Multiple mechanisms control the breeding density of meadow pipits

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Introduction

Since the 1950s widespread declines have occurred in the populations of many species of birds inhabiting agricultural landscapes in Europe. In upland Scotland, bird declines have been associated with increased livestock densities (Fuller & Gough 1999) and a switch from cattle to sheep. However, the mechanisms remain unclear.

We hypothesised that bird abundance would be affected through an interplay between food abundance and habitat structure, determining the availability of food to the birds. Bird abundance should be greater in areas where cattle had increased the heterogeneity of vegetation and hence increased invertebrate food availability. We manipulated grazing regimes and tested these ideas using the meadow pipit *Anthus pratensis* as a model species.

Methods

Experimental design and management

The experiment, consisting of six replicate blocks of four 3.3 ha plots, was established in Glen Finglas, Scotland (200-500 m, 56°16´N 4°24´W) in 2002. The vegetation consisted of a fine grained mosaic of mire, flush and acidic grassland. Experimental grazing treatments were established in January 2003 after a year of baseline monitoring. The treatments were (i) grazing at the current commercial rate, 2.72 ewes ha^{-1}, High, (ii) grazing at one third of this rate, 0.9 ewe ha^{-1}, Low-S, continuing the previous grazing regime, (iii) grazing with sheep and cattle at an equivalent offtake to the Low-S treatment, Low-SC, and (iv) no grazing, None. Sheep were maintained on the plots all the year round except for normal farm operations and during very severe weather. Cattle were grazed in September and October of each year.

Biological sampling

Vegetation height was recorded at 81 points on a 20 m grid within each plot in August. Composition was monitored using a pin frame at 25 points per plot in 2002 and 2005. Change in plant species composition was tested using a Before-After-Control-Impact (BACI) analysis (CANOCO ver 4.5, ter Braak & Šmilauer 2002). Arthropods were sampled at the same 25 locations as the vegetation from 2002 to 2005 using a motorised suction sampler. Material was sorted, abundance recorded and an estimate of arthropod biomass per sample was made. Breeding meadow pipit territories were recorded using 'Common Birds Census' techniques.

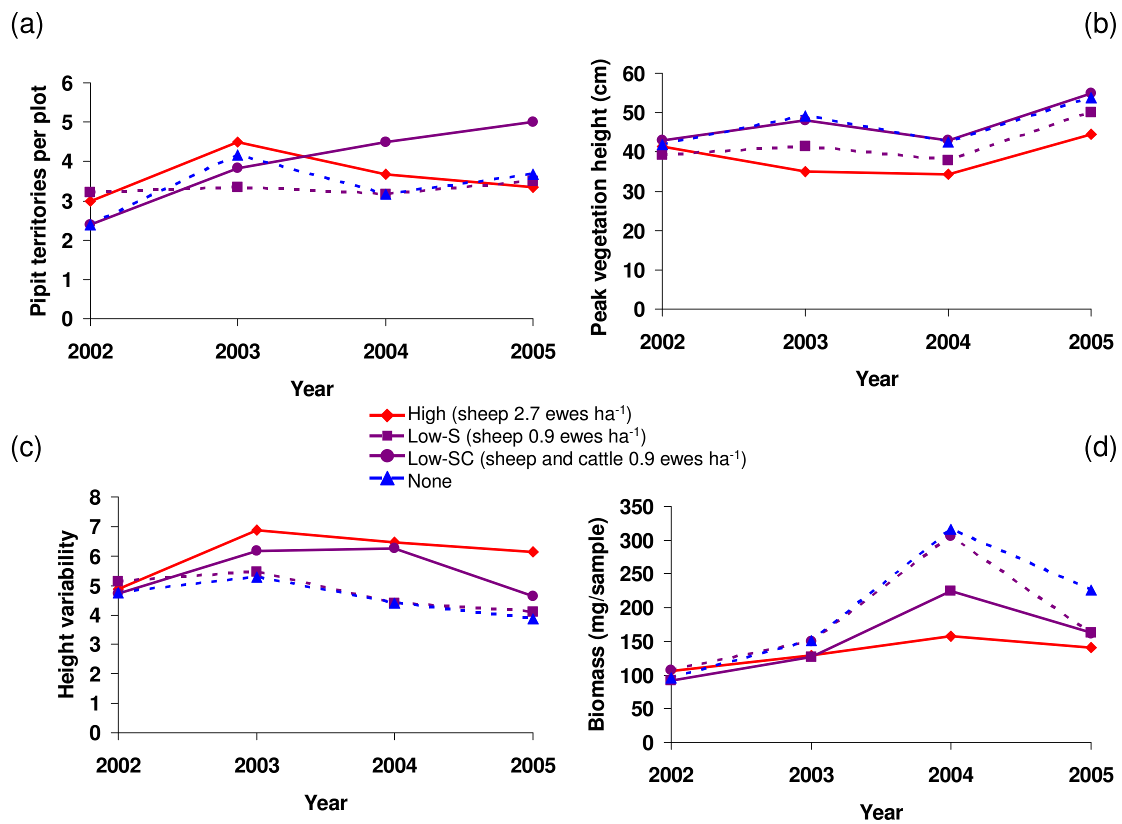
Statistical analysis

Univariate analyses were carried out in using residual maximum likelihood (Lawes Agricultural Trust 2005). First, a general test with a fixed model of Treatment + Year + Treatment.Year. Second, a detailed investigation of specific contrasts to allow for the time lags in treatment implementation: i.e. the meadow pipits could not respond to cattle grazing until 2004. The random model was standardised as Block + Plot + Block.Year + Plot.Year. The Plot.Year term incorporated a lag 1 autoregressive term within plots to allow for the repeated measures aspect of the data, and year-specific residual variances to allow for heteroscedasticity between years.

Results

Over the four years of experimental treatment, meadow pipit numbers were relatively constant on the None, Low-S and High treatments. However, by 2005 there were significantly more meadow pipit territories established where both sheep and cattle grazed the plots (treatment.year Wald/df = 3.35, $p < 0.05$, cattle grazing days Wald/df = 23.09, $p < 0.001$); 5 territories per Low-SC plot compared to c. 3.5 on the other treatments (Figure 1a).

Figure 1. Response of (a) meadow pipit breeding density per 3.3 ha plot, (b) August vegetation height (cm), (c) height heterogeneity (coefficient of variation) from 2002-2005 and (d) arthropod biomass (mg per sample).



Areas stocked at low or zero density had significantly taller swards (treatment Wald/df = 11.76, $p < 0.001$). There was little difference in between the height of the ungrazed (None) and the Low-SC treatment as the measurements were taken before the cattle grazed the plots (Figure 1b). Multivariate (BACI) analysis showed there was no significant change in overall plant species composition on the plots between 2002 and 2005 as a result of the treatments ($p = 0.59$). Height heterogeneity was not linearly related to grazing intensity, rather it was highest in the High and Low-SC treatments and lowest on the ungrazed and Low-S treatments (Figure 1c). Lower stocking rates also resulted in a higher biomass of above-ground arthropods (treatment.year Wald/df = 4.58, $p < 0.01$, Figure 1d).

Discussion

Pipit density only increased on the Low-SC treatment indicating that there were multiple mechanisms regulating pipit abundance. This treatment shared with the grazing removal treatment (None) a high density of food and tall vegetation (Figure 1d and b), but had higher pipit densities (Figure 1a). It had a higher heterogeneity in vegetation height, second only to the High treatment, indicating that food availability as opposed to abundance alone is high. The increased height heterogeneity produced by the cattle (Figure 1d) may act to improve access to the sward for the meadow pipits, whilst their absence in the spring and early summer allows good vegetation growth and hence higher arthropod numbers.

This experiment clearly showed that the breeding density of an upland passerine is determined by the grazing regime without any confounding effects of grazing induced vegetation change. Vegetation height and arthropod abundance alone are not good indicators of pipit density. Multiple mechanisms are controlling population density: there was an interaction between sward characteristics produced by the combined sheep and cattle grazing and the food resources associated with the low stocking levels that is closest to optimal foraging habitat for the meadow pipits.

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