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Low intensity, mixed livestock grazing improves the breeding abundance of a common insectivorous passerine

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Livestock grazing is a major driver of ecosystem change and has been associated with significant declines in various bird species in Britain and worldwide. However, there is little experimental evidence to show how grazing affects bird populations. We manipulated livestock densities in a replicated field experiment and found that mixed sheep and cattle grazing, at low intensity, improved the breeding abundance of a common upland passerine, the meadow pipit *Anthus pratensis*, after two years. Plots stocked with sheep alone (at high or low density) or not stocked at all held fewer pipit territories. Despite a year-on-year decline in pairs of meadow pipits in intensively grazed plots, we found no effect of sheep number on breeding abundance. Our results support the hypothesis that mixed species of herbivores generate greater heterogeneity in vegetation structure, which modifies prey availability, resulting in a greater abundance of birds. The results of our study should inform the management of grassland areas and enhance the abundance of some bird species, particularly in areas that have seen significant shifts from mixed livestock grazing to grazing dominated by single species of animals.

Keywords: sheep; cattle; bird declines; conservation

1. INTRODUCTION

Livestock grazing is a major driver of land use change worldwide (Fleischner 1994; Bardgett *et al.* 1995). Since the 1970s, there has been a large increase in sheep numbers in several European Union countries (Beaufoy *et al.* 1994). In the UK, between 1976 and 1997, the total number of sheep increased by over 50% (Vickery *et al.* 2001). In contrast, the total cattle herd declined by about 18%. In many upland regions of the UK, increase in sheep numbers has coincided with a shift from traditional farming systems of mixed herbivores towards ones dominated by sheep (Sydes & Miller 1988). These changes to traditional agricultural practices have been implicated in dramatic changes in vegetation and bird abundance in the British uplands (Fuller & Gough 1999). Similarly, in North America, the loss and degradation of grassland habitats from grazing has been considered a primary cause of the severe population declines in grassland birds (Knopf 1994; Vickery *et al.* 1999). However, most of these studies are correlative and experimental data are scarce.

Livestock grazing alters habitat structure and thus the suitability of the sward for nesting and feeding birds (Vickery *et al.* 2001). Habitats with a complex vegetation structure, as a result of herbivore grazing, can support a higher diversity of bird species (Martin & Possingham 2005). The foraging behaviour of many grassland birds is highly influenced by sward height, which modifies prey availability, and hence grazed areas are often preferred by invertebrate-feeders (Vickery *et al.* 2001). Too much or too little grazing, on the other hand, might lead to reduced food availability and thus be detrimental to birds (Evans *et al.* 2005). Here, we predict that (i) mixed species of herbivores, at low grazing intensity, will result in a greater abundance of birds (owing to greater vegetation structure heterogeneity) than single species of herbivores and (ii) breeding bird abundance is related to livestock grazing density.

We tested these hypotheses by manipulating livestock densities in a replicated experiment. Our study species was the meadow pipit *Anthus pratensis*, a ground nesting, generalist insectivore and the most common upland passerine in the UK.

2. MATERIAL AND METHODS

A replicated, randomized block experiment consisting of six replicates of four treatments was initiated at Glen Finglas, in central Scotland (56°16′ N 4°24′ W), in 2003. Glen Finglas is a 4039 ha estate grazed by sheep and cattle, and typical of many upland areas of Scotland. Sheep density on the estate prior to the experiment was approximately 0.7 ewes ha^{-1}. Plots were each approximately 3.3 ha in size with altitudes ranging from 200 to 500 m a.s.l.

Treatments of (i) nine ewes per plot (2.72 ewes ha^{-1}), (ii) three ewes per plot (0.91 ewes ha^{-1}), (iii) two ewes per plot (0.61 ewes ha^{-1}), and (iv) ungrazed were randomly allocated to fenced plots within each block in early 2003 (before the meadow pipit breeding season). During the autumn of 2003 (after the breeding season), cattle were added to treatment iii. This enabled us to contrast between solely sheep grazed treatments in 2003 and mixed livestock grazing treatments in 2004 and 2005. Our aim was to apply four weeks of grazing by two cows for treatment iii plots each year, which would mean that the overall annual off-take from treatment iii was similar to that from treatment ii. We used cows with calves as they were considered more likely to settle in the relatively small enclosures. In the first year of the experiment, two cows and two calves (not weaned) were added to the experimental plots in late August. However, owing to technical difficulties, the cattle had to be removed early. In 2004, two cows and one calf (not weaned) were added to all treatment iii plots in late August for the full four weeks. Therefore, we calculated the number of days that cattle were grazing in treatment iii per year (cattle_days). Within each plot, we mapped meadow pipit territories paying particular attention to bird breeding behaviour, such as song flight, alarm calls, food or faecal sac carrying, mate guarding and using nest locations when available (see Evans *et al.* 2005 for methods). We used the number of breeding territories per plot as a surrogate for breeding pipit abundance.

We used GenStat v. 7.2 (VSN International Ltd, Hertfordshire, UK) to analyse the abundance of pipit breeding territories. Owing to the unbalanced allocation of treatments to plots (i.e. cattle grazing would only affect pipits from spring 2004 onwards), the data were analysed by a linear mixed model. The random effects in the model followed the experimental design and allowed for differences between replicates, plots and different replicate effects in each year. Similarly, the fixed effects in the model followed from the experimental design, but here there were subtleties introduced

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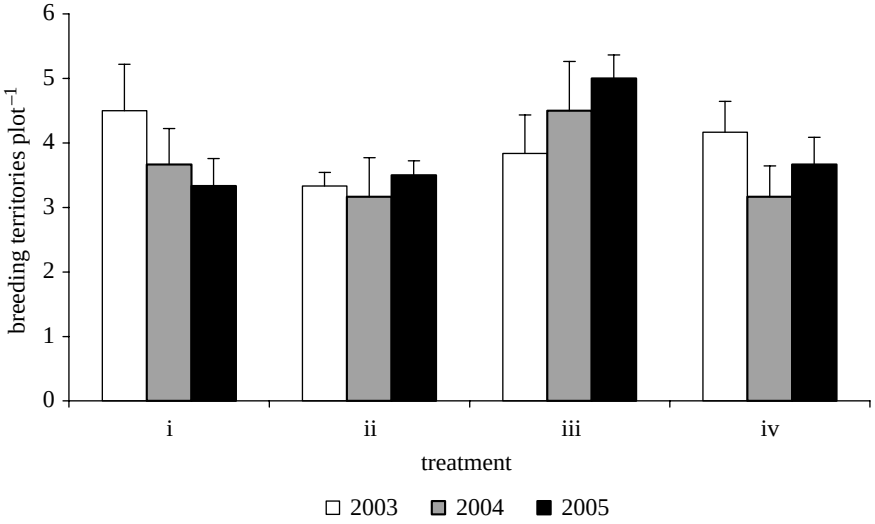

Figure 1. The effects of livestock grazing intensity on the breeding abundance of meadow pipits (means±s.e.m.) at Glen Finglas, Scotland. (treatment i, nine ewes per plot; treatment ii, three ewes per plot; treatment iii, two ewes per plot with cattle; treatment iv, ungrazed). *Note*. Cattle were added to plots after the meadow pipit breeding season in 2003.

by time lags in the imposition of the different grazing treatments. Covariates were therefore introduced as single degree of freedom contrasts for year (linear and quadratic), linear and quadratic terms for sheep density and cattle grazing the previous autumn either as binary (presence–absence) or as a continuous variable for the number of cattle days experienced. Categorical fixed effects for year and treatment were also assessed, but after trying various combinations of fixed effect models it became clear that the only important variable was cattle grazing, and this was best incorporated as a continuous variable for the number of cattle days experienced (cattle_days). Owing to the integer nature of the data, we fitted a reduced fixed effect model, containing a categorical variable for year and the cattle_days covariate. We retained year in the model, as the cattle_days differed between years and we did not wish this to be part of the estimated effect of the cattle_days covariate. We then calculated the *t*-statistic and compared this with the distribution of 1000 *t*-statistics obtained by randomizing the allocation of treatment to plot within replicate.

3. RESULTS

After 2 years of cattle grazing, there was a significant effect of 'cattle_days' on the number of meadow pipit breeding territories in our experiment ($t=3.799$, $p=0.001$, table 1). Significantly more pipit breeding territories were found in the low intensity, mixed livestock grazing plots (treatment iii; figure 1). Although the number of territories declined each year in the intensively grazed plots (treatment i; figure 1), we could find no effect of livestock grazing density or year on the number of territories. The number of territories in treatment ii remained fairly constant throughout the experiment, although fluctuated year-on-year in the ungrazed plots (treatment iv; figure 1).

Table 1. Output from a linear mixed model analysing the effects of livestock grazing on the abundance of breeding pipit territories at Glen Finglas, Scotland. (l and q=linear and quadratic, respectively. *W*=Wald statistic.)

fixed term	*W*	d.f.	*p*
sheep(l)	0.00	1	0.963
sheep(q)	0.00	1	0.989
cattle_days	13.91	1	<0.001
treatment	0.32	1	0.575
year(l)	1.04	1	0.309
year(q)	1.95	1	0.163
sheep(l).year(l)	1.35	1	0.245
sheep(q).year(l)	1.75	1	0.186
cattle_days.year(l)	0.01	1	0.926
sheep(l).year(q)	0.41	1	0.524
sheep(q).year(q)	0.30	1	0.581

4. DISCUSSION

For the first time, we have demonstrated experimentally that low intensity, mixed livestock grazing improves the breeding abundance of a common insectivorous passerine. Although the abundance of breeding meadow pipits was initially relatively constant across treatments in the first year of the experiment, the breeding abundance was consistently higher (and increased year on year) in the mixed, low intensity livestock treatment during 2004 and 2005. These results support the hypothesis that mixed species of herbivores, at low grazing intensity, improve bird abundance when compared with single species of herbivores. Despite a year-on-year decline in pipit breeding abundance in the intensively grazed plots and a relatively stable number in the low grazing intensity plots with solely sheep, we could find no effect of livestock density on breeding abundance. This was partly owing to the fluctuating abundance of breeding meadow pipits in the ungrazed plots.

Within this grazing experiment, previous work has determined that low intensity sheep grazing can positively affect avian reproduction (Evans *et al.* 2005). Here, we demonstrate that a mixture of herbivores, at low grazing intensity, can also be beneficial to birds. There is a growing body of evidence to suggest that food availability is an important factor determining bird abundance (Vickery *et al.* 2001; Atkinson *et al.* 2005). Availability is a function of both food abundance and accessibility and both are affected by grazing. It is generally recognized that arthropod abundance and species diversity increases with greater habitat heterogeneity as a result of livestock grazing (Dennis *et al.* 1998). Indeed, within this grazing experiment, other work has shown that vegetation structure and the

biomass of foliar arthropods are linked (Dennis *et al.* 2005). Compared with intensively grazed areas, our results suggest that low intensity, mixed livestock grazing may provide a more favourable foraging habitat for species such as meadow pipits, by increasing vegetation structure heterogeneity and hence arthropod availability. In the absence of large herbivores, we suspect that prey is available in a lesser quantity for these birds.

Generally, upland birds vary in their preferences for particular compositional and structural vegetation features, and management promoting heterogeneity is likely to support a diverse bird community (Pearce-Higgins & Grant 2006). It is not known specifically why the inclusion of cattle with sheep affects pipit abundance compared with areas grazed solely by sheep. It is likely that different grazing strategies and trampling impacts of the two herbivores result in a greater heterogeneity of vegetation structure. It is also plausible that cattle grazing might result in a greater diversity and/or abundance of arthropods that are attracted to the dung (e.g. Diptera spp.), which could provide a more diverse and better quality of diet for some insectivorous bird species (McCracken & Foster 1994). Further research is necessary to explain the relative importance of each of these factors and understand the mechanisms affecting bird abundance, diversity and breeding performance.

The results of our study should inform agri-environment scheme prescriptions in upland Britain and might also be used by nature conservationists wishing to halt the decline of some grassland bird species, particularly in areas that have seen significant shifts from mixed livestock grazing, to grazing dominated by single species of animals.

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