APPENDIX 4A.4

SYSTEM STUDIES: BIRDS

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1. CHANGES IN VEGETATION STRUCTURE AT REDESDALE AND PWLLPEIRAN SYSTEM STUDIES PADDOCKS IN RELATION TO GRAZING TREATMENT.

INTRODUCTION

The effects of grazing regime on vegetation structure were investigated as part of the system studies at both Redesdale and Pwllpeiran. Determining changes in vegetation structure, as well as composition, was required to enable the predictions of change in meadow pipit and skylark abundance, from the bird-habitat models, to be assessed against the observed change on the system studies paddocks (part (ii) below). Additionally, invertebrate and bird populations are often strongly affected by vegetation structure, and so determining the effects of grazing regime on vegetation structure was an essential element in assessing the likely impacts on some key components of moorland biodiversity.

METHODS

Vegetation structure was measured at each quadrat by the same methods as used in the bird modelling studies in this project (Appendix 3B.1, Pearce-Higgins & Grant 2006). Using a vertically held bamboo cane marked at 5 cm intervals, three measures of vegetation height were made at each quadrat, separately recording the heights of dwarf shrubs, graminoids and other vegetation to the nearest 5 cm. The visibility of white marks at heights of 0, 10, 20, 30 and 40 cm, on a vertically held cane provided an index of density, whilst the proportion of points at which all three 10 cm marks were visible was used as a measure of openness. Height measurements were averaged for each quadrat and summarised into three classes (0 - 15 cm, 15 - 30 cm, > 30 cm) for all vegetation, and separately for graminoids and dwarf shrubs.

The aim of the measurements was to record vegetation structure in early spring (April) and summer (July), replicating the timing of vegetation measures for the bird modelling (Appendix 3B.1, Pearce-Higgins & Grant 2006), and to examine how these measures changed in relation to the grazing treatments. Thus, pre-treatment measurements were made in 2002 and spring 2003, to be compared with post-treatment data from 2006. However, due to logistical reasons, it was not possible to collect the first vegetation data until Autumn 2002, making it necessary to instigate additional sampling in both July and Autumn in a subsequent year, for calibration. Measurements were therefore taken at Redesdale in Autumn 2002, Spring 2003, Summer 2003, Autumn 2003, Spring 2006 and Summer 2006. Measurements were made at Pwllpeiran in Autumn 2002, Spring 2003, Autumn 2003, Summer 2004, Autumn 2004, Spring 2006 and Summer 2006.

Analyses aimed to assess whether there were significant differences in the changes in dwarf shrub height, graminoid height, total vegetation height and vegetation density between the different treatments. Models were produced separately for Redesdale and Pwllpeiran, given the different treatments involved, and separately for early spring and summer vegetation measures. As the analysis involved repeated measures from the same quadrat, a mixed modelling framework was used, with quadrat specified as a random effect and applying the Kenward-Rogers correction to calculate the correct degrees of freedom. For all models, year and treatment were included as class variables, with the interaction between year and treatment the key term to identify any significant effects of treatment on changes in vegetation structure. For the models of summer vegetation structure, season (summer / autumn) was included as a two level factor to correct for the potential change in vegetation structure that may occur from Summer to Autumn. Because there was a replicated design at Pwllpeiran, with three blocks of replicated treatments, block and block*treatment were also included in models relating to that site, to account for initial differences in vegetation structure at those sites. Analyses were conducted in SAS v.9 using proc mixed, as all the vegetation structure data were normally distributed. The significance of differences between treatments were tested using pairwise contrasts of the year*treatment interaction, with year necessarily specified as a covariate.

RESULTS

Redesdale

There were significant treatment effects with regard to changes in spring graminoid height and vegetation density (Table 1), with the pattern of change for dwarf shrub and overall vegetation heights similar but not significant. The analysis of contrasts highlighted significant differences in the change in graminoid height between both cattle grazed treatments compared to the high sheep only treatment, whilst vegetation density was reduced at a greater rate under low sheep and cattle, and high sheep, relative to high sheep and cattle. Although the overall effect was non-significant, the reduction in dwarf shrub height under low sheep and cattle was significantly greater than under both sheep only treatments. Thus, in general, vegetation height and density tended to be reduced more on the two mixed grazing treatments with cattle, than the sheep only treatments, although with some variation. Differences between the high and low stocking treatments were less marked (Figure 1).

The above pattern was replicated in the summer measures (Table 1), with significant effects of treatment on graminoid height, vegetation height and vegetation density. Again, the pattern of change for dwarf shrubs was similar, but non-significant (Figure 2). Significant contrasts were apparent for graminoid height, which was reduced at a much lower rate under high sheep, than the other three treatments, particularly the two cattle grazed treatments, and under high sheep and cattle more than low sheep. Similarly, vegetation height was reduced by a greater amount in the two mixed grazing treatments relative to the high sheep treatment, whilst vegetation density was reduced more under the two mixed treatments relative to both sheep only treatments. Although the overall effect was non-significant, the reduction in dwarf shrub height was significantly greater under the high sheep and cattle regime than both sheep only treatments. With data over three years, there is an interesting contrast in the timing of the reductions in graminoid height and total vegetation height, which appear to happen in the first year, and dwarf shrub height, which happened between 2003 and 2006 (particularly in the low sheep with cattle treatment).

This may arise from there having been sufficient forage for the cattle within the graminoid dominated swards during the first year in which these grazing regimes were implemented, so that the cattle had no impact on dwarf shrub height in the first year with low sheep, but a 7 cm reduction in dwarf shrub height with high sheep. However, between 2003 and 2006 there appears to be little further reduction in graminoid height, but a much greater reduction of mean dwarf shrub height to 23 cm at the end of both cattle treatments, suggesting that having mixed grazing regimes in place for several consecutive could increase the rate of damage and suppression of heather on the Redesdale paddocks.

Pwllpeiran

There were significant treatment effects on graminoid height, and a trend approaching significance for dwarf shrub height in spring, but no significant treatment differences for spring vegetation height and density (Table 2). The significant contrasts were between the cattle only treatment and mixed grazing for graminoid height, and cattle only and high sheep for dwarf shrub height (Figure 3).

In relation to summer structural measures (Table 2), there were significant treatment differences for graminoid height and vegetation density, but not dwarf shrub and vegetation height. Significant contrasts indicate that vegetation density and graminoid height increased steadily under low sheep and cattle only treatments, but showed only a slight increase (density) or decreased (graminoid height) under high sheep and mixed grazing regimes (Figure 4).

Thus, at Pwllpeiran, the main contrasts appeared to be between treatments with low (low sheep and cattle only) and high (high sheep and mixed) stocking treatments, rather than cattle and sheep grazing.

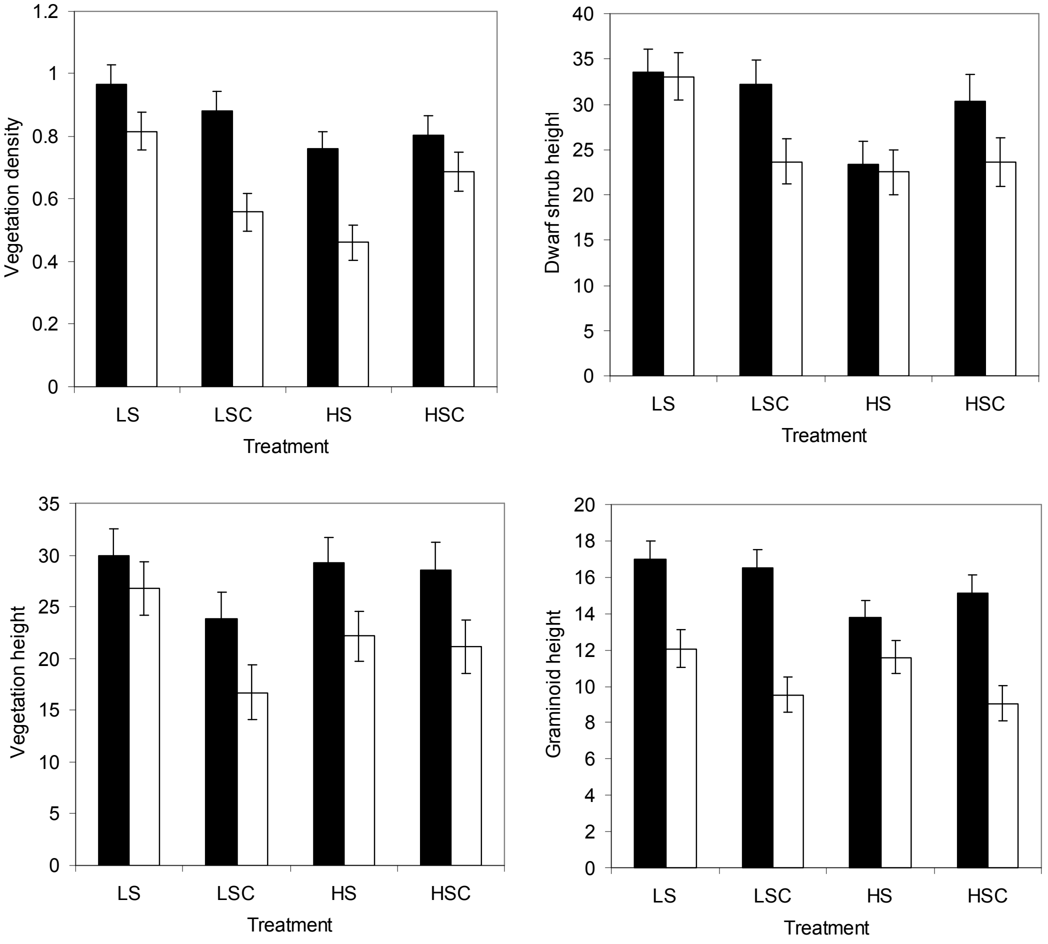


Figure 1 Changes in spring vegetation structure in relation to grazing treatment at Redesdale

Means are presented with standard error bars. Data from 2003 (black) and 2006 (white).

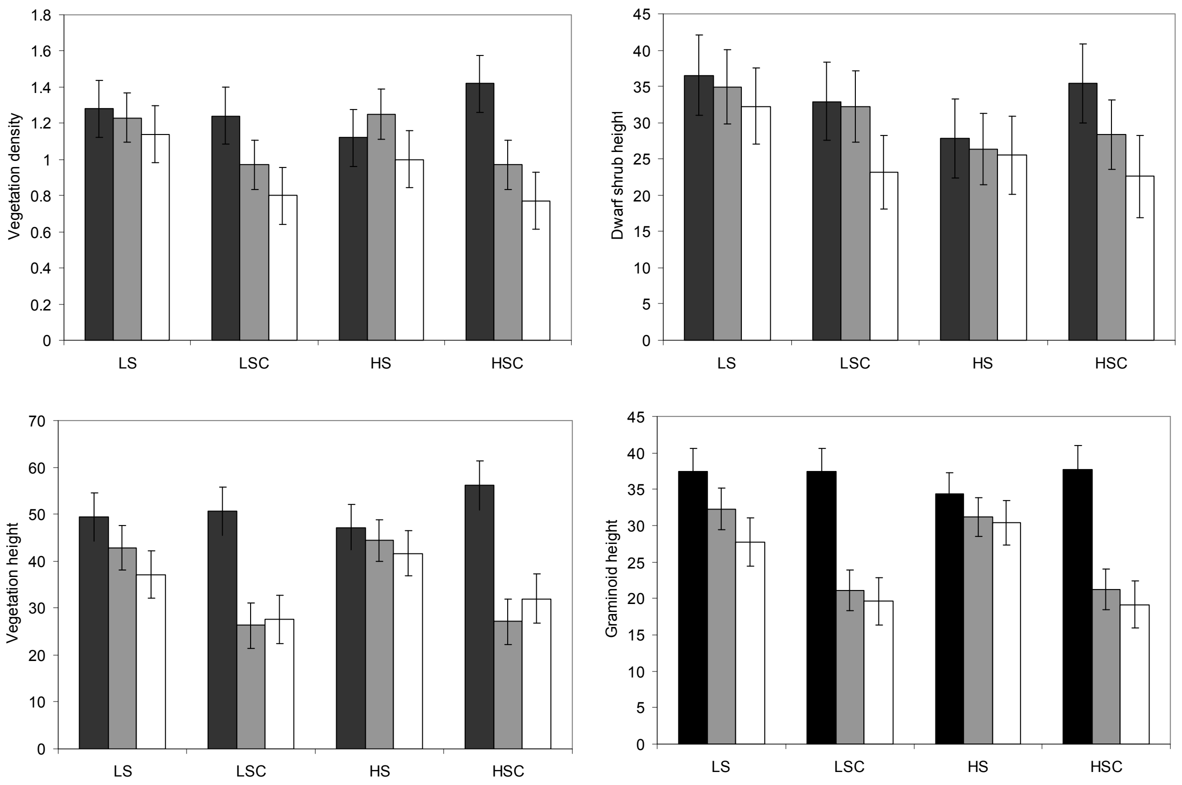


Figure 2 Changes in summer vegetation structure in relation to grazing treatment at Redesdale

Means are presented with standard error bars. Data from 2002 (black), 2003 (grey) and 2006 (white).

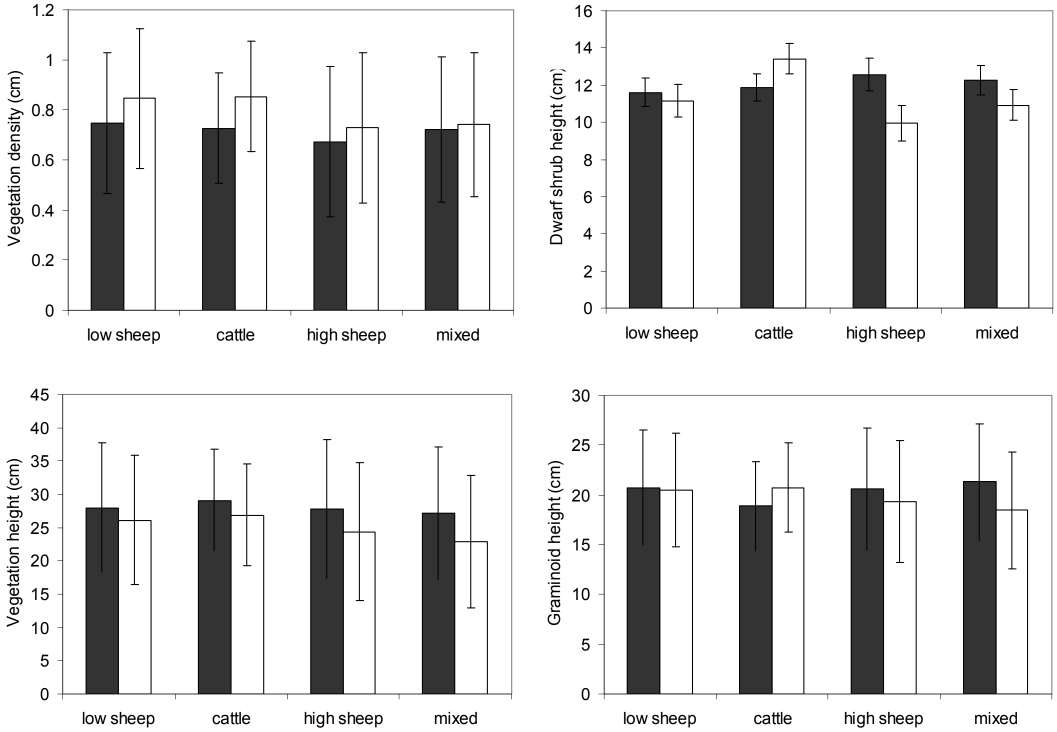


Figure 3 Changes in spring vegetation structure in relation to grazing treatment at Pwllpeiran

Means are presented with standard error bars. Data from 2003 (black) and 2006 (white).

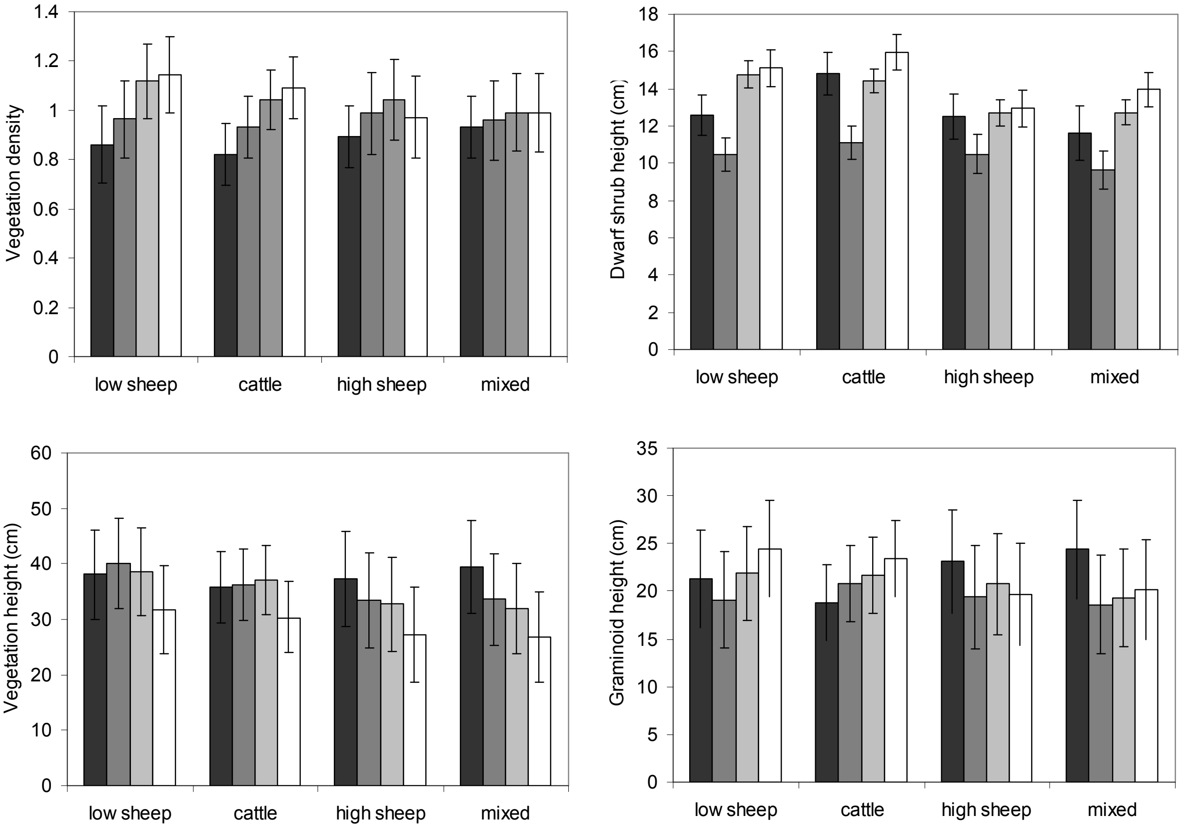


Figure 4 **Changes in summer vegetation structure in relation to grazing treatment at Pwllpeiran**

Means are presented with standard error bars. Data from 2002 (black), 2003 (dark grey), 2004 (light grey) and 2006 (white).

Table 1 Factors affecting vegetation structure at Redesdale

The term of interest with respect to significant effects of grazing treatment is the year*treatment interaction.

	Year	**Treatment**	**Season**	**Year*Treatment**
SPRING				
Dwarf shrub height	$F_{1,62.7}=8.5$, $P=0.0049$	$F_{3,77.5}=3.81$, $P=0.013$		$F_{3,62.1}=2.12$, $P=0.11$
Graminoid height	$F_{1,184}=62.1$, $P<0.0001$	$F_{3,185}=1.93$, $P=0.13$		$F_{3,184}=2.84$, $P=0.039$
Vegetation height	$F_{1,188}=35.9$, $P<0.0001$	$F_{3,191}=2.02$, $P=0.11$		$F_{3,188}=0.93$, $P=0.43$
Vegetation density	$F_{1,190}=50.6$, $P<0.0001$	$F_{3,192}=5.13$, $P=0.0020$		$F_{3,190}=2.69$, $P=0.047$
SUMMER				
Dwarf shrub height	$F_{2,166}=5.52$, $P=0.0048$	$F_{3,82.3}=2.44$, $P=0.070$	$F_{1,163}=0.78$, $P=0.37$	$F_{6,167}=1.79$, $P=0.10$
Graminoid height	$F_{2,463}=48.2$, $P<0.0001$	$F_{3,190}=9.13$, $P<0.0001$	$F_{1,477}=10.70$, $P=0.0011$	$F_{6,452}=13.92$, $P<0.0001$
Vegetation height	$F_{2,438}=30.4$, $P<0.0001$	$F_{3,191}=2.39$, $P=0.0028$	$F_{1,454}=2.39$, $P=0.12$	$F_{6,425}=19.2$, $P<0.0001$
Vegetation density	$F_{2,487}=18.6$, $P<0.0001$	$F_{3,195}=2.04$, $P=0.11$	$F_{1,498}=0.04$, $P=0.85$	$F_{6,480}=9.50$, $P<0.0001$

Table 2 Factors affecting vegetations structure at Pwllpeiran

The term of interest with respect to significant effects of grazing treatment is the year*treatment interaction.

	Year	**Treatment**	**Block**	**Block*Treatment**	**Season**	**Year*Treatment**
SPRING						
Dwarf shrub height	$F_{1,168}=1.48$, $P=0.23$	$F_{3,168}=2.28$, $P=0.081$	$F_{2,168}=3.69$, $P=0.027$	$F_{6,168}=2.27$, $P=0.039$		$F_{3,168}=2.28$, $P=0.08$
Graminoid height	$F_{1,228}=1.03$, $P=0.31$	$F_{3,228}=2.63$, $P=0.051$	$F_{2,10.7}=0.61$, $P=0.56$	$F_{6,89.3}=1.39$, $P=0.23$		$F_{3,228}=2.63$, $P=0.051$
Vegetation height	$F_{1,231}=7.18$, $P=0.0079$	$F_{3,231}=0.26$, $P=0.86$	$F_{2,13.5}=3.39$, $P=0.064$	$F_{6,101}=1.09$, $P=0.38$		$F_{3,231}=0.26$, $P=0.85$
Vegetation density	$F_{1,230}=8.83$, $P=0.0033$	$F_{3,230}=0.92$, $P=0.43$	$F_{2,1}=0.72$, $P=0.64$	$F_{6,10.4}=1.08$, $P=0.43$		$F_{3,230}=0.92$, $P=0.43$
SUMMER						
Dwarf shrub height	$F_{1,381}=3.00$, $P=0.084$	$F_{3,381}=0.72$, $P=0.54$	$F_{2,381}=4.45$, $P=0.012$	$F_{6,381}=6.27$, $P<0.0001$	$F_{1,381}=1.80$, $P=0.18$	$F_{3,381}=0.72$, $P=0.54$
Graminoid height	$F_{1,584}=0.00$, $P=0.96$	$F_{3,584}=8.27$, $P<0.0001$	$F_{2,1}=0.18$, $P=0.85$	$F_{6,15.4}=5.49$, $P=0.0033$	$F_{1,584}=4.18$, $P=0.041$	$F_{3,584}=4.18$, $P=0.041$
Vegetation height	$F_{1,602}=18.50$, $P<0.0001$	$F_{3,602}=1.20$, $P=0.31$	$F_{2,15.8}=4.97$, $P=0.021$	$F_{6,148}=4.19$, $P=0.0056$	$F_{1,602}=15.35$, $P<0.0001$	$F_{3,602}=1.21$, $P=0.306$
Vegetation density	$F_{1,592}=15.83$, $P<0.0001$	$F_{3,592}=4.72$, $P=0.0029$	$F_{2,58.9}=2.84$, $P=0.067$	$F_{6,328}=2.65$, $P=0.016$	$F_{1,592}=4.45$, $P=0.035$	$F_{3,592}=4.72$, $P=0.003$

2. ASSESSING THE PERFORMANCE OF BIRD-HABITAT MODELS: COMPARING PREDICTED AND OBSERVED CHANGES IN MEADOW PIPIT AND SKYLARK ABUNDANCE UNDER DIFFERENT GRAZING TREATMENTS ON THE SYSTEM STUDIES PADDOCKS

INTRODUCTION

The assumption of the modelling approach is that the models of spatial variation in moorland bird abundance as a function of habitat presented in Appendix 3B, can be used to explain temporal variation in abundance following changes to vegetation composition and/or structure. We have been able to test this assumption for two species, meadow pipit and skylark, which were common enough to allow sufficient data collection from the system study paddocks. Therefore, in addition to directly testing the treatment effects on passerine abundance in the system study paddocks, we use the observed changes in vegetation top-cover and vegetation structure to predict how the abundance of these two species should have changed during the course of the study based upon the respective habitat models, and assuming an immediate population level response to habitat change.

METHODS

For details of the system study paddocks see Appendices 4A.1 and 4A.2.

Meadow pipits and skylarks were counted in the system study paddocks in 2003 and 2006. Surveys were conducted along line-transects once early morning (06:00-09:00) in both May and June, following standard methods (Buchanan et al. 2006, Pearce-Higgins & Grant 2006). For the four Redesdale paddocks , line-transects within each system study paddock were 1 km in length, but due to the smaller area of the Pwllpeiran paddocks, they varied in length from 431 – 1112 m. Following Buchanan et al. (2006), abundance was summarised as the mean number of individuals recorded within 25 m of the transect line across the two visits for meadow pipits, and the mean total number of skylark recorded. For Pwllpeiran, values were then scaled up to produce relative densities per 1 km transect, to standardise for the variable transect length between separate paddocks.

As there were no treatment replicates at Redesdale, the significance of treatment effects cannot be quantified, but are simply presented. In contrast, there were three replicates of each treatment at Pwllpeiran. Here, the significance of any difference in trends between the study paddocks was assessed using generalised linear models (GLM), with bird abundance modelled as a function of paddock, year and the paddock*year interaction, with the last term highlighting significant differences in the change in populations between treatment. It was necessary to correct for over-dispersion for the analysis of meadow pipit data, which was therefore tested using an F-test, rather than the Chi-square test used for skylark.

The vegetation data on top cover (Appendices 4A.1 and 4A.2) and vegetation structure (part (i) above) were used to assess how the likely suitability of each paddock had changed for meadow pipits and skylarks, using the models for these species outlined in Appendix 3B. To calculate densities, in the absence of specific non-vegetation information about each paddock, estimates of the non-vegetation variables necessary for each model were derived from mean values across the North Pennines study plots for Redesdale, and the Wales study plots for Pwllpeiran.

Predictive performance was tested in two ways. Firstly, we correlate observed against predicted abundance across the counts from each of the paddocks in both years within a GLM, with site and year as two-level factors, and the interaction between site and year included to account for differences in density between sites and years. Interactions between predicted count and year, site and year*site interaction were used to test for variation in predictive power. A Poisson error structure was used, and log-link function; therefore the natural log of the predicted count was used in the model. Secondly, predictive success was tested by simply correlating the predicted change in abundance on each study paddock with the observed change, where change was summarised as ln (count06 / count 03). The interaction between site and predicted change tested for significant differences between the two sites.

RESULTS

The observed changes in meadow pipit and skyark abundance in Redesdale are presented in Figure 5. Although no statistical test has been performed, it is interesting that skylark appear to have declined in both the cattle grazed paddocks, relative to the sheep grazed paddocks, whilst for meadow pipit, the reverse was true.

At Pwllpeiran, there was a close to significant effect of treatment on passerine abundance for meadow pipit ($F_{3,32}$ = 2.57, *P* = 0.072) and a non-significant effect on skylark abundance (χ^2 = 5.31, *P* = 0.150). Results suggest that meadow pipit abundance increased under the high sheep grazing treatment, but showed little consistent trend across the other three treatments, whilst skylarks appear to have increased most under the low sheep grazing regime (Figure 6).

Unfortunately, the predictive model for meadow pipits is one of the worst performing models (Appendix 3B.2), whilst the skylark model performed well in only one of the two test regions (Appendix 3B.2). However, we tested the ability of the final models built using data across all four regions to predict the observed changes in the abundance of these two species.

Observed and predicted meadow pipit abundance were not significantly correlated ($F_{1, 27}$ = 0.06 *P* = 0.80) with site ($F_{1, 27}$ = 60.51, *P* < 0.001), year ($F_{1, 27}$ = 1.05, *P* = 0.31) and site*year ($F_{1, 27}$ = 2.76, *P* = 0.108) included in the model (Figure 7). There was no significant correlation between observed and predicted change in meadow pipit abundance ($F_{1, 12}$ = 0.09, *P* = 0.77), effect of site ($F_{1, 12}$ = 0.11, *P* = 0.74) or interaction between the two sites ($F_{1, 12}$ = 0.54, *P* = 0.47). Similarly, there was no significant correlation between observed and predicted skylark abundance across all paddocks ($F_{1, 27}$ = 0.77, *P* = 0.39), with site ($F_{1, 27}$ = 70.85, *P* < 0.001), year ($F_{1, 27}$ = 0.52, *P* = 0.48) and site*year ($F_{1, 27}$ = 0.42, *P* = 0.39) included (Figure 7). Change in skylark abundance was also not well predicted by the models ($F_{1, 12}$ = 0.00, *P* = 0.98), with no significant effect of site ($F_{1,\ 12}$ = 0.21, *P* = 0.65), or variation in predictive power between the two sites ($F_{1, 12}$ = 0.35, *P* = 0.57).

Given the fact that few of the moorland sites that the models were produced from were cattle grazed, together with the apparent effect of cattle on the changes in skylark and meadow pipit abundance, we tested whether there was a significant difference in the ability of the models to predict change between the cattle and non-cattle grazed sites (Figure 8). There was a significant effect of whether a site was cattle grazed and the change in meadow pipit abundance ($F_{1,\ 12}$ = 6.21, *P* = 0.03), with model performance significantly worse in cattle grazed sites ($F_{1,\ 12}$ = 6.97, *P* = 0.02). Similarly, skylark also tended to decline more on cattle-grazed sites ($F_{1,\ 12}$ = 4.84, *P* = 0.05), but with a non-significant tendency for predictive power to be reduced on cattle-grazed treatments ($F_{1, 12}$ = 2.99, *P* = 0.11). The correlations between predicted and observed counts on the sheep only treatments alone were close to significant for meadow pipit (r_s=0.69, *P* = 0.059) and skylark (r_s=0.70, *P* = 0.053).

DISCUSSION

The comparisons undertaken between the predicted and observed changes in the abundance meadow pipit and skylark on the systems studies paddocks have been made over a short period only, with the observed change in abundance measured in two years only (so providing snapshots, rather than trends). Therefore, these comparisons can only be viewed as preliminary assessments of the performance of the bird-habitat models and may be of limited reliability.

From the analysis presented here, it appears that the models for meadow pipit and skylark had limited ability to predict the recorded changes in abundance between 2003 and 2006 on the system study paddocks at Redesdale and Pwllpeiran overall. However, when separated by sheep and cattle grazing treatments, it appears that the models are unable to predict change under the cattle grazed treatments, but showed evidence of predictive power on the sheep only treatments (Figure 8). The bird-habitat models themselves were produced using data from sites that were largely sheep grazed, and it may be that, at least in the short term, cattle grazing produces a differential bird response to sheep grazing. In particular, for both species, the trend in abundance was significantly less positive on the cattle grazed sites than predicted from the models, suggesting a significant negative effect of such grazing on both species relative to the habitat condition it produces. It would be interesting to see whether this apparent additional negative effect of cattle grazing continues in the longer term, as the system study paddocks used in the study were arguably still in a transitional period from previous grazing treatments.

Interestingly, the results from Redesdale are broadly similar to those of Evans et al. (2006) from an acid grassland site at Glen Finglas (in the Trossachs area of Scotland), in that meadow pipit populations declined least under mixed sheep and cattle grazing treatments; albeit declining by more than predicted from the change in vegetation condition (see above). However, the results from Pwllpeiran differ from Redesdale and Glen Finglas, in that the greatest increase in meadow pipit abundance was on the high density sheep grazed paddocks. For a species such as meadow pipit (associated with vegetation conditions that are intermediate on a spectrum from those typical of high to low grazing - Pearce-Higgins & Grant 2006, Appendix 3B.1), it seems likely that different grazing treatments are required on different sites to produce the preferred habitat conditions, given that the ‘initial’ vegetation conditions will differ.

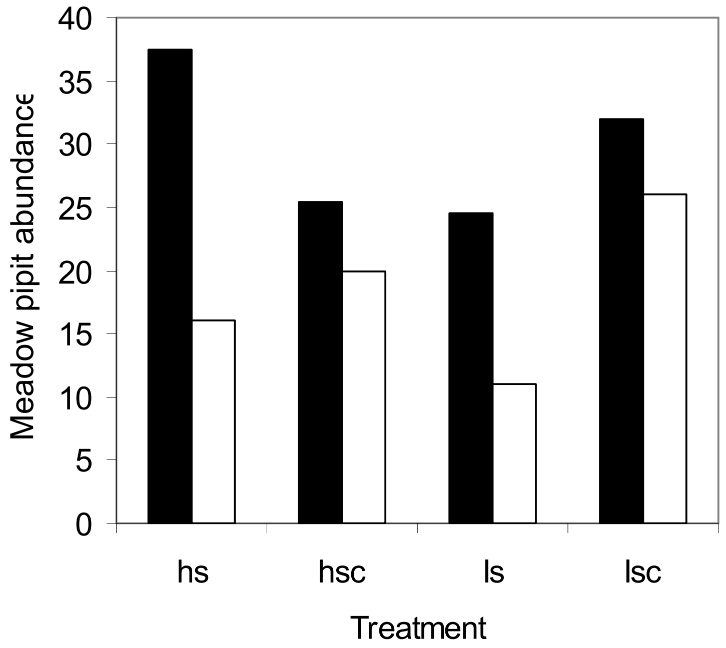
Skylark require areas of relatively short grass (Pearce-Higgins & Grant 2006, Appendix 3B.1), and therefore would be expected to benefit from relatively high grazing levels. Interestingly, declines in skylark appear to have occurred on the two cattle grazed sites at Redesdale, and one of the two cattle grazed treatments at Pwllpeiran, where numbers increased under the ESA sheep treatment. The significant tendency for the changes in the abundance of both bird species to be worse than expected from the habitat change, under cattle grazed treatments may result from additional trampling risk to nests from the cattle, or subtle changes to the vegetation that are not identified by our models. More research is required to disentangle this effect further.

REFERENCES

Buchanan, G.M., Pearce-Higgins, J.W. & Grant, M.C. 2006a Observer variation in estimates of meadow pipit Anthus pratensis and skylark Alauda arvensis abundance on moorland. Bird Study 53: 92-95.

Evans, D.M., Redpath, S., Evans, S.A., Gardner, C.J., Elston, D.A., Dennis, P. & Pakeman, R.J. 2006. Low intensity, mixed livestock grazing improves the breeding abundance of a common insectivorous passerine. Biology Letters 2: 636-638.

Pearce-Higgins, JW & Grant, MC 2006. Relationships between bird abundance and the composition and structure of moorland vegetation. Bird Study 53: 112–125.



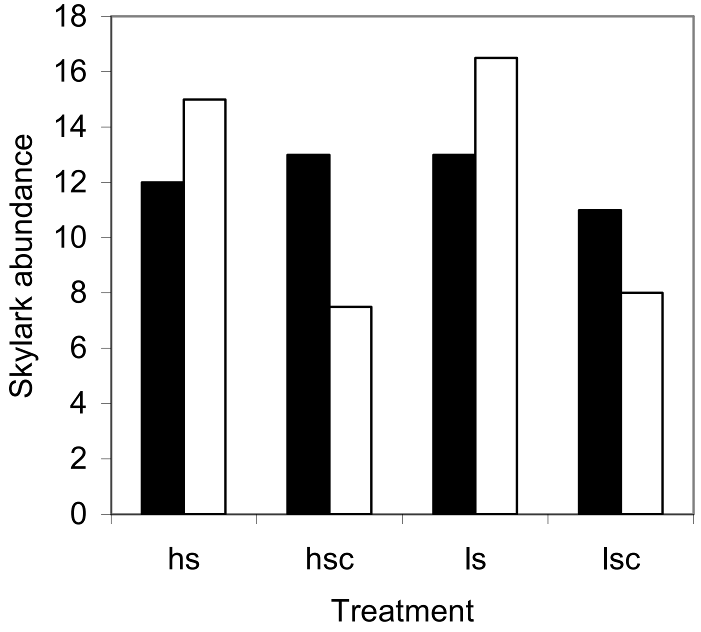


Figure 5 Changes in meadow pipit and skylark abundance from 2003 (black bar) to 2006 (white bar) at Redesdale in relation to the four grazing treatments

(hs – high sheep, hsc – high sheep plus cattle, ls – low sheep, lsc – low sheep plus cattle). Meadow pipit abundance is the number of birds counted within 25 m of the transect, whilst skylark abundance is the total number of skylarks recorded per transect.

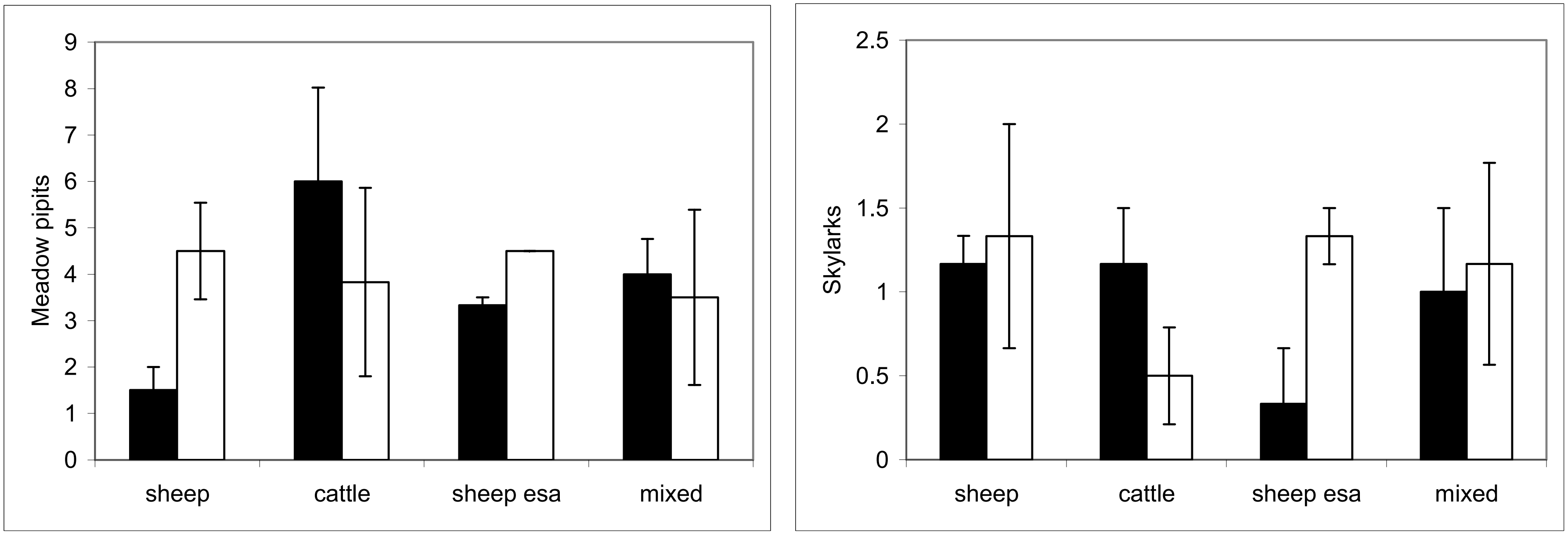


Figure 6 **Changes in meadow pipit and skylark abundance from 2003 (black bar) to 2006 (white bar) at Pwllpeiran in relation to the four grazing treatments**

Meadow pipit abundance is the number of birds counted within 25 m of the transect, whilst skylark abundance is the total number of skylarks recorded per transect.

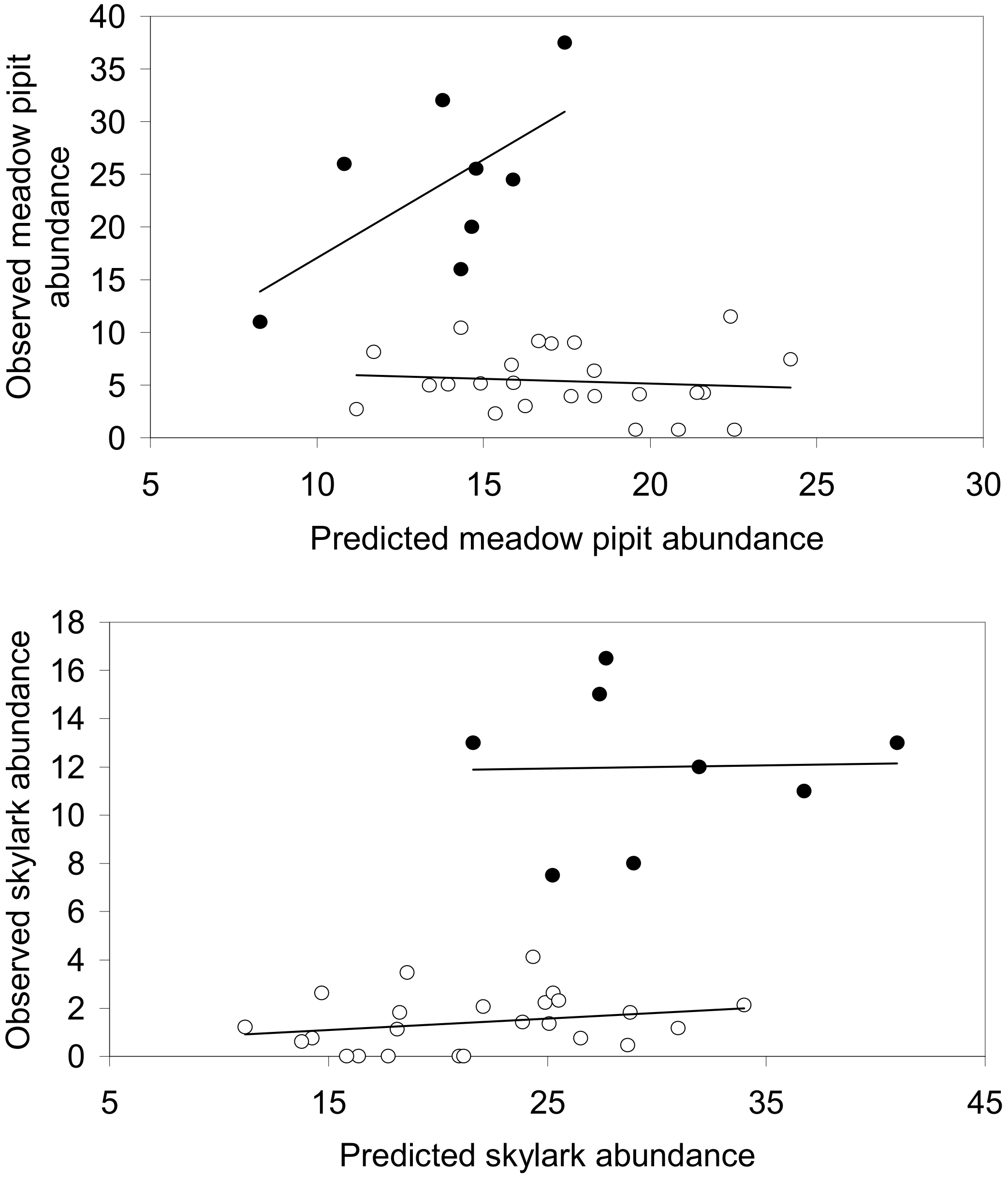
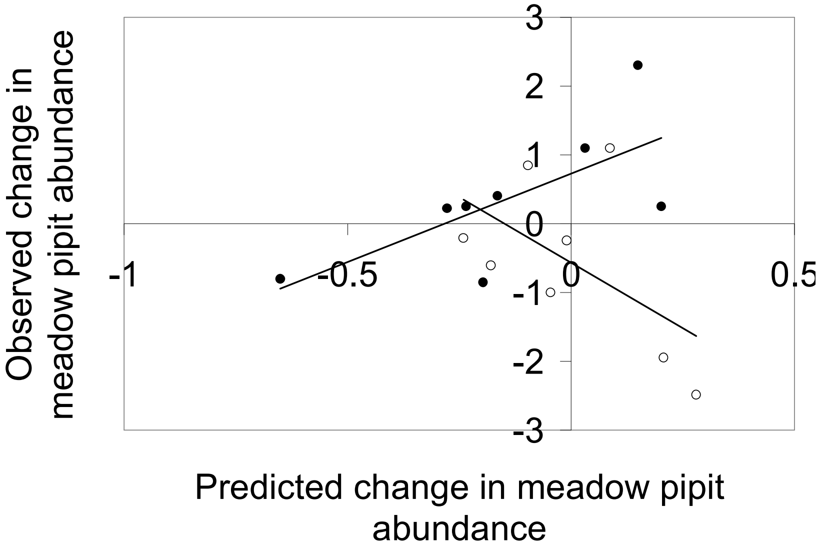


Figure 7 **Predicted against observed meadow pipit (top) and skylark (bottom) abundance for Redesdale (filled circle) and Pwllpeiran (open circle)**

Each paddock contributes two data points, from 2003 and 2006.



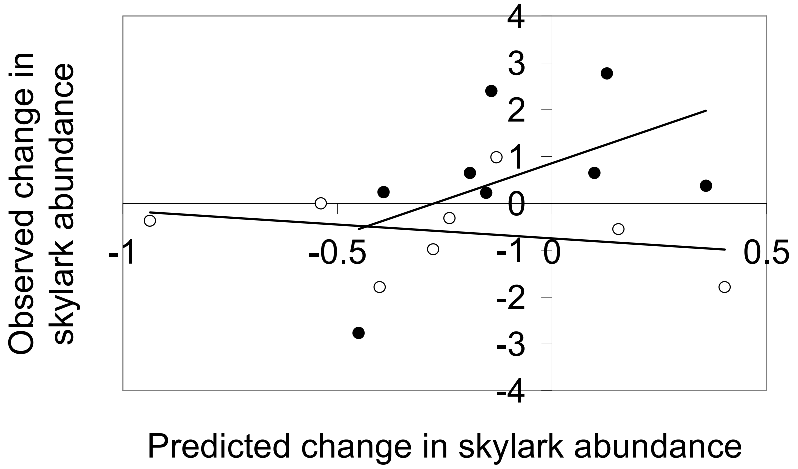


Figure 8 **Predicted against observed meadow pipit (top) and skylark (bottom) abundance for non-cattle grazed (filled circle) and cattle grazed (open circle) treatments**

Change is the log-ratio of count in 2006/ 2003.