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# Testing solutions in grass-dominated landscapes: a review of current research

DAVID L. BUCKINGHAM,[1,2]* PHIL W. ATKINSON[3] & ANDREW J. ROOK[4]
[1] *The Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire SG19 2DL, UK*
[2] *Centre for Agri-Environmental Research, University of Reading, Reading RG6 6AR, UK*
[3] *British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU, UK*
[4] *Institute of Grassland and Environmental Research, North Wyke, Okehampton, Devon EX20 2SB, UK*

In this paper we review the experimental development of agri-environment measures for use on grasslands. Sward structure has been shown to have a strong influence on birds' ability to forage in grasslands, but the effects of food abundance on foraging behaviour are poorly understood and this hinders development of grassland conservation measures. The experiments described have a dual purpose: to investigate the foraging ecology of birds on grasslands and to test candidate management measures. Most of the work featured focuses on increasing invertebrate food resources during the summer by increasing habitat heterogeneity. We also identify important gaps in the habitats provided by existing or experimental measures, where similar dual-purpose experiments are required.

Agri-environment prescriptions for arable systems are well developed, but in order to meet the Government's Public Service Agreement target to restore farmland bird populations (Defra 2002), a wider range of targeted measures will be required for grass-dominated areas. Local extinctions of farmland birds have been most prevalent in western Britain, where farms have specialized in pastoral agriculture (Chamberlain & Fuller 1999). The loss of arable habitats from grassland areas has been shown to be detrimental to farmland bird populations (Robinson *et al*. 2001). Furthermore, agricultural intensification over the last 40 years has resulted in wholesale changes to grassland management. Evidence is beginning to emerge that some of these changes have been detrimental to birds (Vickery *et al*. 2001). The performance of existing grassland agri-environment options is very variable, with many agreements providing few benefits to birds. Table 1 summarizes how existing Countryside Stewardship Scheme options might benefit birds along with possible reasons why many do not do so.

In this paper we review current projects that are developing practical ways of managing grassland for birds (Table 2). We focus on dry grasslands, which predominate in the lowlands (Fuller 1987). Wet grasslands are not considered here in view of their rarity and because the management requirements of wet grassland specialists, particularly the waders, differ from more widespread grassland species (Wilson *et al*. 2004). The key issues that new grassland agri-environment measures must address are foraging opportunities, breeding sites for ground-nesting birds and the reinstatement of mixed farming systems. These issues are used below as headings to review the current research, highlight gaps in our knowledge and discuss problems in research methodology. Most of the studies are in their early stages so we concentrate on aims and methodology, rather than data that have yet to be critically analysed.

Understanding of bird ecology on agricultural grasslands lags behind that on arable land. To address this, investigation of the underlying ecological processes is a key aim of the studies described here. The agronomic impacts of proposed measures are also quantified. For new agri-environment measures to be adopted they must not affect agricultural productivity or, failing that, the payments they attract (for profits foregone) must be competitive relative to existing agri-environment tools.

Modern grasslands are poor foraging habitats for birds that feed on seeds (winter or summer) or on sward-dwelling invertebrates (mainly in summer). The granivorous passerines – larks, buntings, sparrows

*Corresponding author.
Email: david.buckingham@rspb.org.uk

**Table 1.** Potential benefits from existing agri-environment options (Countryside Stewardship Scheme) and reasons why these may not be realized.

| CSS option | Potential benefits | Causes of shortfalls |
|---|---|---|
| P1 Grazed pasture | summer: soil invertebrates<br>foliar invertebrates<br>winter: soil invertebrates | high soil nutrient status<br>low plant diversity<br>low structural heterogeneity<br>intensive/ill-timed grazing |
| H3 Hay meadows | summer: foliar invertebrates<br>seeds<br>winter seeds<br>soil invertebrates<br>nest-sites | high soil nutrient status<br>low plant diversity<br>excess autumn regrowth<br>mowing during nesting period |
| Buffer/wildlife strips | summer: foliar invertebrates<br>seeds<br>winter: seeds<br>nest-sites | soil nutrient status (too high/low)<br>low plant diversity<br>low structural heterogeneity<br>no access for soil invertebrate feeding birds |

**Table 2.** Summary of research projects reviewed in this paper.

| Project | Participants | Duration | UK locations |
|---|---|---|---|
| Grass Headlands for Wildlife and Game | SAC, GCT, SEERAD | 1996–2000 | Dumfries and Galloway |
| Conservation Headlands in Grassland Systems | SAC, SEERAD | 2001–2004 | Dumfries and Galloway |
| PEBIL | IGER, BTO, CAER, Defra | 2002–2007 | Devon, Bucks |
| FORBIOBEN | EU project: UK (IGER), Italy, Germany, Spain and France | 2002–2008 | Devon |
| RSPB Winter Seed Experiment | RSPB, EN | 2002–2003 | Shropshire |
| Cereal-Based Whole Crop Silages Project | RSPB, CAER, Harper Adams, Defra | 2003–2007 | Shropshire, Cheshire |

and some finches – are particularly affected by these problems (Atkinson *et al*. 2004). Most of these species have undergone large declines. In contrast to this, species feeding on soil-dwelling invertebrates, such as the thrushes, are relatively tolerant of modern grassland management (Atkinson *et al*. 2004). However, seasonal drying-out of drained soils is an emerging issue for this bird guild as it reduces food availability (Peach *et al*. 2004a, 2004b). The mechanisms involved include complex interactions between drainage and soil compaction, which have yet to be investigated, so they are not dealt with in this paper.

Researchers have sought to explain patterns of grassland usage by birds in relation to two conflicting factors: food abundance and the accessibility of that food. Food abundance tends to increase with sward height, particularly for seeds and sward-dwelling invertebrates (Curry 1994, Vickery *et al*. 2001). In contrast, accessibility decreases and the costs of predator avoidance rise as sward heights increase (Butler & Gillings 2004, Devereux *et al*. 2004). Studies have tended to show that accessibility is more important than food abundance (Fuller *et al*. 2003). However, most studies have considered bird usage at the scale of the whole field, summarized across whole seasons. Insect abundance can vary substantially, both within fields and from day to day. Interactions between accessibility and food abundance also occur, because the management practices that make swards accessible to birds (mowing or grazing) can cause catastrophic reductions in food abundance (Curry 1994). The lack of fine-scale resolution in existing studies has probably led to an underestimation of the effects of food abundance on bird usage. Heterogeneous swards may simultaneously provide both food and access (e.g. Vanhinsbergh 1999, Devereux *et al*. 2004), although the scales and patterns of heterogeneity required by birds are largely unknown

(McCracken & Tallowin 2004). Several studies in this paper manipulate heterogeneity to improve foraging conditions.

## THE EXPERIMENTS

### Summer invertebrate food

Sward-dwelling invertebrates are important in the diets of many declining farmland birds during the breeding season (Wilson *et al.* 1996a, Evans *et al.* 1997). There have been few attempts to characterize the best grasslands for foraging, but these tend to be extensively managed or unproductive. These habitats are scarce in farmland (Fuller 1987) and most bird-related research aims to recreate such habitats. Constraining the productivity of grasslands in this way could be costly, so the economic implications of the treatments are measured to help set payment levels in future agri-environment schemes.

#### *Grass headlands for wildlife and game*

Conservation headlands are an established technique for enhancing the availability of invertebrate food to birds in arable farmland (Boatman *et al.* 2000). Yield losses result from reduced pesticide use, but these only affect a small proportion of the field area, minimizing costs. The Scottish Agricultural College (SAC) and Game Conservancy Trust (GCT) applied similar principles to grass fields in two experiments testing whether invertebrate prey populations could be enhanced.

Both experiments ran for 2 years on unfertilized headlands. Sheep grazed off excess grass cover each winter, to maintain accessibility for foraging birds. The first experiment compared grazing and spraying treatments in a 2 × 2 factorial design (Haysom *et al.* 2000). In the grazing treatment, stock were excluded by fencing or allowed normal access during the summer. In the spraying treatment, herbicide was applied or the plots were left unsprayed. A broad-spectrum herbicide was sprayed once in a pattern of X's to increase structural heterogeneity and access for foraging birds. The four treatment combinations were replicated on seven permanent pastures, in 10-m-wide, 50-m-long plots. The second experiment compared three different cutting treatments in the headland of a single intensively managed silage field (Haysom *et al.* 1999). The treatments were no cutting, a single late hay cut (in August) or three silage cuts. There were nine 10-m × 10-m plots in one field: three for each treatment.

The grazing experiment detected significant differences in numbers of invertebrates known to be important as food for gamebird chicks (Table 3). Ungrazed plots held the most prey in the first year. Invertebrate numbers were also high on the sprayed treatments, but only after a 1-year time lag.

#### *Conservation headlands in grassland systems*

SAC used the results of the preceding study to design and trial a grass headland prescription for birds. The trial headlands were not cut or grazed in the summer, but the swards were grazed short in the winter. Fertilizers were not allowed but limited reactive pesticide use was permitted. Bird usage was measured on 10-m-wide, 100-m-long headland plots during 2002 and 2003. However, few birds used the trial headlands and numbers may be too low to allow meaningful analysis (D.I. McCracken *et al.* unpubl. data). Final results were due in spring 2004.

#### *Potential for Enhancing Biodiversity on Intensive Livestock Farms (PEBIL)*

This experiment explores the biodiversity implications of creating structural heterogeneity in the

**Table 3.** Effects of experimental headland treatments on invertebrates important in gamebird chick diet.

| Treatment | Level | Impact on invertebrates |
|---|---|---|
| Grazing | Ungrazed | more Heteroptera, adult Symphyta and caterpillars (Lepidoptera and Symphyta); numbers increased between years |
| | Grazed | fewer insects in above groups; numbers stable or falling between years |
| Herbicide | Sprayed-Xs | fewer caterpillars and adult Symphyta in first year relative to unsprayed plots; numbers increased in second year, when caterpillars most numerous on this treatment |
| Mowing | no cuts | carabid species diversity increased between years |
| | 1 hay cut | carabid species diversity increased between years |
| | 3 silage cuts | carabid species diversity fell between years but highest counts of carabids in field centre and field boundary (not in headlands) |

**Table 4.** Management of the experimental treatments in the PEBIL project.

| Treatment no. | Management of margin treatment plots |
|---|---|
| 1 | N fertilizer allowed; 2 silage cuts (5 cm high) May + July; grazed to 5–7 cm from July onwards |
| 2 | No N fertilizer; 2 silage cuts (5 cm high) May + July; grazed to 5–7 cm from July onwards |
| 3 | N fertilizer allowed; 2 silage cuts (10 cm high) May + July; grazed to 5–7 cm from July onwards |
| 4 | N fertilizer allowed; 2 silage cuts (5 cm) May + July; no aftermath grazing |
| 5 | No N fertilizer; 1 silage cut (10 cm high) May; no aftermath grazing |
| 6 | No N fertilizer; 1 hay cut July; no aftermath grazing |
| 7 | No N fertilizer; no cutting or grazing until following February when topped |
| 8A | Spring barley undersown with grass/legume mix to remain uncut until July in year 2 |
| 8B | Spring barley undersown with grass/legume mix to remain uncut until July in year 3 |
| 9A | Sown to kale, quinoa, mixed cereal, linseed & legumes in year 1 and left in place for 2 years |
| 9B | Sown to kale, quinoa, mixed cereal, linseed & legumes in year 2 and left in place for 2 years |

headlands of intensively managed grasslands. PEBIL extends the SAC/GCT headland studies, using a larger number of different treatments to link changes in vegetation structure and composition with changes in invertebrate and bird communities.

Nine experimental treatments were replicated three times on each of four farms, in 50-m × 10-m field margin plots. The plots were established during spring 2002 on permanent pastures (> 5 years old). Permanent pastures are the most frequent grassland type, comprising 83% of the agriculturally improved grassland (June 2001 Agricultural Census Statistics).

The treatments test the effects of increasing sward heterogeneity, in terms of canopy height, architectural complexity and botanical composition. The treatments (Table 4) ranged from simple options, easily adopted by farmers (e.g. raised mowing heights, lenient grazing or delayed cutting dates) to more complex prescriptions. The latter included leaving grass uncut/ungrazed throughout the summer, establishing structurally diverse leys by undersowing spring barley, or planting mixtures of seed- and nectar-producing species. Cattle were used to graze treatments 1–8 as their grazing patterns and dung deposition create greater spatial heterogeneity than sheep.

Here we describe preliminary findings from the first summer after the plots were established. Botanical studies showed that the grassland plots were spatially uniform in composition and structure across all the farms and dominated by Perennial Ryegrass *Lolium perenne* along with very low forb cover. It is anticipated that heterogeneity will increase in subsequent seasons. The sown plots had three times the plant species diversity, one-third being contributed by arable weed species responding to the soil disturbance.

Vertical vegetation structure strongly influenced the invertebrate fauna. The raised mowing height treatments enhanced beetle abundance and generic richness. Spider abundance was also positively correlated with vegetation height. Relationships between vegetation height and other invertebrate groups were weak, but are expected to increase as sward heterogeneity develops over time.

Birds were counted monthly in blocks, comprising the treatment plot and adjacent portions of field and boundary hedge. Each treatment block was observed for 5 min per visit. The occurrence of species in each treatment block was modelled using logistic regression. Bird numbers on the plots were generally low: nine species (none of which is in decline) occurred at least 20 times, allowing logistic regression models to be fitted. Five species of granivores or small insectivores responded significantly to treatment type (Table 5). All preferred the sown treatments, where seed food and cover were most plentiful. Only the small insectivores selected grass plots, avoiding the least intensively managed treatments, but varying in their responses to greater management intensity.

### *Grazing for Biodiversity Benefits (FORBIOBEN)*

This European Union project consists of an experimental programme at five sites across Europe (UK, France, Germany, Italy, Spain). It examines the effects of grazing intensity and breed of grazing animal ('commercial' or 'traditional') on natural and semi-natural grassland systems. Integrated measurements of animal foraging behaviour, agronomy, animal production, botanical diversity, structural heterogeneity, invertebrate and vertebrate biodiversity, and socio-economic outcomes will produce a mechanistic and thus generalizable understanding of the effects. For bird conservation purposes, the study provides detailed information on how invertebrate-rich foraging habitats can be produced by extensive grazing. It

**Table 5.** Significant preferences for treatments in the PEBIL experiment, from logistic regression presence–absence models on each treatment block.

| Species | Preferred treatments | Description of preference |
|---|---|---|
| Wren *Troglodytes troglodytes* | 8B, 9A & B | greatest structural complexity |
| Dunnock *Prunella modularis* | 3, 4, 5, 8, 9 | intermediate grass management intensity |
| Robin *Erithacus rubecula* | 1, 6, 8, 9, not 7 | unmanaged grass avoided |
| Chaffinch *Fringilla coelebs* | 9A | seed-rich treatments |
| Greenfinch *Carduelis chloris* | 9A | seed-rich treatments |

is often difficult to translate target sward conditions, as defined by ecological studies, into practical farming advice. Linking sward condition with grazing behaviour at fine scales will provide the necessary mechanistic understanding of how grazing can be used to produce desirable swards.

The UK site, run by the Institute of Grassland and Environmental Research (IGER) at North Wyke, illustrates the experimental design used in each country. On this site, yearling steers are grazing unfertilized, relatively species-poor permanent pastures (NVC MG6 and MG10 communities (Rodwell 1992)). The commercial breed, Charolais × Holstein crossbreeds, is kept at moderate or lenient grazing intensities with swards maintained, respectively, at 3000 or 4500 kgDM/ha (kg herbage dry matter mass/ha, based on calibrated rising-plate sward height measurements). The traditional North Devon breed, which is presumed to have adapted to local pasture types through breeding or evolution, is kept at 4500 kgDM/ha. The three treatments are maintained in 1.5-ha plots in each field and replicated on three fields. The pasture types, species and breed of grazing animals vary between countries. The second grazing season took place in 2003.

Detailed botanical surveys are carried out on three occasions during the grazing season. The study focuses on the impact of spatial and architectural sward complexity on invertebrate populations and whether the breed of cattle influences sward heterogeneity. It is predicted that the lenient grazing treatments will produce a mosaic of tall and short patches, providing more habitats, feeding and breeding sites for a range of invertebrate taxa than the more intensive grazing treatment. Butterfly, grasshopper, ground-dwelling arthropod and bird abundance are measured throughout the grazing season. Bird abundance monitoring also continues over winter.

In order to understand the mechanisms underlying any effects of treatments, dietary selection by the grazing animals (tall or short sward and herbage species) is monitored at a bite level on three occasions during the year. These measurements are linked to detailed measurements of sward structure. Sward surface height is measured at 500 random points and at 10-cm intervals along a 50-m transect in each paddock. Live weight gains of the animals and overall live weight production are measured across the grazing season and these results are integrated into economic models.

Preliminary results show grazing intensity has a greater effect than cattle breed on foraging behaviour, agronomy and biodiversity. The higher grazing intensity has created large areas of very short 'lawns' that are dominated by White Clover *Trifolium repens*. It is already apparent that these lawn areas have a distinctive impact on invertebrate populations compared with taller grass-dominated patches. Numbers of birds using the site were low, making any interpretation difficult at this stage. The main species observed have been Skylark *Alauda arvensis* in the summer and Common Snipe *Gallinago gallinago* and Meadow Pipit *Anthus pratensis* in the winter.

## Winter seed food

Granivorous birds are scarce on modern grasslands during the winter, but some species respond positively to suitable grazing (Wilson *et al*. 1996b; Atkinson *et al*. 2004). Seed abundance tends to be low as frequent defoliations (mowing and grazing) prevent plants from setting seed. However, Fuller *et al*. (2003) found no clear relationships between seed abundance and management intensity or between seed abundance and bird usage.

### *RSPB winter seed experiment*

Ryegrass *Lolium* swards can produce abundant, large seeds on fertile soils, but grass is rarely allowed to flower on farmland as this reduces its nutritional value. Where ryegrass swards have been allowed to go to seed, the decomposition of excess foliage may damage the sward, reducing its subsequent productivity.

On rare occasions where fields have been left, they have attracted large flocks of wintering birds (principally Yellowhammer *Emberiza citrinella*, Cirl Bunting *E. cirlus*, Reed Bunting *E. schoeniclus* and Chaffinch *Fringilla coelebs*, D.L. Buckingham unpubl. data). This experiment allowed productive silage fields to go to seed to identify the requirements of granivorous birds and to assess the risks to silage production in the following spring.

The experiment had a 2 × 2 factorial design, contrasting the effects of seed abundance (mown vs. unmown plots) and accessibility (grazed vs. ungrazed plots). All four treatment combinations were established in half-hectare plots set in the same field. This design was replicated on four silage fields on separate farms in Shropshire. Seed abundance was boosted by leaving plots uncut when the last silage crop was taken in 2002. Accessibility was improved using aftermath grazing by cattle, delayed until late September so that the unmown plots could set seed first. Bird usage was measured eight times between November 2002 and February 2003. Seed abundance and sward structure were measured in each half of the winter. The farmers were asked to try to restore the swards to production after the experiment. To assess their success, relative herbage mass was measured on the four treatment combinations using a standard plate meter (Castle 1976), just before the first silage crop in 2003.

Granivorous birds were almost entirely confined to the unmown plots. Ungrazed, unmown plots were also far better than grazed, unmown plots. Accessibility was clearly of secondary importance, compared with food abundance. Yellowhammers and Reed Buntings were the dominant species, reaching high peak densities of 132 and 52 per ha, respectively. No finches used the plots, although several species were present. Herbage mass for the first 2003 silage crop was lowest on the unmown, ungrazed plots, where the average productivity relative to the control plots (mown and grazed) was –14% (range –28% to +4%). The analysis of seed samples is still in progress.

## Mixed farming

The presence of arable crops in grass-dominated areas has a strong positive effect on bird densities (Robinson *et al.* 2001). Certain arable crops, stubbles and fallows are good sources of seed and invertebrate food, which is scarce or inaccessible in grassland. Suitably managed cereals are particularly valuable, providing nesting sites, winter seed food (stubbles) and ripening grain to sustain nestlings through cool, wet weather when invertebrate prey is unavailable (e.g. Sitters 1991).

Whole-crop silage (WCS) is becoming more popular with livestock farmers. WCS treats arable crops as fodder crops. The whole of the crop, including the foliage and stems, is harvested and conserved as silage. Agronomic advantages over grass include higher yields, more efficient utilization of fertilizers and consistently high fodder quality. The technique can be applied to many arable crops, including crops valuable to birds, such as spring-sown barley. However, maize and winter wheat are the most commonly employed as these maximize productivity.

The Cereal-Based Whole Crop Silages Project will investigate the use of WCS as a conservation mechanism for farmland birds. The study will compare commercially managed WCS fields (winter wheat and spring barley) with a potential agri-environment option: spring barley WCS managed with minimal pesticide inputs (following guidelines in the Pilot Entry Level Scheme, Defra 2003). Bird usage, invertebrates and weed populations will be measured on the WCS fields and paired control fields of maize and grass silage. The WCS crops will be grown on 16 farms for 2 years. Yields and silage quality will be measured to quantify the agronomic costs of the different WCS crops. Bird work commenced in spring 2004.

## Gaps in current research

There are additional problems that birds experience on grasslands for which no agri-environment fix is currently available. Grasslands are no longer used to a great extent by species that feed their young on seeds, such as Linnets *Carduelis cannabina* or Turtle Doves *Streptopelia turtur*. Linnets can make appreciable use of grasslands that either include a lot of dandelions *Taraxacum* or are rich in forb species; neither of which are frequent on modern farms (D.L. Buckingham unpubl. data). Considerable botanical research efforts are being directed at restoring species-rich grasslands, although this is proving a somewhat intractable problem. There is no current research on Linnet feeding ecology on grasslands, but work on Twite *C. flavirostris* should provide some information on species-rich hayfields. Hay fields that were used heavily by Turtle Doves in a pre-intensification study were no longer used during recent follow-up work (Murton *et al.* 1964, Browne & Aebischer 2001).

Very few modern hayfields provide valuable feeding habitats for birds, although there is weak evidence that granivorous birds prefer hayfields on species-rich communities, rather than improved swards (unpubl. data from studies summarized in Atkinson *et al.* 2004). In addition, hayfields subject to very late cuts (August or later) can act as good winter seed sources (D.L. Buckingham unpubl. data). Restoring fields to hay management is a widely used agri-environment option, but this is not currently addressing the requirements of granivorous birds. An investigation into the reasons for this would be timely.

Ground-nesting birds experience problems with unsuitable sward structures in grasslands and high nest losses from mowing and grazing. Most research has focused on the requirements of wading birds on wet grasslands and in-bye grassland (Wilson *et al.* 2004), and safer mowing techniques to benefit Corncrakes *Crex crex* (Tyler *et al.* 1998). Species nesting in silage fields have received less attention. Skylarks experience heavy nest losses when silage cuts are taken. They nest again, but there is insufficient time for their young to fledge before subsequent silage cuts. Two studies have indicated that the interval between silage cuts should be at least 7 weeks for Skylarks to maintain their numbers (Flade *et al.* 2003, P. Lynas unpubl. data). This result has not been confirmed on high-productivity silage fields, where intervals of this length would entail expensive losses in fodder quality. An untested solution might be to leave islands or strips of unharvested grass in field centres, analogous to beetle banks in arable crops. Late-cut hayfields may also have a role in extending the nesting seasons of Corn Buntings *Miliaria calandra* (Brickle & Harper 2002) and Reed Buntings.

## CONCLUSIONS

Attempts to design grassland agri-environment measures for birds are at an early stage and the complexity of the grassland ecosystem has hampered progress. Experience gained during the studies highlights areas where improved methodology would expedite research. A more detailed knowledge of bird diet on grasslands would enable studies to focus attention on the most influential diet items. The reproductive phenology of key food items may make them vulnerable to badly timed defoliations (Brown *et al.* 1990). Thus, better knowledge of prey demography could strongly influence the design of feeding resources for birds. Experimental approaches are essential to counteract complex multicollinearity between management and ecological processes in grassland. However, small dataset sizes for birds have been a recurrent problem in the experimental studies described here. Workers involved in these studies have suggested that study areas should be chosen carefully, to ensure that the target bird species are present in adequate numbers. At the present time, locating studies in mixed farming areas may be the most practical solution to this problem.

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