Article (refereed) - postprint

Pywell, Richard F.; Heard, Matthew S.; Bradbury, Richard B.; Hinsley, Shelley; Nowakowski, Marek; Walker, Kevin J.; Bullock, James M.. 2012 Wildlife-friendly farming benefits rare birds, bees and plants. *Biology Letters*, 8 (5). 772-775. 10.1098/rsbl.2012.0367

Wildlife-friendly farming benefits rare birds, bees and plants

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Agricultural intensification is a leading cause of global biodiversity loss, especially for threatened and near-threatened species. One widely implemented response is 'Wildlife-friendly farming', involving the close integration of conservation and extensive farming practices within agricultural landscapes. However, the putative benefits from this controversial policy are currently either unknown or thought unlikely to extend to rare and declining species. Here we show that new, evidence-based approaches to habitat creation on intensively managed farmland in England can achieve large increases in plant, bee and bird species. In particular, we found that habitat enhancement methods designed to provide the requirements of sensitive target biota consistently increased the richness and abundance of both rare and common species, with 10-fold to >100-fold more rare species per sample area than generalised conventional conservation measures. Furthermore, targeting landscapes of high species richness amplified beneficial effects on the least mobile taxa: plants and bees. Our results provide the first unequivocal support for a national wildlife-friendly farming policy, and suggest that this approach should be implemented much more extensively to address global biodiversity loss. However, to be effective these conservation measures must be evidence-based, and developed using sound knowledge of the ecological requirements of key species.

Keywords: agri-environment schemes; habitat restoration; eco-agriculture; ecosystem services

1. INTRODUCTION

Rapid population growth is driving an unprecedented demand for food production across the globe, resulting in wide scale habitat loss, catastrophic declines in biodiversity and potential disruption of ecosystem services (Chivian & Bernstein 2008). Thus the need to balance biodiversity conservation and agricultural production has never been more pressing (Godfray *et al*. 2010). Wildlife-friendly farming, by reducing the intensity of agricultural management and implementing conservation actions in farmed landscapes (Scherr & McNeely 2008), directly addresses the headline Convention on Biological Diversity 2020 target of sustainable agricultural management (Normile 2010). There has been a strong drive for wildlife-friendly farming across various parts of the world (Rands 2010), notably in Europe through agri-environment schemes (AES) incorporated into the Common Agricultural Policy (CAP). Although AES pay farmers €2.5 billion annually (EU 2011) to manage their land to promote particular habitats and species, current evidence suggests they are failing to halt declines in farmland biodiversity (Kleijn *et al.* 2011), and provide few benefits for rare and declining species (Kleijn *et al.* 2006; Davey *et al.* 2010). Indeed a recent report by the European Court of Auditors concluded that AES are not designed and monitored so as to deliver tangible environmental benefits (EU 2011).

In light of these severe criticisms, AES urgently need to be refined to make them more effective and better targeted, in particular to meet the requirements of rare species (EU 2011). To address this we quantified the effectiveness of the English 'Entry Level Stewardship Scheme' (ELS)(Natural England 2010), a whole-farm AES designed to deliver environmental protection and enhancement over large areas (annual budget = €202 million, coverage 5.6 million ha = 60% of utilisable farmland). It comprises over 60 management prescriptions either to enhance or to create wildlife habitat on farmland. Most of these have broad environmental aims and are simple and cheap to implement ('general' prescriptions). In contrast, a small number of prescriptions are closely tailored to the ecological requirements of target taxa largely based on research programmes funded by the UK Government and Conservation Agencies ('evidence-based' prescriptions). We compared the effectiveness of general with evidence-based habitat creation methods in promoting diversity and abundance of plants and bees, using national monitoring; and of birds, using multi-site experiments. In addition, large-scale processes may impose a further constraint on AES effectiveness: if the surrounding landscape has low biodiversity then the AES habitats may be colonised poorly (Whittingham 2007). This simple hypothesis has not been tested formally across different taxa so we investigated the relationship between the richness of rare species in the surrounding landscape and that found on the sample of evidence-based habitat patches.

2. MATERIAL AND METHODS

For plants, bees and birds we took a common approach of comparing an intensively managed cereal crop (control) to agri-environment management prescriptions with either broad environmental objectives (general option) or those based on the ecological requirements of the target taxa (evidence-based). Details of each prescription varied depending on the taxa. For plants we compared cropped 'conservation headlands' (general) with non-crop, annually-cultivated field margins (evidence-based). Conservation headlands are strips of cereal crop managed with restricted pesticide inputs in order to improve the survival of broad-leaved plants and beneficial insects (Dover 1997). An example of each option and control was selected at random from thirty nine 20×20 km squares across lowland England (see electronic supplementary material figure S1, *n*= 117 sites). Plant diversity and abundance was recorded from thirty 0.25 m^2 quadrats within a 100×6 m sampling zone at each site (Walker *et al.* 2007). For bumblebees we contrasted the crop to a widespread general option that provides nesting habitat and limited pollen and nectar resources (an uncropped field margin sown with grasses, Pywell *et al.* 2006) and an evidence-based approach (margin sown with pollen- and nectar-rich plants; Carvell *et al.* 2007). An example of each measure was selected from thirty eight 10×10 km squares (supplementary material figure S1, *n*= 114 sites). On each option bumblebee species were counted along a randomly located 100×6 m transect in July and August (Pywell *et al.* 2006). For farmland birds we analysed three datasets derived from experiments at eight farms (site details in supplementary material, figure S1), comparing the crop with uncropped field margins sown with grasses (general) and the evidence-based approach of sowing patches with between 4-7 seed-bearing crop species. We recorded bird utilisation during the winter using timed counts followed by flushing the birds from each patch.

Species were classified as rare or common based on a range of rarity criteria (supplementary material). Treatment effects on rare and common plants and bumblebees were tested using analysis of variance with post-hoc Tukey's pairwise comparisons. The farmland bird studies involved different experiments so we used a meta-analysis approach to calculate the weighted mean effect size (Hedge's *d*) for all pairwise comparisons of the evidence-based, general and control treatments. Finally, we used poisson regression to investigate the relationship between the species richness of rare species in the surrounding landscape (10×10 km) and on the local evidence-based habitats.

3. RESULTS

Species richness of both common and rare taxa was consistently higher on the evidence-based options compared to the general options and control for all three taxa (figure 1 and table S1 supplementary material). Indeed, the evidence-based options had between 10-fold and over >100-fold more rare species on average *per* sampling unit than either the control or general options. In contrast, the general options were remarkably unsuccessful, leading to only small increases in the diversity of common plants and bees, and having no effect on birds or on rare species of any taxon. Identical patterns were seen in data on abundance for each taxa (supplementary material, figure S2). Moreover, the number of rare plant and rare bee species both showed positive landscape-local relationships, but there was no such relationship for farmland birds in winter (figure 2).

4. DISCUSSION

The relative lack of success of the general options may explain the poor performance of agri-environment schemes reported in other studies (Kleijn *et al.* 2011), particularly for rarer species (Kleijn *et al.* 2006). The evidence-based options reflect the value of research into the mechanisms by which agricultural intensification has led to declines in farmland taxa (Newton 2004; Carvell *et al*. 2007). Thus: uncropped, annually cultivated field margins provide herbicide-free, uncompetitive conditions for rare arable plants; pollen- and nectar-providing plants supplement declining food resources for bumblebees; and plants producing high yields of oil-rich, small seeds provide invaluable, high energy winter food resources for farmland birds.

These results also suggest that landscape factors can influence the outcome of AES prescriptions, but this depends on the mobility of the taxa considered. The relationship was strongest for the least mobile taxon; dispersal of rare arable plants is generally very limited such that seed movement even between adjacent fields is uncommon (Bischoff 2005). Bumblebees, which showed a weaker effect of landscape species richness, have greater mobility and forage at scales of more than 1 km (Osborne *et al.* 2008). Spatial targeting of resources appeared unimportant for the most mobile taxon, farmland birds, which will forage over several kilometres whilst searching for scarce resources in winter (Siriwardena *et al.* 2006). However, spatial targeting may be more important for birds during their breeding season when they effectively become central place foragers over limited areas (Whittingham 2007).

Finally, both general and evidence-based conservation measures might provide wider environmental benefits not considered by this study, such as the protection of water and soil resources from the impacts of agriculture. The potential to deliver such multiple benefits is an additional measure of performance that requires further investigation.

In conclusion, evidence-based habitat enhancements represent a much more effective means of reconciling the need for increased food production with the conservation of biodiversity than the widely applied general measures, especially if they can be spatially targeted to areas of high diversity. However, general prescriptions in the English ELS account for over 630,000 ha (99%) of created habitat compared with just 8,100 ha (1%) of evidence-based habitat (Natural England 2009). If the conservation potential of this voluntary scheme, and AES in general, is to be maximised there is a need to have clear biodiversity targets and to design enhancement activities using scientific evidence. Such problems are not confined to AES. While there is much conservation activity taking place worldwide, the scientific evidence behind management decisions is being increasingly scrutinised (Pullin & Knight 2009). Indeed, the conclusion that current efforts to stem biodiversity losses are inadequate (Butchart *et al*. 2010) might partly be due to the use of inappropriate conservation actions.

Data collection was funded by UK Department of the Environment, Food and Rural Affairs, Natural England Syngenta, Unilever and Jordans Cereals. We thank Mark Stevenson, Andy Cooke and Mike Green for their support. We are grateful to the Botanical Society of the British Isles, Bees, Wasps and Ants Recording Society and the British Trust for Ornithology for species distribution data.

Bischoff, A. 2005 The importance of seed dispersal in restoring weed communities. *Agri. Ecosyst. Environ.* **106**, 377-387.

Butchart, S. H. M. *et al.* 2010 Global Biodiversity: Indicators of recent declines. *Science* **328**, 1164-1168.

Carvell, C., Meek, W.R., Pywell, R.F., Goulson, D. & Nowakowski, M. 2007 Comparing the efficacy of agri-environment schemes to enhance bumble bee abundance and diversity on arable field margins. *J. Appl. Ecol.* **44**, 29–40.

Chivian E. & Bernstein, A. (eds) 2008 *Sustaining Life: How Human Health Depends on Biodiversity*. New York: Oxford University Press.

Davey, C.M., Vickery, J.A., Boatman, N.D., Chamberlain, D.E., Parry, H.R. & Siriwardena, G.M. 2010 Assessing the impact of Entry Level Stewardship on lowland farmland birds in England. *Ibis* **152**, 459–474.

Dover, J.W. 1997 Conservation headlands: effects on butterfly distribution and behaviour. *Agric. Ecosys. Environ.* **63**, 31-49.

EU 2011 *Is Agri-environment Support Well Designed and Managed*? European Court of Auditors Special Report No. 7/2011. Luxembourg: European Commission.

Godfray, H.C. *et al.* 2010 Food Security: The Challenge of Feeding 9 Billion People. *Science* **327**, 812-818.

Kleijn, D. *et al.* 2006 Mixed biodiversity benefits of agri-environment schemes in five European countries. *Ecol. Lett.* **9**, 243–254.

Kleijn, D., Rundlo, M., Scheper, J., Smith, H.G. & Tscharntke, T. 2011 Does conservation on farmland contribute to halting the biodiversity decline? *TREE*. **26,** 474-481.

Natural England 2009 *Agri-environment Schemes in England 2009: A Review of Results and Effectiveness*. Peterborough, UK: Natural England.

Natural England 2010 *Entry Level Stewardship Handbook*, 3rd edn. Peterborough, UK: Natural England.

Newton, I. 2004 The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. *Ibis* **146**, 579-600.

Normile, D. 2010 U.N. Biodiversity Summit Yields Welcome and Unexpected Progress. *Science* **330**, 742–743.

Osborne, J.L., Martin, A.P., Carreck, N., Swain, J., Knight, M.E., Goulson, D., Hale, R.J. & Sanderson, R.A. 2008 Bumblebee flight distances in relation to the forage landscape. *J. Anim. Ecol.* **77**, 406-415.

Pullin, A.S. & Knight, T.M. 2009 Doing more good than harm: building an evidence-base for conservation and environmental management. *Biol. Conserv.* **142**, 931-934.

Pywell, R.F., Warman, E.A., Hulmes, L., Hulmes, S., Nuttall, P., Sparks, T.H., Critchley, C.N.R. & Sherwood, A. 2006 Effectiveness of new agri-environment schemes in providing foraging resources for bumblebees in intensively farmed landscapes. *Biol. Conserv.* **129**, 192-206.

Rands, M. R. W. et al. 2010 Biodiversity Conservation: Challenges Beyond 2010. *Science* **329**, 1298-1303.

Scherr, S.J. & McNeely, J.A. 2008 Biodiversity conservation and agricultural sustainability: towards a new paradigm of ‘ecoagriculture’ landscapes. *Proc. R. Soc. B* **363**, 477-494.

Siriwardena, G.M., Calbrade, N.A., Vickery, J.A. & Sutherland, W.J. 2006 The effect of the spatial distribution of winter seed food resources on their use by farmland birds. *J. Appl. Ecol.* **43**, 628-639.

Walker, K. J., Critchley, C. N. R., Sherwood, A. J., Large, R., Nuttall, P., Hulmes, S., Rose, R.J., & Mountford, J. O. 2007 The conservation of arable plants on cereal field margins: An assessment of new agri-environment scheme options in England, UK. *Biol. Conserv.* **136**, 260-270.

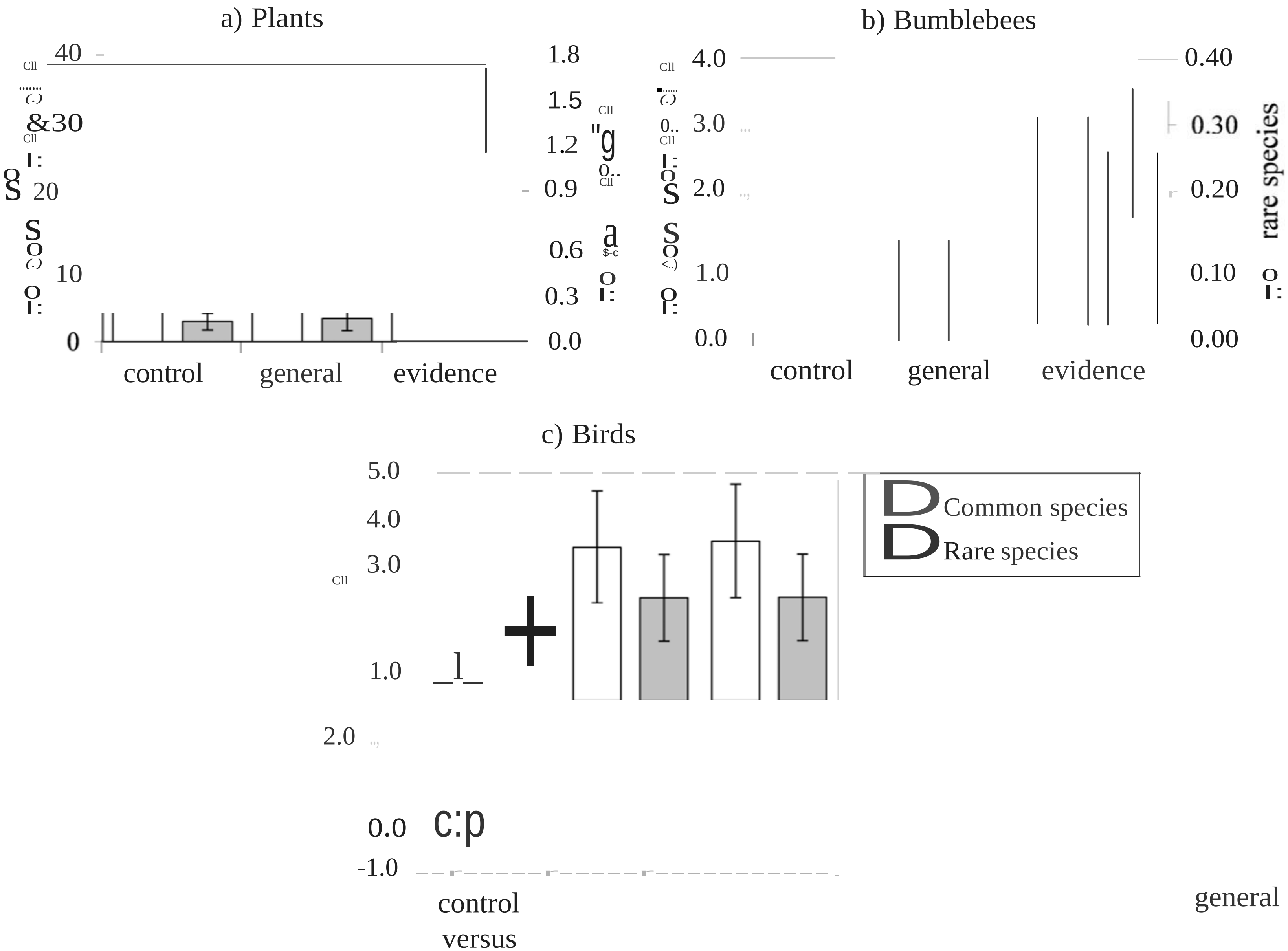
Whittingham, M.J. 2007 Will agri-environment schemes deliver substantial biodiversity gain, and if not why not? *J. Appl. Ecol.* **44**, 1–5.

Figure legends

Figure 1. The number (±SE) of rare and common a) plant and b) bumblebee species, and c) Hedge's *d* (±95% confidence intervals) comparing bird species number, recorded on general and evidence-based habitats with a cereal crop control. Species richness of common and rare plants was highest on evidence-based habitats and similar between general and control habitats (common, $F_{2,76}$=112.39, P<0.001; rare, $F_{2,76}$=17.16, P<0.001). The same pattern was seen for species richness of common and rare bumblebees, except that common bees were also more diverse on general than control habitats (common: $F_{2,73}$=75.38, P<0.001; rare: $F_{2,73}$=6.70, P<0.01). Common and rare bird numbers were higher (signified by d>0) in the evidence-based habitat compared with both the general habitat and the control, and the latter two treatments had similar numbers (d was not significantly different to 0).

Figure 2. Poisson regressions of rare species richness recorded on evidence-based habitats against richness of rare species in the surrounding 10×10 km square for a) plants, b) bumblebees, and c) birds. The fitted relationship is shown for cases with a slope significantly >0 (i.e. plants and bumblebees). Dashed lines indicate 95% confidence intervals. The X^2 and significance of the slope are given, along with the X^2/df ratio of the full model. A value <2 for this ratio indicates good model fit. A jitter has been applied to the points for clarity. Data for rare species comprised post-1970 occurrence records held by the UK Biological Records Centre.

Fig. 1. Final draft – replacement figure sent to Biology Letters 22/05/2012



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