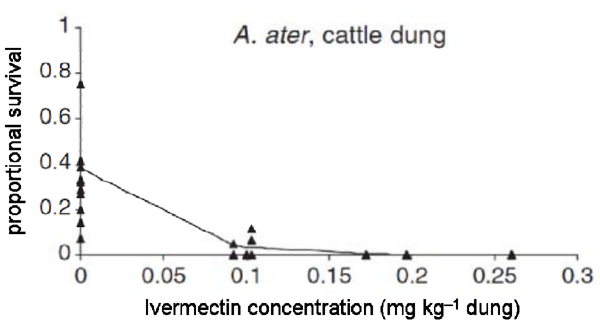

Fig. 2. Example of effects of ivermectin concentration on proportional survival of larvae of *A. ater*. Plotted values are the final number of individuals as a proportion of the initial number of eggs.

In general, ivermectin concentration did not have significant negative effects on adult survival (over a period of 4-10 days). The number of eggs per female *A. rufipes* was significantly reduced by ivermectin concentration in one of two bioassays, but the magnitude of the effect was not large.

Conclusions

Larval development rates were significantly slowed by ivermectin. Ivermectin had significant negative effects on the survival of larvae. Overall, ivermectin concentration caused large and significant reductions in the cohort size from an individual dung pat that would potentially contribute to the next generation of beetles.

Extrapolating from controlled experiments at the scale of individual pats to field conditions, however, invokes several factors that affect the levels of ivermectin in dung pats, and the actual impact on dung beetle populations and other farmland wildlife (see O'Hea *et al*. (2010) for further discussion). Given the variety of factors involved across several scales, it is not surprising that there is considerable uncertainty about the extent to which dung beetle populations are depleted by ivermectin usage, and about the knock-on effects on populations of vertebrate wildlife that prey on dung beetles.

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Experts' assessments of biodiversity options and supplementary measures in REPS 4

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Introduction

Agri-environment schemes (AESs) in the EU are a major contributor towards CAP objectives to reverse biodiversity decline, achieve good water quality by 2015 and achieve the Kyoto targets for mitigating climate change. Member States are obliged to implement monitoring and evaluation of their respective agri-environment programmes. The evaluation process is intended to identify the extent to which policy objectives are being fulfilled, and to identify any changes necessary to bridge the gap between policy aims and outcomes. Summary reports on agri-environment policy evaluations have concluded that there has been insufficient measurement of the precise environmental outcomes from agri-environment schemes. Participation in AESs *per se* does not guarantee the actual delivery of environmental protection or improvement, and only the monitoring of actual performance and environmental outcomes can demonstrate the true value and environmental impacts of agri-environment schemes (Kapos *et al*., 2009). A consequence of the lack of environmental monitoring of schemes is their impaired ability to identify either successes or failures, and to learn how to improve their environmental effectiveness. In the absence of national-scale quantitative data (Finn and Ó hUallacháin, in press), the aim of this study was to elicit experts' judgements on the expected environmental performance of selected elements of REPS.

Materials and Methods

We consulted with a group of eight Irish agri-environmental experts to assess the wildlife value of current supplementary measures and options in the REPS 4 scheme. The selection of experts was based on several criteria: knowledge and experience of biodiversity, agri-environment policy, applied agro-ecological research and applied interpretation of REPS policy in advising farmers (Finn *et al*., 2009).

The assessment utilised experts' judgements of the effectiveness of the REPS options and supplementary measures that are relevant to biodiversity. The assessment occurred in two stages.

First, experts scored each option using a scoring scale for each of five criteria, as follows:

- validity of the cause-and-effect relationship between the intended objective and the prescribed management,
- degree of institutional implementation,
- degree of farmer compliance,
- the extent to which the measure achieved an appropriate match between the distribution of environmental issues and participation and,
- the extent to which participation was sufficient to achieve the environmental objective.

Second, the scores were collated and the group of experts discussed each option, elaborated on the justification for their decisions and aimed to achieve consensus.

Results and Discussion

The majority of biodiversity options received high scores for both the cause-and-effect and compliance criteria. Therefore, for the majority of measures and options, correct implementation of the management prescriptions is expected to achieve the environmental objective. Nevertheless, many measures were considered unlikely to be as effective as expected. Several options were expected to have little or no environmental effect, and some of these were associated with medium to very high participation levels. The assessment identified specific reasons why certain options were not expected to be wholly effective. Many options are likely to have low or no effectiveness (at the scheme scale) because of insufficient participation levels (Figure 1).

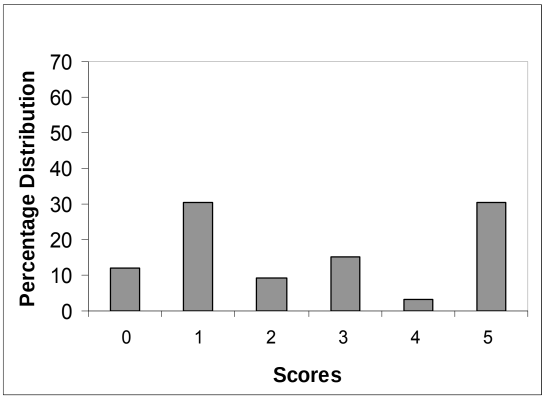

Fig. 1. Distribution of experts' assessments of REPS options and supplementary measures across the score categories for the participation criterion. A score = 0 indicates insufficient participation to achieve the environmental objective.

The experts recommended that the aims and objectives of the scheme and individual options should be stated with greater clarity and precision. The objectives should clearly identify the type of biodiversity to be benefited/ targeted, and better explain how this will be achieved by the management prescriptions.

Other recommendations were relevant to design and implementation choices at the scheme-scale:

- move away from a 'one-size-fits-all' approach in favour of spatial targeting.
- consider the additional effectiveness that may be achieved from spatial targeting or incentivised participation of groups of farmers at the ladscape scale, as well as recommended minimum participation levels to achieve specific environmental objectives.
- reduce the choice of measures within the agri-environment scheme. A tiered approach was recommended, with the choice of options being strongly guided toward those best suited to the farm conditions.

The experts consistently emphasised a number of other comments.

- Biodiversity and habitat conservation objectives should be afforded higher priority, especially given that most agri-environment funding in Ireland is allocated to biodiversity. REPS should improve the provision of advice for the protection and management of existing habitats. For relevant habitats, there should be measures that target the achievement of favourable conservation status.
- Clearly prioritise and distinguish among the need for conservation of existing habitats, enhancement of degraded habitats, and creation of new habitats.
- Ensure greater alignment between biodiversity objectives in REPS and those of local and national biodiversity priorities, with the overall aim of achieving the renewed EU target of halting biodiversity loss by 2020. Guidance on the latter is provided by the National Biodiversity Plan, relevant policy documents and other publications e.g. Red List Data books, National Strategy for Plant Conservation etc.

The issues raised by the experts would be relevant to any evaluation of the design and structure of existing measures that may be included in future agri-environment schemes. However, highest priority should go towards:

- strengthening links between the biodiversity objectives of REPS and national conservation priorities. This will be necessary to meet the new EU target of halting biodiversity loss by 2020, and;
- monitoring and measuring the environmental effectiveness of REPS. Where necessary, monitoring would also help learn how improve any measures with deficiencies. Most importantly, the aim of monitoring would be to demonstrate the environmental benefit of well-designed measures and options.

Conclusions

The use of expert groups proved to be an efficient and effective method to:

(i) assess the likely environmental effectiveness of biodiversity options;
(ii) identify specific aspects of options that are in need of improvement, and;
(iii) highlight modifications that should improve environmental effectiveness.

The use of experts' judgements can be particularly useful as a method for achieving rapid feedback on the design of new schemes or measures.

Acknowledgments

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HNV farming and the management of upland biodiversity on the Iveragh Peninsula, South Kerry.

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Introduction

This short paper deals with issues surrounding farming systems and the management of priority upland habitats on the Iveragh Peninsula. We combined a comprehensive farm management survey of 80 Iveragh hill sheep farms with habitat mapping and a detailed ecological survey on a subset of 21 core farms. The management survey covered issues relating to farming systems – grazing management, stocking density, animal breeds, along with environmental practices and farm economics. Using ecological criteria, the farms were classified as undergrazed, overgrazed or sustainable grazed.

Active management of farming systems, in particular grazing management, is critical to upland biodiversity. Both under- and over-grazing adversely affect plant diversity. Over the years, European CAP policy has had a major influence on the management of the uplands, as we move from the high stocking densities and overgrazing associated with the European Ewe Premium in the 1980s, to the implementation by the Irish Government of the Commonage Framework Plan in 1998 (which brought about a compulsory destocking of all commonages), through to the 2005 Single Farm Payment (SFP), which effectively decoupled income from production and led to a further destocking of the uplands.

Results

Overall, grazing management on the Iveragh was found to be extensive, but there was variability depending on site specific and production objectives. Mean annual stocking rates on semi-natural upland areas were calculated to be 0.29 LU/ha. However, this figure masks the fact that at 0.48 LU/ha, stocking rates during the grazing season can be significantly higher. Stocking density as an indication of grazing pressure is problematic as it gives no indication of the density of feeding. Furthermore, it does not take into account the altitude at which grazing occurs, the spatial distribution of the grazers, foraging behaviour, impact of shepherding, breed and age of animals, burning regime, supplementary feeding, time of year, along with previous management history. On the Iveragh Peninsula we remarked that the same stocking rate may cause one area to be ecologically damaged, and yet leave another almost undisturbed. Consequently, we recommend that grazing controls should be locally specific and a habitat specific stocking rate would be of more use than applying a blanket stocking density. Livestock grazed the uplands for an average of 221 days, a significant reduction to the traditional year round grazing regime. We also remarked that the decline in store cattle grazing in the uplands, or the switch to supplementary feed suckler cows, is associated with the current spread of bracken, gorse and hard rush. In keeping with current market demands for heavier lambs, the farm survey found that 42% of the traditional rustic Blackface ewes are now cross-breed with lowland breeds, resulting in different foraging behaviour. The harsh conditions and low quality of hill grazing resulted in low breeding success rates of 0.6-0.8 lambs per ewe.

The mean surface area of the 80 farms surveyed was 138 ha, and the average farm manager's age was 49 years. The hill farms typically consisted of 59% upland, 20% improved 'greenland' and 21% rough land. Seventy percent of the farms had a share in an upland commonage, which constituted 32% of the area farmed (on average). Eighty-six percent of surveyed farms participated in the Rural Environment Protection Scheme (REPS) and 52% of holdings were designated as Special Areas of Conservation (SAC). Of surveyed respondents, 73% had reclaimed land since their time as farm operator. The resultant 'greenland' allowed farmers to keep more livestock on low ground for longer periods and thereby reducing farmers' dependency on upland rough grazing and rustic sheep breeds. This observation combined with the fact that the majority of the farm managers are today involved in off-farm work has led to an overall simplification of the traditional management structure. We identified a trend towards moving farming down slope, concentrating the farming system around the reclaimed 'greenland', and the less intensive use of the upland rough grazing and commons

(O'Rourke and Kramm, 2009; Kramm *et al*., 2010). Over half the farmers surveyed noted a significant increase in scrub over the last five years in the uplands. We remarked a trend towards intensification and extensification (even abandonment) on the same holding. The ecological data from the core 21 farms studied found that the majority (52.4%) were classified as undergrazed, 19% were sustainably grazed and 28.6% were overgrazed.

The analysis of the labour structure on the 80 farms found one Annual Work Unit (AWU) per 60 Livestock Unity (LU), a value compatible with low intensity farming systems. The farm management survey found a high incidence of pluriactivity on farms. Only 19% of farm households were solely dependent on their farms for a living. In the remaining cases, either the farm manager and or spouses had an additional income. Thirty-five percent of the surveyed farmers who worked off farm worked in construction, a sector that has subsequently seen a major down turn. However, it is important to note that even during the Celtic Tiger, farming still constituted 61% of family farm income. Even though the Iveragh Peninsula is a designated area of outstanding natural beauty, only 17% of the surveyed Iveragh hill farmers were involved in tourism, and for those that were, tourism contributed less than 25% to the family farm income. Only 2.8% of our respondents saw farm multifunctionalism as a viable future, they have *en mass* opted for pluri-activity in the form of off farm work. Forty-nine percent of our respondents indicated that they had no definite successor. However, 78% were confident that they would remain farming in the future, with the main motivation being attachment to the family farm, place, heritage and a way of life. They are not solely rational economic actors.

Another important finding from this research is, despite the fact that the 80 hill farmers are operating under similar environmental, policy, and market conditions, there is a marked diversity within their farming styles, again with biodiversity implications. A statistically rigorous Farm Typology produced four distinct farm types, which we labelled: Environmental Stewards (29 farms), Support Optimisers (12 farms), Traditionalists (25 farms), and Production Maximisers (6 farms). The farms managed by the environmental stewards had the highest amount of sustainablymanaged upland grazing area, with the least incidence of scrub encroachment. The traditionalists, who were less inclined to see the environment as a valuable public good, had the heaviest stocking levels and the highest number of holdings classified as overgrazed. The support optimisers and the yield maximisers, the two extreme farming styles, had the highest incidence of scrub encroachment on their mountain grazing areas and the highest dependence on 'greenland'. Overgrazed farms received similar levels of REPS payments to sustainably grazed farms, with undergrazed farms receiving significantly less. We also found that overgrazed farms received the highest SFP per ha. Despite the fact that 83% of our respondents participate in REPS, their management styles, goals and attitudes to nature conservation differ considerably. It seems unlikely that the maintenance of the Iveragh's biodiversity-rich upland habitats can be guaranteed by current undifferentiated support programmes alone. This suggests the need for a more targeted and customised approach to financial support. We conclude that effective policies for the conservation and management of farmland biodiversity requires a cross-sectional approach that can take account not only of environmental criteria, but also the policy environment and land managers' decision making process & socio-economic objectives.

Acknowledgements
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Mapping the broad habitats of the Burren using satellite imagery

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Introduction

National and international commitments increasingly require decision-makers in the rural environment to conserve and protect high-nature-value habitats, which are known to commonly occur on farmland and other areas throughout Ireland. But where exactly do such habitats occur? Often, there is surprisingly little knowledge on the extent and distribution of high-nature-value habitats, and such knowledge is an essential prerequisite for informed decision-making. High-quality information on the quality and distribution of habitats allows more local-scale (e.g. county level or DED-level) prioritisation of habitats that are of very high quality, or are severely threatened. In turn, such information can facilitate more targeted conservation management. Traditionally, habitat mapping has occurred on a field-by-field basis, which is very labour-intensive. Here, we use the Burren as a case study area for the implementation of a methodology that uses satellite remote sensing to identify different habitat and vegetation types.

Materials and Methods

Three cloud-free images were chosen for the study; Landsat 5 from May 1999 and Landsat 7 ETM+ from April 2003 and August 2000. The images were processed in Erdas Imagine 8.6 and an unsupervised classification was carried out using 10 classes to provide a baseline habitat map for testing. Initial findings indicated that these late spring/early summer images were most suitable for mapping improved grassland, species-rich grassland, limestone pavement, water bodies, urban/dwellings and dense scrub.

The unsupervised classification was used to inform the spatial location of ground-truthing, which involved habitat data being collected at approximately 850 individual points. Based on the ground-truthing data, a supervised classification produced 15 classes that clearly corresponded to broad habitat types (full details in Parr *et al*., 2006). This study also described the grassland and heath vegetation of conservation interest in the Burren, and correlated the vegetation data with environmental and management factors (see Parr *et al*., 2009).

Results and Discussion

The final habitat map was created using a variety of techniques as described above, in an attempt to improve the level of accuracy obtained solely by a supervised classification. The methods used to classify the habitats meant that the end result was a composite of multiple images rather than a single one containing all the relevant habitats. A summary of the area (in percentage cover terms) associated with different broad habitats of the Burren is shown in Table 1.

The following habitats were mapped (values in brackets represent the percentage of the study area occupied by the habitat): unimproved grassland (31%) comprising 17% 'strong winterage' and 14% 'weaker winterage'; improved grasslands (28%); limestone pavement (20%) comprising 10% bare limestone pavement and 10% part-vegetated limestone pavement; scrub (14%); Calluna heath and open scrub (3.4%), water bodies (1.5%) (incl. lakes, turloughs and lacustrine vegetation); dunes (0.2%) and; tillage (0.2%) (Table 1).

Scrub was one of the least satisfactory classes defined, mainly due to its confusion with shadow and some other classes. Scrub is an important threat in the Burren, so additional image processing was carried out to try and improve its accuracy. A new image was produced by combining the April 2003 and August 2000 images. This resulted in improved separation of scrub from other habitats. Scrub was estimated to cover 15-20% of the Burren karst region (Table 1). The greatest challenge is to distinguish between low, open scrub and the limestone heaths of high conservation value that occur at higher altitudes.

Conclusions

This map was one of the first to show the distribution of the broad habitats of the Burren and will be an important tool in aiding future decisions as to how the habitats of the Burren should be managed to the benefit of both the farmer and the environment. The map provides the first estimate of the area of the Burren affected by scrub encroachment – this being one of the most significant threats to the EU priority habitats in the region. Full details in Parr *et al*. (2006, 2009).

On a particularly challenging area with a high diversity and complexity of habitats, remote sensing appears to offer a very effective and cost-efficient alternative to broad-scale habitat mapping on a field-by-field basis.

The outputs provided by such mapping approaches could inform the targeting of agri-environmental objectives, and increase the efficiency of detecting areas of high conservation value for monitoring by more conventional methods.

This study indicates that satellite imagery is a very useful tool for long term monitoring of habitats in the Burren.

Acknowledgments

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Table 1. Broad habitats identified in the study area using satellite imagery from about 2000).

Broad habitat	**Area (% cover)**	**Description**
Unimproved grassland	31%	Lower productivity, species-rich, mostly winter grazed.
• Strong 'winterage'	(17%)	More productive, calcareous to neutral on deeper/clay soils including - wet grassland, short *Calluna* heath & some Improved Grassland on thin soils.
• Weaker 'winterage'	(14%)	Less productive, calcareous, rocky, thin soils including *Sesleria*-dominated grassland and *Dryas*-dominated heath
Improved grassland	28%	More intensively farmed - higher productivity, relatively species-poor, including 'rushy' land
Limestone pavement (LP)	20%	Ranges from bare 'massive' limestone pavement through isolated vegetated patches/bands to ~ 75% vegetated with very thin soils
• Bare LP	(10%)	
• Vegetated LP	(10%)	
Scrub	14%	Predominantly closed hazel but also whitethorn, blackthorn and holly scrub, including ash-hazel woodland.
Calluna heath & open scrub	3.4%	These two habitats tended to overlap, but as guidance: 1) high, exposed plateaux & north-facing steep slopes tend to be *Calluna* heath with tall, mature and/or senescent *Calluna* 2) sheltered areas adjacent to existing scrub tend to be low or open scrub
Greggan's Wood shale	1.7%	Conifer plantation, blanket bog, 'rushy' grassland on shale
Water/lacustrine/turlough	1.5%	Includes water body and tall lacustrine vegetation
Dunes	0.2%	
Tillage	0.2%	Underestimated, but small

The National Survey of Upland Habitats

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Introduction

The uplands form Ireland's largest expanses of semi-natural habitats and lie above the upper limits of enclosed farmland. Almost 19% of Ireland is considered to support upland habitats including blanket bog, heath, grassland, flushes, lakes, springs, exposed rock and scree. The conservation value of these areas is unquestionable, with numerous EU Habitats Directive Annex I habitats and many rare and threatened floral and faunal species being recorded there. Furthermore, over 40% of the terrestrial area designated as candidate Special Area of Conservation (cSAC) in Ireland lies above 150 m in altitude. The vast majority of the uplands are actively farmed as marginal grazing land, mainly for sheep, with large areas being held as commonage.

Loss and degradation of extensive areas of upland habitats increased since the introduction of forestry grants and ewe headage payments in the 1980s and encroachment or intensification of other human activities including wind energy developments. Negative impacts include changes in plant species composition, habitat fragmentation, drainage, soil erosion and, in some areas, landslides. Upland habitats may also be especially vulnerable to climate change, including extreme weather events.

Sensitive, evidence-based land management policies are needed to ensure that Annex I upland habitats maintain or attain favourable conservation status and to prevent the decline of rare or threatened species. Towards this end, the National Survey of Upland Habitats (NSUH) was commissioned by NPWS and commenced in 2010 following a pilot survey in 2009. The principal aims are to:

- survey a representative sample of the full range of upland habitats in Ireland,
- map the location, extent and condition of habitats recorded and to produce baseline maps,
- map the distribution of rare and threatened upland flora,
- conduct a baseline conservation assessment of Annex I upland habitats and establish a series of geo-referenced plots for periodic monitoring,
- devise a classification system for upland vegetation based on analysis of relevés,
- identify impacts, threats and trends especially in relation to Annex I habitats.

Materials and Methods

A manual detailing the methodology to be used in the NSUH has been produced (Perrin *et al*., 2010).

Survey sites
During 2009 and 2010, six sites covering 389.7 km^2 were comprehensively surveyed (Table 1).

Table 1. Sites surveyed during 2009 and 2010.

Site no.	Site	Area (km^2)
1	Mweelrea/Sheeffry/Erriff Complex cSAC	209.8
2	Corraun Plateau cSAC	38.9
3	Comeragh Mountains cSAC	62.9
4	Carlingford Mountain cSAC	31.0
5	Nephin Mountain	14.1
6	Croaghaun/Slievemore cSAC	33.0

Habitat mapping
Much of the uplands consist of intricate environmental gradients that reflect changes in topography, hydrology, soils and geology and are far too complex to map separately in the conventional fashion. Hence the NSUH has adopted an approach of mapping units that reflect consistent habitat mosaics. Prior to field work, aerial photograph interpretation is used to digitise survey sites into high resolution polygons that represent areas of consistent pattern or topography.

Field surveyors use ruggedized PDAs with GIS software and a real-time GPS location to navigate accurately. Within each polygon, the percentage cover of each Fossitt (2000) and Annex I habitat is recorded. A provisional, subjective uplands classification is used to record in more detail the various vegetation communities encountered.

Assessment of conservation status
Whilst all habitats encountered during fieldwork are mapped, the assessment procedure is focussed on 12 Annex I habitats that form the primary focus of the project (Table 2). Three aspects of these habitats are assessed: i) changes in area, ii) structure and function, through the recording of a series of monitoring stops across the site, each of which includes a relevé, iii) future prospects, through an examination of the intensity and trends in land use and impacts.

Compilation of rare species data
Whilst the NSUH is not a rare species survey, existing records of rare species are being collated with new NSUH records on a site-by-site basis.

Production of a relevé-based classification
Relevé data recorded by the NSUH are being combined with existing relevé datasets from the Irish uplands (primarily PhD theses) to produce an objective vegetation classification. To facilitate this, relevés are also being recorded in non-assessment habitats. Multivariate statistical techniques including hierarchical cluster analysis and indicator species analysis are being employed.

Results and Discussion

Habitats and relevés
The main habitats mapped within the six sites surveyed to date were 4010 Wet heath, *7130 Active blanket bog and 4030 Dry heath, comprising 23.6%, 15.0% and 10.1% of the overall survey area. Neither 6150 Siliceous alpine and boreal grassland nor the upland ledge aspect of habitat 6430 had previously been recorded in Ireland. Similarly, 6170 Alpine and subalpine calcareous grassland was recorded for the first time during a reconnaissance survey of Ben Bulben. The approach to these three habitats is under review. A total of 377 relevés have been recorded, including 339 in Annex I habitats (Table 2). There is considerable variation in species richness (alpha diversity) between habitats, but it is important to note that many upland habitats support specialist species. Hence, even where species richness is low, there may be considerable contribution to the beta or gamma diversity of the farmland landscape.

Conservation status
The most serious impacts recorded to date are overgrazing by sheep and peat erosion, which resulted in the overall assessment of habitats 4010 and *7130 as unfavourable at all sites. Whilst there has been significant destocking of commonages in the last decade, it appears that areas that are already severely damaged are likely to continue to erode without practical intervention. At one site, widespread inappropriate heather burning resulted in the unfavourable assessment of habitat 4030. Rocky slope and scree habitats have largely been assessed as favourable.

Rare and notable species
New county records were made for the clubmoss *Diphasiastrum alpinum* (Co. Waterford) (Roche & Perrin, in press) and the mosses *Andreaea megistospora*, *Racomitrium affine* and *Polytrichum alpinum* (Co. Louth). New stations were recorded for notable species such as cowberry *Vaccinium vitis-idaea* and the moss *Amphidium lapponicum.*

Relevé-based classification
A dataset of 3,742 relevés has been used to produce a provisional objective classification of six main groups divided into 63 vegetation types.

Conclusions

The uplands contain some of Ireland's most biodiverse and specialised habitats but sensitive, evidence-based farming and conservation management practices are needed if we are to fulfil our obligations under the Habitats Directive and conserve this resource. The NSUH is providing the scientific data to underpin these policy decisions.

Table 2. Species richness in Annex I habitats from the six surveyed sites. N = sample size. R = richness. † indicates non-primary focus habitats.

Hab. code	Habitat name	N	R
4010	Northern Atlantic wet heaths	77	20.8
4030	European dry heaths	46	20.2
4060	Alpine and Boreal heaths	40	19.5
6150	Siliceous alpine and boreal grasslands†	12	16.6
***6230**	Species-rich *Nardus* grasslands	9	30.3
6430	Hydrophilous tall herb fringe communities†	3	34.0
7130	Blanket bog (*active only)	73	19.5
7140	Transition mires	7	17.1
7150	Depressions on peat substrates of the *Rhynchosporion*	16	16.8
7230	Alkaline fens	12	23.5
8110	Siliceous scree of the montane to snow levels	21	18.5
8120	Calcareous and calcshist screes of the montane to alpine levels	0	-
8210	Calcareous rocky slopes with chasmophytic vegetation	2	27.0
8220	Siliceous rocky slopes with chasmophytic vegetation	20	18.2

Acknowledgments

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Floral resources for bumblebees on Irish farmland

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Introduction

Worldwide declines in bumblebees are echoed by losses in Ireland. These are attributed mainly to the loss of flower-rich habitats (Fitzpatrick *et al.*, 2007). Bee genetics and ecology, as well as our horticultural dependency upon pollinators, requires that bees are conserved over large geographical areas. Bumblebee conservation is dependent upon measures applied on this type of broad scale.

Although the decline of bees is well established, to date, no measures directed at conserving 'pollinator diversity' have been developed as part of Irish agri-environment schemes. In the UK, initiatives that target bees have been implemented within the Environmental Stewardship scheme and found to be successful in supporting bees (Carvell 2006). Providing flowers for forage has been a cornerstone of the UK approach.

This brief study considers how abundant flowers are on Irish farms; identifies the major floral resources used by Irish bumblebees throughout the summer and examines whether farms with more flowers do support more bees. Bringing this information together suggests approaches to bee conservation on Irish farmland. The aim is to initiate debate and research that will stimulate action to reverse bee declines in Ireland.

Materials and Methods

The data presented is derived from three field studies, carried out from 2003 to 2005 as part of the Ag-Biota project (Purvis *et al.*, 2009). All farms were located in the eastern half of Ireland.

(a) *Flower abundance on farms*
The abundance of all flowers, per square metre, in swards and as a percent of hedgerow length was quantified during a study of 50 farms (2005). Composite flowers, umbels and other flower clusters e.g. clover were each counted as one flower. Farms were surveyed in early summer (May-June), mid-summer (July), late summer (August).

(b) *Major floral resources for bumblebees*
The most frequently visited plant species were identified from observations of bees foraging during transect surveys on 19 farms throughout the summer (2003). (Period 1= 6 Jun – 14 Jul (42 transects), Period 2 =15 Jul – 12 Aug (44 transects) and Period 3= 14 Aug – 9 Sep (42 transects) respectively).

(c) *Relationship between flower and bee abundances*
The relationship between abundances of bees and flowers was analysed using data from a pan-trapping survey of 18 farms (2004). The percentage cover of flowers was recorded using the Braun Blanquet cover scale and converted to median percentage cover values for analysis. A negative binomial GLM was used to analyse the relationship between floral abundance and bee abundance.

Results and Discussion

(a) *Flower abundance on farms*
At each sampling period, 50% of swards had fewer than 1 flower per 2 square metres (score of 1 on scale) (Figure 1). Over half of the hedges sampled had flowers along at least a fifth of their length in every sampling period.

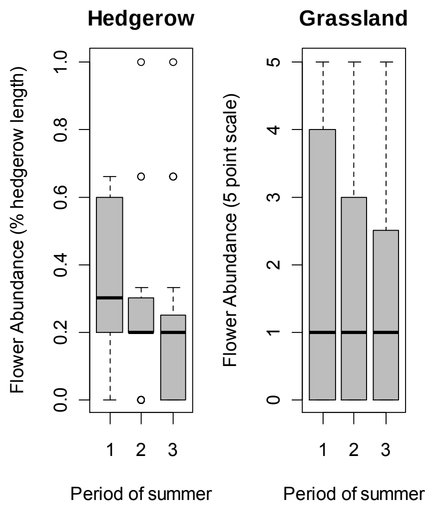

Fig. 1. Boxplots of flower abundance in hedgerows and grassland. (5 point scale used in grasslands: flowers absent=0; <0.5 flowers per m^2=1; 0.5-1 flower per m^2= 2; 1-5 flowers per m^2=3; 5-10 flowers per m^2=4; >10 flowers per m^2=5.)

(b) *Major floral resources for bumblebees*
Of a total of 684 observed foraging events, 84% of flower visits were to only five plant species (Table 1). These flowers tended to have long flowering periods.

Table 1. The plant species most visited by bees. (Early summer, E; mid+late summer, M+S.)

Species	%	Periods in top 5
Rubus fruticosus agg.	40.9	E, M+S
Trifolium repens	15.9	E, M+S
Cirsium vulgare	9.1	M+S
Cirsium arvense	9.0	E, M+S
Vicia sepium	7.0	E

(c) *Relationship between flower and bee abundances*

In a sample of 407 bees, there was a significant relationship between the abundance of bees and the abundance of flowers in the hedgerow (Fig. 2; negative binomial θ=6.62: n=16, F=24.2, p=0.0002, pseudo-R^2=0.63) and a weak effect in response to flower abundance in the sward (negative binomial θ=2.62: n=16, F=5.2, p=0.04, pseudo-R^2=0.27).

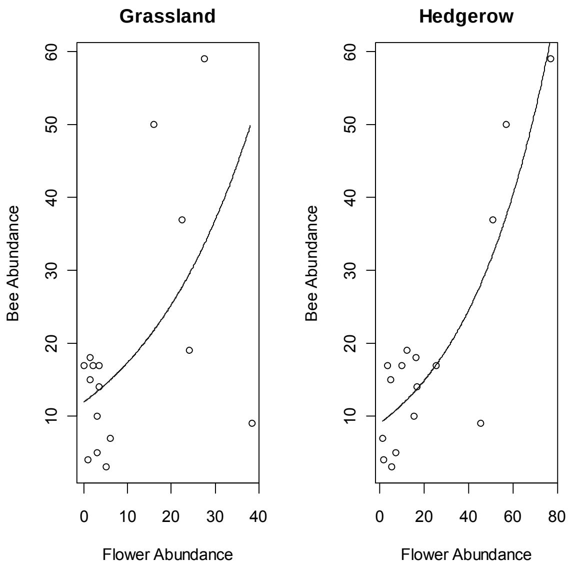

Fig. 2. GLM regression of bee abundance on the percentage cover of flowers in grassland and hedgerow.

Discussion

Higher abundances of flowers in grasslands or hedgerows support larger numbers of bees. Few agricultural grasslands or hedgerows, in the eastern half of the country, have high abundances of flowers or bees. Flower abundances could be enhanced to boost bee numbers. Possible targets, based on this scant dataset, might be ~20% flower cover in grasslands and ~40% cover in hedgerows. Obviously, further study is required in the setting of such targets but the suggestion is made to stimulate discussion. Would targets be desirable? How could they be implemented and maintained on the farm with ease and minimum costs? One approach could be to plant flowers for forage. Another would be to encourage, via slight shifts in management, more flowers from herbs, trees and shrubs already growing on farms. These should perhaps be regarded as complementary methods rather than alternatives. Specifications in the Agri-Environment Options Scheme (AEOS), such as ‘Traditional Hay Meadow’ and ‘Species rich grasslands’ offer opportunities to enhance flowering within existing semi natural habitats. The alternative suggestion, planting forage for bees, is considered further in this paper.

Of the small range of flowers that are presently supporting the majority of bumblebees, all were shown to be common species, most with long flowering periods. They are also perennials. These characteristics can be used to design a relatively cheap forage seed mix for bees that contains *Asteraceae* (daisy family) such as *Centaurea* as an alternative to thistles and Fabaceae (legume family) such as clovers and vetches for the longer tongued bees. Ideally the mix would flower continuously throughout the summer. Irish farmers are already planting for birds with the Wild Bird Cover specification in AEOSS. Perhaps forage for bees could be integrated into this scheme. However uptake of similar schemes has not been widespread in the UK (Blake, 2011). A further option, that requires study, could be the incorporation of more ‘bee-friendly’ legumes and a small number of other herbs, into rotational grassland leys. If plant species were selected on the basis of nutritional benefits for livestock and bees as well as ease of management for persistence and flowering, uptake might be on a much wider scale than wildlife specific initiatives. If successful this could introduce flower-rich grasslands into intensive pastoral farming.

Conclusions

Increasing the abundance of flowers on Irish farms would have benefits for bees. This could be achieved through a combination of the management of existing habitats and new planting. Research is necessary to develop low-cost methods that are attractive to farmers as well as bees so that they are taken up on a large scale.

Acknowledgments

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Agri-environment management of grassland field margins

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Introduction

Agricultural grassland field margins associated with field boundary complexes such as hedges, earth banks and ditches have a distinctive plant community structure (Marshall and Moonen, 2002) which can provide a partial reserve for plant species (Smart *et al.*, 2006) in intensively managed landscapes. There is a large research literature on the community structure of arable field margins, but not for grass field margins.

In Northern Ireland (NI), enclosed improved and semi-improved grassland, described as Improved Grassland and Neutral Grassland in the UK Broad Habitats classification, cover an estimated 804,126 hectares (56.8%) of NI. Field margin management of these grassland types is an option of agri-environment schemes in NI. Improved Grassland is dominated by *Lolium spp.*, whereas Neutral Grassland is managed less intensively and is more species rich. Our paper assesses the regional species composition of Neutral Grassland field margins to determine if their plant species assemblages are of particular biodiversity interest to the agriculture industry.

Materials and Methods

From the UK Neutral Grassland Broad Habitat, the Northern Ireland Countryside Survey (NICS) Primary Habitat types A11 and A09 were selected for study (McCann et al., 2009). Their management intensity and species richness are intermediate to Improved Grassland and Semi-natural grassland Broad habitats.

An area-proportional random sample of field-mapped A11 and A09 grassland patches from ¼ kilometre sample grid squares was selected from across NI. Sample stratification was by multivariate land class, the sampling rate was 1 quadrat ($4m^2$) per 5 hectares. A total of 212 quadrats were surveyed comprising 106 field margin quadrats (1m x 4m) and 106 paired grassland field quadrats (2m x 2m). Fieldwork was carried out between late June and early September 2009. Within each field, a 2m x 2m quadrat was randomly located within a random $100m^2$ (10m x 10m) sub-sample. The field margin quadrat (1m x 4m) was randomly located next to the nearest field boundary. In each quadrat, the percentage cover of plant species was estimated according to the DOMIN scale.

Multivariate analysis

Field margin quadrats were classified by two-way indicator species analysis using TWINSPAN for Windows 2.3 (Hill and Šmilauer, 2005). Pseudospecies cut levels were set as 0-5 incorporating DOMIN values recorded. The classification was stopped by inspection to give 4 groups. Multivariate ordination was carried out using Canoco for Windows 4.5 (after Braak and Šmilauer, 2002). Detrended Correspondence Analysis (DCA) was used to assess the main gradients of species composition. Canonical Correspondence Analysis (CCA) was used to determine whether species where significantly more abundant in the field margin quadrats compared with the grass field quadrats via Monte Carlo Permutation testing.

Results and Discussion

Inspection of species lists of the field margin and grass field quadrats gave a combined total of 164 species (excluding trees and shrubs). There were 105 species in the grass field quadrats and 150 species in the field margin quadrats. A classification of the field margin quadrats gave four end groups (Table 1).

Table 1. TWINSPAN classification groups.

	Vegetation group			
	1	**2**	**3**	**4**
Mean no. spp. per quadrat	17	14	10	10
Number of quadrats	13	55	18	22
Proportion of sample (%)	13	50	17	20

The groups lay along the first axis of a DCA ordination (Fig. 1) in the order 1, 2, 3 and 4, with groups 1 and 2 separated by the second axis. Ellenberg soil nitrogen and pH indicator values and the Grime competition values showed a strong positive correlation with the first axis of the ordination. Grime stress tolerance values showed a strong negative correlation with axis 1. The main ordination axis, therefore, represents an inferred gradient of increasing soil nutrient status. High values of the Ellenberg soil moisture indicator species are correlated with axis 2. This axis, therefore, separates samples along a soil wetness gradient.

Groups 1 and 2 of the field margin classification, characterised by stress-tolerant species of low nutrient status soils, had the highest biodiversity. Group 1 field margins were associated with species of better-drained soils, such as *Festuca rubra* and *Cynosurus cristatus*.

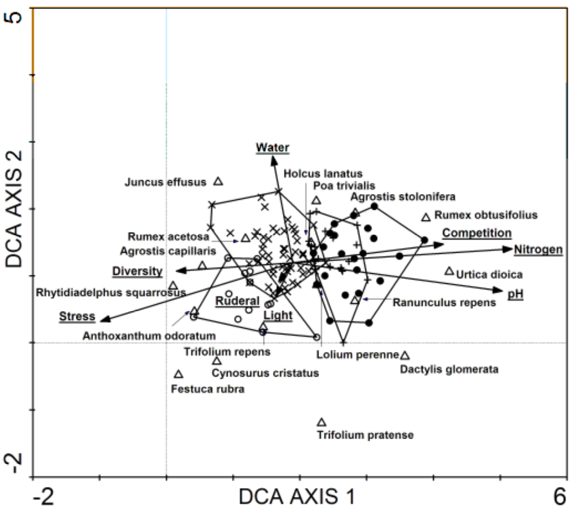

Figure 1. First and second axes of a DCA ordination showing groups of quadrats delimited by a TWINSPAN classification along with species with a frequency of >75% in any one group and all TWINSPAN indicator species. Variables included are; diversity (mean number of species per quadrat), Ellenberg indicator values for moisture, nitrogen, pH and light and Grime competitive, stress-tolerant and ruderal life strategies. Scaling factor of explanatory variables = 7.25.
Note: TWINSPAN groups are labelled as follows: Group 1 (○), Group 2 (X), Group 3 (+) and Group 4 (●). Axis 1 eigenvalue = 0.320, Axis 2 eigenvalue = 0.214 and Axis 3 eignevalue = 0.161.

Group 2 field margins were associated with species of poorly-drained soils, such as *Juncus effusus*. The area-proportional sampling system used means that the frequency of field margin quadrats in each class is directly proportional to their occurrence in the countryside. Therefore, we estimate that group 1 represents 13% of field margins and that group 2 represents 50% of field margins. These two groups, in particular group 1, have the greatest potential value for targeting agri-environment prescriptions. The remaining 47% of field margins (groups 3 and 4) have a relatively low plant species diversity, not greatly different from the managed grass field.

According to a CCA ordination, field margin quadrats have a significantly different species composition compared with the grass field quadrats ($F = 2.71$) ($p = 0.002$). A t-value biplot showed that there were 57 species more abundant in the field margin quadrats of which 12 were significantly more abundant. They were *Cirsium vulgare, Galium aparine, Lathyrus pratensis, Rubus fruticosus, Urtica dioica, Veronica chamaedrys, Vicia cracca* and *Vicia sepium* (mainly scramblers and tall herbs of open habitats), *Geranium robertianum, Hedera helix, Primula vulgaris* and *Viola riviniana* (mainly broadleaf woodland species). There were 41 species more abundant in the grass field quadrats, six of which were significantly more abundant. These were *Cardamine flexuosa/hirsuta, Carex panicea, Lolium perenne, Ranunculus flammula, Ranunculus repens* and *Trifolium repens,* all common species of agricultural grasslands.

Conclusions

We show that across NI as a whole, Neutral Grassland field margins, whether grazed or cut for a grass crop, have species composition different to that of the managed part of the field and are characterised by species covering a wide range of environmental tolerances and life strategies. Field margin composition was determined largely by a soil nutrient gradient, from low to high nutrient status, in particular soil nitrogen. We conclude that the species diversity of field margins is directly related to management inputs (in particular fertilizers) with more species-rich margins associated with a lower soil nutrient status and with plant species considered to be agricultural weeds associated with a higher soil nutrient status. Agri-environment management for increased plant species diversity in grassland field margins should aim to reduce nutrient inputs within 2m of field boundaries. Preferential funding, targeted at grasslands with species-rich field boundaries such as hedges and earth banks, from which dispersal into the grassland margin could take place, would give greater biodiversity gains.

Acknowledgments

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Mapping High Nature Value farmland in Ireland

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Introduction

Farming sustains the high nature value of many agricultural landscapes across Europe and is integral to maintaining their biodiversity (Bignal and McCracken, 1996). High Nature Value (HNV) farmland occurs where agriculture sustains a high species and habitat diversity (Anderson *et al.*, 2004). The identification of High Nature Value (HNV) farmland throughout Europe has become an important goal for EU Member States. They are required to ensure that their current RDPs (2007-2013) put priority on HNV farmland identification, support and maintenance and to monitor any changes in HNV farmland extent (CEC, 2006). However, the range of HNV farmland and farming systems throughout the EU leads to challenges for each member state in identifying these areas.

Existing nature conservation designations will, at best, protect a minority of HNV farmland and do not target areas of high farmland biodiversity within more intensively-managed agricultural landscapes (Henle *et al.*, 2008). Spatial targeting of HNV farmland is the key to providing the support necessary to maintain these HNV landscapes, particularly those outside of designated sites (Sullivan *et al*, 2011). This paper examines the use of modelling to map areas of HNV farmland. It focuses on modelling semi-natural habitats in particular as, based on the current definitions of HNV farmland, identification of HNV relies heavily on semi-natural habitat cover. If successful, this model could have many other useful applications for planning and local government.

Materials and Methods

Thirty two farms were selected randomly from six different District Electoral Divisions (DEDs) in east Galway outside of designated areas. All habitats on each farm were identified according to Fossitt (2000). Farm management data such as stocking density, farming enterprise and reseeding practices were collected from each farmer at the time of field sampling. The habitat data were collected from May to October of 2006 and 2007. All farms and habitat areas were digitised and areas calculated using ArcGIS 9.3. Fields and hedgerows were surveyed in further detail. A range of variables that might explain the habitat diversity on the farms was selected based on a literature review (Table 1). Both farm-level and landscape-level variables were considered. Factors affecting semi-natural habitat cover were modelled using General Additive Modelling (GAM). See Sullivan *et al.* (2011) for further details.

Table 1. Explanatory variables tested in GAM model to predict semi-natural habitat area on farms. * indicates distance to nearest feature.

Variable	
Field boundary density	Secondary road*
Field boundary length	3rd class road*
Farm enterprise	4th class road*
DED	Any class of road*
AE scheme participation	City*
Average field size	Town*
Stocking density (LU/ha)	Lake*
Soil diversity index	SAC*
Elevation	SPA*
River and stream length	NHA*
Regional road*	pNHA*
Primary road*	Native woodland*

Results and Discussion

Farmland habitat diversity

The average cover of semi-natural habitats on a farm was 15.2% (±3.0 s.e.). This figure varied from 0% to just over 60% (Fig. 1), with just three farms having no non-linear semi-natural habitat cover. All farms surveyed were grassland-dominated, and a total of 24 habitats were recorded on the 32 farms. More than 50% of those were semi-natural habitats.

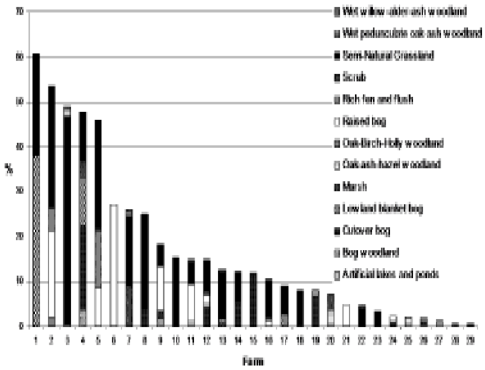

Fig. 1. Percentage semi-natural habitat per farm (by habitat type). Three farms with no semi-natural habitats are excluded.

Semi-natural grassland (predominantly Wet Grassland) was a common component of the semi-natural habitat cover on the majority of those farms with semi-natural habitats (See Fig. 2 for examples farm habitat maps). These data illustrate the variation in semi-natural habitat diversity as well as the spatial location of the habitats that occur on lowland farms.

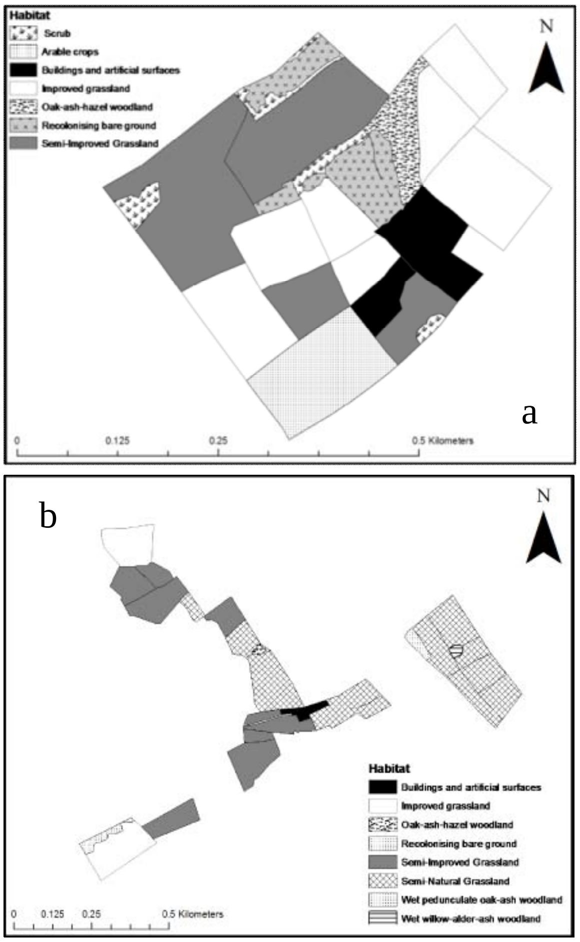

Fig. 2. Habitat composition of a) a 15.6 ha beef farm with 7% semi-natural habitat cover and b) a 25.3 ha beef farm with 47% semi-natural habitat cover.

Modelling semi-natural habitats

The GAM analysis demonstrated that the percent semi-natural habitat cover can be predicted from the variables. There were five models where the intercept and all variables gave statistically significant results. Soil diversity and stocking density featured as explanatory variables to predict extent of semi-natural habitat in three of the five models. Using this method, higher levels of semi-natural habitat cover are indicated by lower stocking density, higher soil diversity and longer river and stream lengths.

Future applications

This model could be applied to all farms in east Galway, providing a map of potential semi-natural habitat areas in the region. Further ground-truthing would allow accuracy testing and refinement of the model.

This modelling approach could be modified for use in different regions and different countries. Thus, it could be adapted to help identify areas that surpass threshold levels of semi-natural habitat cover (and additional criteria), thereby indicating the likely presence of HNV farmland. If an area or region meets these criteria, then they could be targeted for more detailed investigation of their HNV status (e.g. Sullivan *et al*., 2010).

Modelling the spatial distribution of semi-natural habitat area would also lead to improved spatial targeting of management actions for nature conservation by local councils. National maps of semi-natural habitat cover on farms would also benefit agri-environment policy decisions as areas identified with low or no semi-natural habitat cover could be targeted for biodiversity restoration projects or recruitment of farmers in certain low-biodiversity regions into agri-environment schemes.

Acknowledgments

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Impact of riparian vegetation structure on small mammal communities

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Introduction

Intensification of agriculture over the last number of decades has led to a dramatic change in agricultural production methods. This in turn has resulted in a loss of ecological heterogeneity (Petit and Firbank, 2006) and has contributed to the loss of biodiversity (Robinson and Sutherland, 2002), resulting in significant implications for wild species of flora and fauna.

Protection of uncultivated field margins, hedgerows, ditches and watercourse margins is vital to ecosystems, because they are an increasingly important source of seed and invertebrate food (Wilson et al, 1999). Small mammals on farmland are largely confined to these areas of non-crop habitat and are therefore particularly vulnerable to agricultural intensification (Bates and Harris, 2009).

The Rural Environment Protection Scheme (REPS) guidelines (Measure 3) require farmers to fence all water-course margins to prevent bovine access. No further management of these fenced areas is required. Such fencing will give rise to natural succession of vegetation from grassy (primarily herbaceous species) to scrubby (e.g. bramble, gorse) to woody (e.g. alder, willow) vegetation. These fenced sites are seen as potential refuges for biodiversity, however, little information exists in relation to the effect that succession of the margin vegetation has on small mammal communities. Small mammals constitute the main prey biomass that influences the diversity and number of predator species such as kestrel *Falco tinnunculus*, barn owl *Tyto alba* (Red-listed species) and pine marten *Martes martes*, thus, contributing to the complexity of food webs (Korpimaki and Norrdahl, 1991).

The aim of this study was to highlight the impact of vegetation succession in watercourse margins on small mammal communities.

Materials and Methods

The study took place on a number of sites in Co. Wexford. Thirty-metre stretches of watercourse margin were selected for study. All watercourses were between 1 m and 3 m in width and flowed for at least nine months of the year. A total of 42 sites were selected (14 grassy, 14 scrubby and 14 woody). Each site was dominated by either grassy vegetation, scrubby vegetation or woody vegetation. Grassy sites were dominated by gramineous plants such as *Lolium* and *Agrostis* and by forbs such as *Cirsium arvense* and members of the *Ranunculaceae*, *Polygonaceae*, and *Leguminosae* families. Scrubby sites (vegetation less than 2 metres in height) were dominated by *Ulex europaeus*, *Rubus fruticosus*, *Prunus spinosa* and members of the *Umbelliferae* family. Woody sites (vegetation above 2 metres in height) were dominated by *Crataegus monogyna*, *Fraxinus excelsior* and by members of family *Salicaceae*

Small mammals at sites were sampled using Longworth traps. Traps were placed in pairs every 10m in trap lines, at distances of 1 m and 5 m from the stream edge. Therefore, each 30 m section of margin contained 16 traps. Traps were left *in situ* for two nights during each sampling session and inspected at dawn, dusk and at least once during the day. Captured mammals were marked and weighed, with additional information such as sex, age group, breeding condition and length of hind foot being noted. The results in this paper are based on three sampling sessions, early summer (May), late summer (August) and winter (December) in 2007.

Abundance data were analysed using SAS and a split plot in time analysis with Poisson distribution and log-transformed data. The Shannon-Weiner Index was used when assessing species diversity of each habitat. The weights of small mammals were analysed using ANOVA.

Results and Discussion

The results in this paper are gleaned from 4,032 trap nights in 2007. A total of 317 captures occurred, of these, 90.5% were woodmouse (*Apodemus sylvaticus*), 7.6% were shrew (*Sorex minutes)* and 1.9% were house mouse (*Mus domesticus).* The remaining small mammal species found in Ireland, the bank vole *Clethrionomys glareolus* and greater white-toothed shrew *Crocidura russula* are not found in the study area.

From the results, it was found that habitat had a significant effect ($P < 0.01$) on small mammal abundance. Significantly more mammals were caught in woody habitats as opposed to scrubby or grassy habitats. Scrubby habitats had the lowest capture rate (the lower rate for grassy habitats apparent in Table 1 is as a result of a high number of traps catching non-target species in these sites).

The low capture rate in scrubby habitats is largely due to the availability of food. Habitats such as gorse, despite providing excellent cover for small mammals, provide considerably less of their favoured food than many woody sites (Montgomery *et al*., 1991). This theory is given further credence by the fact that woodmouse found in scrub, weighed significantly less than

those found in either grassy or woody habitats ($P < 0.05$).
More mammals were caught at a distance of 1 metre as opposed to 5 metres from the stream edge ($P < 0.0001$).
Sampling period (early summer, late summer and winter) also played a significant role ($P < 0.05$) with more small mammals being caught in winter than in either early or late summer. This is largely due to the fact that small mammals are less territorial in winter and must also travel greater distances to forage, therefore increasing their likelihood of encountering a trap.

In relation to the condition of small mammals (woodmouse), distance from stream, season, sex and breeding condition had a significant effect on the weight of adult woodmice.
Mice trapped adjacent to the stream weighed significantly more than those trapped at a distance of 5m from the stream ($P < 0.05$). Males were significantly heavier than females ($P < 0.001$) and breeding mice were significantly heavier than non-breeding mice ($P < 0.001$). This latter point is not surprising considering that during the breeding season, the genitals swell to many times their non-breeding weight (Gurnell and Flowerdew, 2006) thus increasing the overall weight. There was a significant correlation ($P < 0.001$) between the weight and the tarsus length of the animal. Both measurements are used as an indicator of fitness.

Although abundance of small mammals is greatest in woody habitats, these sites were the least diverse (Shannon-Weiner index in Table 1). Grassy habitats showed the most diversity with the small mammal community consisting of 78% woodmouse, 19% pygmy shrew and 3% house mouse, whereas the community of woody habitats were dominated (98%) by woodmice.

Table 1. Small mammal captures in watercourse margins (aggregated across 14 replicate sites over three seasonal sampling events).

	Grassy	Scrubby	Woody
No. caught at 1 m	63	54	108
No. caught at 5 m	11	54	27
Total capture	74	108	135
Shannon-Weiner Index (H’)	0.26	0.17	0.05
Adult woodmouse mean weight (g)	23.57	21.72	22.64
Adult Woodmouse mean tarsus (mm)	13.26	12.96	13.04

Conclusions

Small mammals play an important role in agricultural ecosystems, and management prescriptions that promote and enhance their abundance and diversity should be promoted. Increased small mammal populations on farmland are crucial to improving the biodiversity of agricultural ecosystems (Bates and Harris, 2009).
The current REPS guidelines of fencing all watercourse margins, and the subsequent succession it gives rise to, is not promoting small mammal diversity within riparian habitats. Watercourse margin management prescriptions which include fencing (and the resultant succession of vegetation) do not provide a suitable habitat for pygmy shrews (Bern Convention, Annex II species).
It is likely that periodical cutting, grazing and alternative managements of margins would promote heterogeneity and in-turn give rise to a greater diversity of small mammals and also of floral and faunal communities in general.

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