APPENDIX 4A.2

REDESDALE SYSTEM STUDY

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ABSTRACT

Upland wet heaths in the UK are of international conservation significance but high grazing pressure by sheep has resulted in widespread degradation. Simply reducing sheep numbers can cause competitive grasses such as *Molinia caerulea* to increase, preventing regeneration of dwarf shrubs. Cattle could potentially reduce grass biomass but their utility as a conservation tool is also dependent on economic viability. The aim of this study was to assess the effect of two sheep-only and two mixed cattle-plus-sheep grazing regimes on vegetation and livestock performance at a system scale on heterogeneous degraded wet heath. A 103 ha heath was split into four paddocks and grazed, respectively, by Scottish Blackface sheep all year at 1.5 or 0.66 ewes ha^{-1} with 25% removed in winter, with or without weaned Continental cross suckler cows at 0.75 cows ha^{-1} for up to ten weeks in summer for four years. Plant species cover, frequency and a grazing index were recorded annually from a grid of 196 fixed quadrats and six vegetation types identified by fuzzy clustering analysis. Liveweights and body condition scores of cows were recorded at turn out and removal from paddocks, of ewes in October and February and lamb liveweights at birth, 4 and 20 weeks of age. In both mixed grazing paddocks after cows were introduced, *M. caerulea* cover declined substantially in vegetation types where it was abundant, exposing the moss and litter layer, and its grazing index increased. *Calluna vulgaris* declined slightly in the mixed grazing paddocks, primarily because of localised trampling. *M. caerulea* increased in the sheep-only paddocks and *C. vulgaris* declined slightly despite low grazing indices. Other plant species showed minor changes. Cow daily liveweight gains were adequate to regain body condition prior to calving, but these and ewe tupping weights and lamb weaning weights were lower in paddocks with 1.5 than 0.66 ewes ha^{-1}. Ewe and lamb performance were similar in mixed and sheep-only paddocks at each ewe stocking rate. It was concluded that cows can be grazed with sheep to remove *M. caerulea* biomass without detriment to livestock performance. The stocking levels used in this study would not be sustainable every year because the cow grazing period was reduced after year 2 to prevent grazing of *C. vulgaris*. Despite suitable conditions being created in the mixed grazing

paddocks, there was no evidence that heathland vegetation was being restored after four years. Restoration by grazing alone probably requires a longer timescales.

INTRODUCTION

Upland heaths in the UK are of international conservation significance (Usher & Thompson, 1993; Thompson et al., 1995). Wet heaths occur on peat up to 0.5 m deep at 250-600 m above sea level and usually contain a mosaic of plant communities characterised by dwarf shrubs, grasses, sedges and bog-mosses (Rodwell, 1991). These heaths are traditionally managed by extensive grazing systems that maintain the semi-natural plant communities and provide valuable income to farms in the hills and uplands (Usher & Thompson, 1993). High grazing pressure due to increasing numbers of sheep in the second half of the 20th century resulted in degradation of upland heaths, with dwarf shrubs and bog-mosses being replaced by competitive grasses (Bardgett et al., 1995).

To counteract these trends, agri-environment schemes were introduced in the UK in the late 1980s to encourage farmers to reduce sheep numbers. Where dwarf shrubs such as *Calluna vulgaris* are still present, their biomass can increase if grazing pressure is reduced (Hulme et al., 2002; Pakeman et al., 2003). However, if the dwarf shrub component is scarce or has been lost completely, reduced stocking results in an increase in competitive grasses such as *Molinia caerulea*, which prevent recolonisation or spread of dwarf shrubs (Adamson et al., 2001; Marrs et al., 2004). Therefore, simply reducing grazing pressure on severely degraded heath is unlikely to result in successful restoration (El Aich & Waterhouse, 1999).

Heavy summer grazing can reduce *M. caerulea* (Grant et al., 1963; Hulme et al., 2002). Since cattle selectively graze *M. caerulea* in summer (Grant et al., 1996; Mandaluniz et al., 2005), they could aid restoration of degraded wet heath by reducing competition from grasses. Cattle grazing can also increase species and structural diversity (Pykala, 2005) and cause more disturbance from trampling than sheep, potentially creating bare patches and enhancing allowing seedling germination. However, cattle numbers are in decline with many hill farms now only keeping sheep. Suckler cow numbers declined from 1.95 million head in 1998 to 1.77 million head in 2005 (Defra, 2005). Whilst there are annual fluctuations, of particular concern is the number of in calf beef heifers being retained for future breeding, which had dropped from 225,000 in 1998 to only 193,000 in 2005. With CAP reform and low economic returns from suckler cows, it is widely considered that suckler cow numbers will continue to decline.

An alteration of grazing regimes for heathland restoration will only be acceptable to farmers if livestock productivity and welfare are not compromised. Managed grazing of *M. caerulea* can potentially provide adequate forage for cattle in summer (Common et al., 1997). In addition, selective grazing behaviour of livestock results in spatial variation in grazing pressure at heterogeneous sites (Clarke et al., 1995; Hester & Baillie, 1998; Palmer & Hester, 2000; Palmer et al., 2003; 2004). Vegetation response to altered grazing regimes also varies amongst locations and vegetation types (Hope et al., 1996; Virtanen et al., 2002; Gordon et al., 2004; Marrs et al., 2004; Vandvik et al., 2005). At a farm system scale therefore, uncontrolled grazing by cattle and sheep at heterogeneous sites is likely to produce varying responses amongst different heathland plant communities.

The aim of this project is to assess the effect of two sheep-only and two mixed sheep-plus-cattle grazing regimes on vegetation and livestock performance when applied to a heterogeneous degraded wet heath. Specifically, the following questions were addressed: (1) how do (a) grazing of *M. caerulea* and *C. vulgaris* and (b) cover and frequency of plant species vary temporally and among vegetation types and (2) how does livestock performance vary temporally and between paddocks under the four different grazing regimes?

METHODS

Study Site and Grazing Regimes

The study was carried out on 103 ha of degraded wet heath on a gently sloping site at 260 - 350 m above sea level, on amorphous peat and silty clay loam with impeded drainage over silty or sandy clay loam at the ADAS Redesdale Research Centre, Northumberland, UK (grid. ref. NY 831950). The vegetation most closely resembled a degraded form of the *Scirpus cespitosus - Erica tetralix* (M15) community (Rodwell, 1991), with small scale variation in the relative abundance of species such as *C. vulgaris*, *M. caerulea*, *Juncus* spp., *Nardus stricta*, *Eriophorum vaginatum*, *Carex nigra*, *Deschampsia flexuosa*, *Polytrichum commune*, *Festuca ovina* and *Agrostis capillaris*. The area was split (running down- to upslope) into two equal-sized paddocks and, from 1995 to 2002, had been grazed by Scottish Blackface sheep at 1.5 and 0.66 ewes ha^{-1} respectively, minus 25% from 1 October to 28 February, and with all ewes removed for 3 weeks in November for mating and April for lambing. For this study, from 2003 to 2006 each paddock was again split into two, ensuring that there were similar areas of the different vegetation types (see below) in each paddock. The same sheep grazing regimes were continued but one paddock with each sheep regime was grazed also by non-lactating, autumn calving Simmential X Holstein and Belgium Blue X Holstein mature cows at 0.75 cows ha^{-1} from mid-June each year (Table 1). After cows were released in the paddocks the vegetation was checked weekly and cows were removed from both paddocks after the first signs of grazing of *C. vulgaris* by cows in either paddock in mid-summer. This was intended to minimise damage to *C. vulgaris*, since cows remove more of the shoot than sheep. It also mirrored livestock husbandry decisions based on welfare grounds, since cows only graze *C. vulgaris* when more palatable species are no longer available. Cows were grazed for 9-10 weeks in the first two years but this was truncated to 4 weeks by the fourth year as they started grazing *C. vulgaris* earlier in the season (Table 2). Immediately after removal of cows, the vegetation condition was checked by measuring the length of five randomly selected laminae of *M. caerulea* at each of thirty randomly located points in each paddock.

Table 1 Grazing regimes in the four paddocks

Paddock	Grazing regime (animals ha^{-1})	Area (ha)
Low sheep (LS)	0.66 ewes	26.7
Low sheep plus cows (LSC)	0.66 ewes + 0.75 cows (summer only)	28.6
High sheep (HS)	1.5 ewes	25.5
High sheep plus cows (HSC)	1.5 ewes + 0.75 cows (summer only)	22.0

Vegetation

A rectangular grid of 196 points at 75 m spacing was superimposed on the site and vegetation recorded at each point from a fixed 1 x 1 m quadrat subdivided into 100 cells of 10 x 10 cm. Percentage top cover was estimated using a sighter with cross-wires in the centre of each cell and recording the plant species, plant litter, bare ground or dung present at the cross-wire intersection. The presence of all plant species in each quadrat was also recorded. Local frequencies of *M. caerulea* and *C. vulgaris* were calculated as the number of cells per quadrat in which they were present. A grazing index was calculated for both species as the proportion of occupied cells in which grazed shoots were present. Overall sward height and height of *C. vulgaris* was measured from five random locations within each quadrat. All measurements were made in 2001 before introduction of the new grazing regimes (except the *C. vulgaris* grazing index). Cover, frequency and grazing index measurements were repeated annually during July - August from 2003 to 2006 and quadrat species lists repeated in 2006.

Species cover data from 2001 were subjected to Detrended Correspondence Analysis (DCA) using CANOCO software (ter Braak & Šmilauer, 1998). Fuzzy clustering (Equiha, 1990) was then applied to the sample scores from the DCA ordination to identify the main vegetation types. The fuzzy clustering specification used 3-8 clusters, a fixed fuzziness criterion of 2 and a convergence coefficient of 0.001. The resulting six vegetation types were described within the framework of the National Vegetation Classification (Rodwell, 1991; 1992). Species cover data from 2006 were added as supplementary variables to the DCA of 2001 data (ter Braak & Šmilauer, 1998) and change assessed from mean axis scores of the vegetation types.

Differences between vegetation types and over time in each paddock were analysed using multivariate repeated-measures Analysis of Variance on arcsin($\sqrt{x}$) transformed cover, local frequency and grazing index data, using the General Linear Model procedure in Statistica 6.0 software (Statsoft Inc, 2001). Mean vegetation heights from each quadrat were transformed by log(x+1) and subjected to the same analysis. Grazing indices were analysed for the three vegetation types in which *C. vulgaris* or *M. caerulea* were dominant. Differences in *M. caerulea* lamina lengths between years were tested using one-way Analysis of Variance on sample point means.

Livestock Performance

Liveweight and tactile body condition scores (MAFF, 1994) were recorded for all ewes at tupping (October), and at pregnancy scanning (February) in each year. Liveweights were also recorded for lambs within 24 hours of birth, at marking (approximately 4 weeks of age) and at weaning (approximately 20 weeks of age). Cattle liveweights were recorded at turn out to paddocks and removal from paddocks. All livestock performance data were analysed using the method of residual maximum likelihood in Genstat 8.1 (Lawes Agricultural Trust, 2005). The model comprised fixed effects for paddock and year and the interactions between paddock and year for all variables.

RESULTS

Vegetation

In the LSC paddock, no difference was detected in *M. caerulea* lamina lengths between years (Table 2). In the HSC paddock, laminae were longer in 2004 than in other years, which coincided with higher June and July rainfall (Table 3). In the absence of cows, laminae were of similar length each year in the HS paddock but longer in 2005 and 2006 than the first two years in the LS paddock.

Table 2 **Cow grazing periods and mean (standard error in parentheses) *M. caerulea* lamina lengths (cm) at removal date with one-way ANOVA results**

Year	On	Off	Weeks		LS	LSC	HS	HSC
2003	10 June	13 August	9		25.4 (1.61))	10.1 (0.81)	23.7 (1.38)	8.1 (0.59)
2004	10 June	17 August	10		25.3 (1.68)	11.1 (1.29)	24.5 (1.87)	11.6 (1.34)
2005	14 June	26 July	6		34.9 (1.47)	8.6 (0.84)	26.3 (1.50)	7.3 (0.56)
2006	14 June	12 July	4		31.2 (1.22)	10.9 (1.06)	25.4 (1.57)	8.3 (0.65)
				$F_{3,116}$	9.75***	1.19 ns	0.51 ns	5.10**

Table 3 **Total cumulative rainfall (mm) and average daily maximum air and soil (10 cm depth) temperatures (0C) from Redesdale weather station (grid ref NY 834955) for June-July during 2001-2006**

	Rainfall			**Air temp.**			**Soil temp.**		
	June	**July**	**June+July**	**June**	**July**	**Mean**	**June**	**July**	**Mean**
2001	56.9	82.4	139.3	15.0	17.9	16.5	10.9	13.4	12.2
2002	99.2	110.8	210.0	15.5	16.9	16.2	11.3	12.6	12.0
2003	59.0	34.5	93.5	13.3	14.9	14.1	12.8	14.9	13.9
2004	76.0	68.6	144.6	12.3	13.1	12.7	12.7	13.8	13.3
2005	67.6	44.2	111.8	17.3	18.1	17.7	12	14.3	13.2
2006	32.5	14.6	47.1	18.4	22.6	20.5	12.5	15.6	14.1

Plant communities

Six distinct vegetation types were identified. The dominant species were, respectively, *C. vulgaris* (Cv), *C. vulgaris* plus *M. caerulea* (CvMc), *M. caerulea* (Mc), *C. nigra* (Cn), *N. stricta* (Ns) and *Juncus* spp. (*J. effusus*, *J. acutifloris* and *J. articulatus*; Js) (Annex A). The first three were variants of the M15 *Scirpus cespitosus – Erica tetralix* wet heath community (Rodwell 1991). The Ns type resembled U5 *Nardus stricta – Galium saxatile* grassland (Rodwell 1992), with the Cn type intermediate between M15 and U5. The Js type resembled the M23 *Juncus effusus/acutiflorus – Galium palustre* rush pasture.

In the DCA of 2001 species cover data, the main gradient along axis 1 (eigenvalue 0.76, 13% of variation) was from the wet heath vegetation types to those associated more with mineral soils (Figure 1). There were only minor changes in overall plant species composition between 2001 and 2006. The main trends were in the Cv and Mc types in the paddocks with sheep plus cows. The Cv type tended to move towards the CvMc type and the Mc type towards the Cn and Ns types. The CvMc type also moved away from the Cv type in the LSC paddock. In the HS paddock, the CvMc, Cn and Ns types showed some trends towards *M. caerulea* but in the LS paddock there were only small changes.

Cover and Sward Height

M. caerulea cover declined significantly after introduction of cows in both mixed grazing paddocks (29 to 21% in LSC; 27 to 15% in HSC) (Table 4; Figure 2a). Significant interactions showed this occurred in the Mc and CvMc types only. In contrast, *M. caerulea* increased in both sheep only paddocks, from 2001 (24%) to 2003 (33%) in LS and from 2001-2003 (30%) to 2006 (43%) in HS. *C. vulgaris* cover in 2001 was 20-21% in the low sheep paddocks and 12-15% in the high sheep paddocks, suggesting it was already affected by the previous sheep grazing regimes. Trends in the sheep only paddocks were the reverse of *M. caerulea*. *C. vulgaris* showed a decreasing trend in LS between 2001 (21%) and 2003 (18%) (P=0.06) and in HS from 2001 (12%) to 2006 (8%). In the latter, this occurred only in the Cv and Cv/Mc vegetation types, where dead *C. vulgaris* increased ($F_{20,150.2}$=3.82, P<0.001), probably as a consequence of an earlier outbreak of heather beetle (*Lochmaea suturalis*). *C. vulgaris* also declined in both mixed grazing paddocks (just outside the limits of statistical significance in HSC; P=0.08). A significant interaction showed this was limited to the Cv and CvMc vegetation type in LSC where cover of dead *C. vulgaris* increased from 0-1% in 2001 to 11-12% in 2006 ($F_{20,127}$=4.30, P<0.001) as a result of trampling of older plants.

C. nigra showed significant temporal trends in all paddocks, which were consistent across vegetation types within each paddock. In all but LS, cover tended to decline from 2001 to 2004 but then recovered in 2005 and 2006. *N. stricta* showed converse temporal trends, being highest in 2004 in all but the HS paddock. Significant interactions showed this was confined to the Ns vegetation type in LS (40% in 2004, 26% min. in 2003) and HSC paddocks (55% in 2004, 41-42% in other years). *E. vaginatum* only varied temporally in the HS paddock, where it was marginally higher in 2003 and 2004. These three species appeared to reflect annual variation in rainfall and temperature (

Table 3). June-July air temperatures declined from 2001 to 2004 and then increased to 2006, while June-July rainfall was relatively high in 2004 (but also in 2001). *Juncus* spp. cover was lowest in 2004 in LS and LSC paddocks but only in the Ju type. In HSC, *Juncus* spp. cover increased between 2003 (10%) and 2006 (14%).

Moss cover increased after 2001 in both mixed grazing paddocks in the CvMc and Mc types. In HSC, there was a general trend upwards in all vegetation types but particularly in the Cn type. Plant litter cover in the sheep only paddocks was highest in 2006 and tended to be lowest in 2004. In contrast, in the mixed grazing paddocks, it was lowest in 2001 (1.2 and 0.2%) and highest in 2003 (8.0 and 6.6%) when cows were first introduced. This was primarily in the Mc, CvMc and Cv types but in HSC all other vegetation types also showed this trend. After 2003, the overall trend was for litter cover to decline (but not to 2001 level) and then gradually increase again. Data on bare peat and dung were too sparse for analysis but cover values tended to be higher in mixed grazing paddocks after introduction of cows.

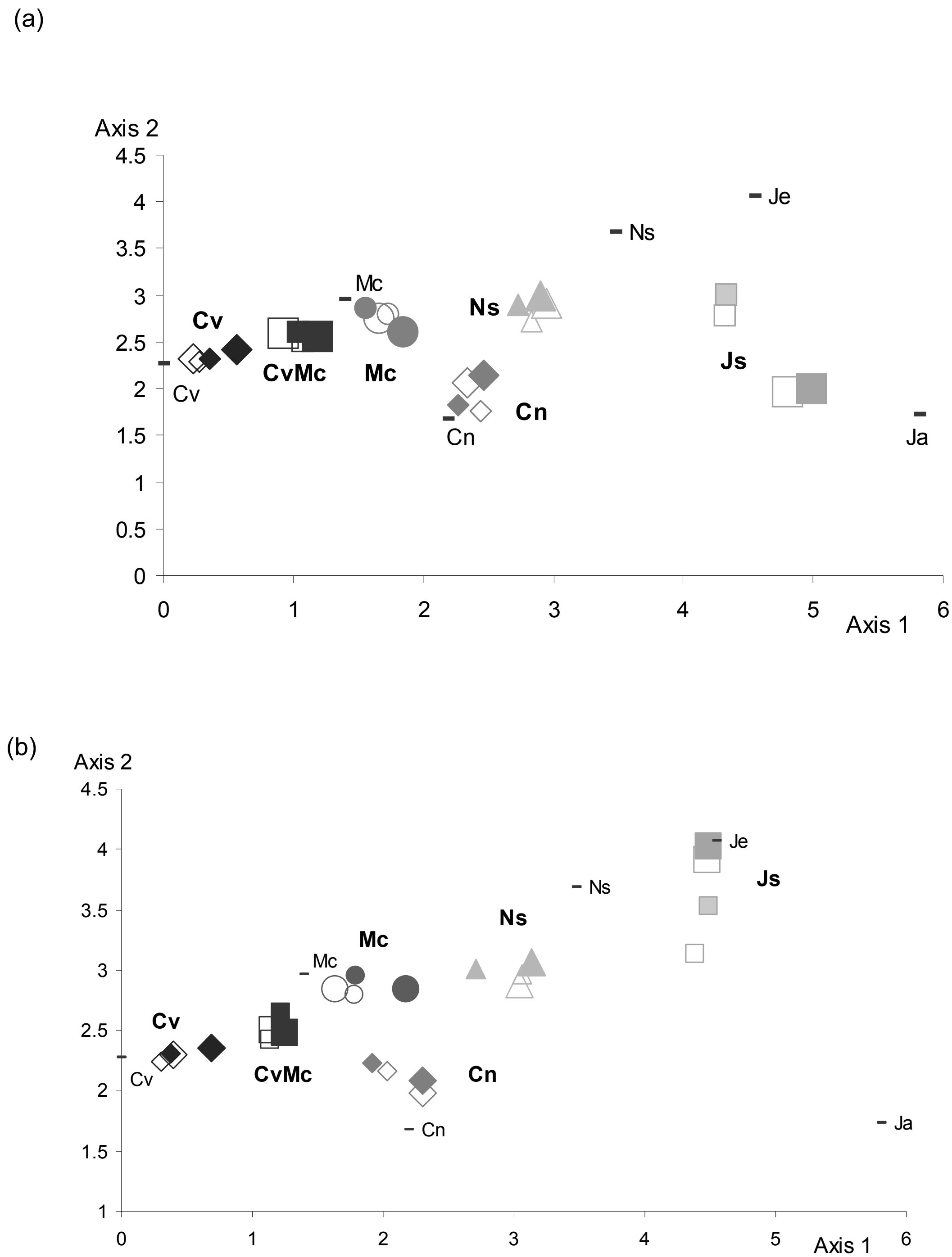

Figure 1 **DCA ordination of 2001 (open symbols) and 2006 (filled symbols) cover data showing mean axis 1 and 2 scores of vegetation types (codes as in text, in bold) and principle species (as vegetation codes, plus Je *Juncus effusus*, Ja *Juncus acutiflorus*). (a) LS (small symbols) and LSC (large symbols) paddocks, (b) HS (small symbols) and HSC (large symbols) paddocks**

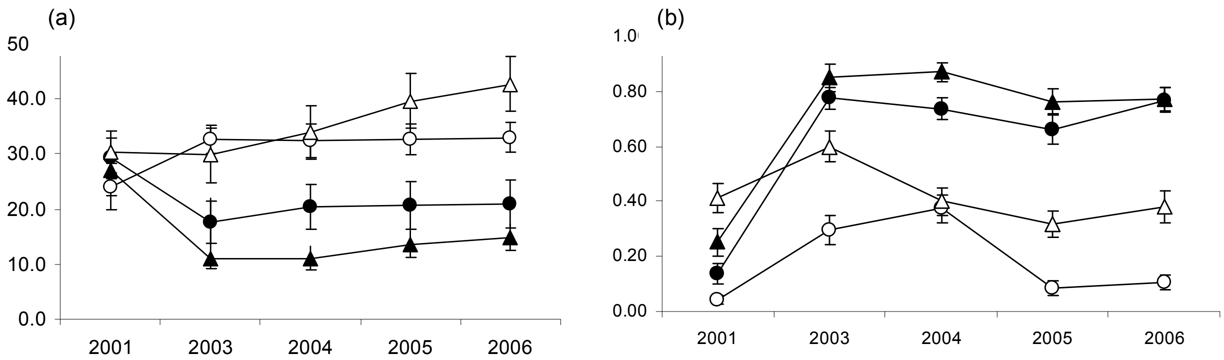

Figure 2 **Change in *M. caerulea* (a) total % cover and (b) grazing index in Cv, CvMc & Mc vegetation types 2001 - 2006 in LS (○), HS (△), LSC (●) and HSC (▲) paddocks (means, SEs)**

Sward height varied significantly among vegetation types in all paddocks. Ju was always tallest (*c.* 50cm) and Cn shortest (*c.* 20cm). Sward height increased over time, especially after 2001, in both sheep-only paddocks. Interactions showed the magnitude of increase varied among vegetation types; in LS it was less marked in the Cv type (where it was taller to begin with). In the mixed grazing paddocks, sward height in the Mc type declined in 2003 and then recovered but tended to increase overall in the other vegetation types.

Grazing Effects on C. vulgaris *and* M. caerulea

C. vulgaris was not recorded in the Ns or Ju types in HS or HSC paddocks. *C. vulgaris* frequency increased from 2003 in LS (in contrast with cover) and *C. vulgaris* grazing indices were very low, with no grazing recorded in LS in 2003 or 2005 (Table 5). A significant interaction for the index was attributable to grazing in the Mc type in 2006 but not 2004. No change was detected in frequency or grazing index in the HS paddock (where cover declined) but height of *C. vulgaris* increased between 2001 (23.1 ±1.64 cm) and 2005 (30.8 ±5.45 cm) ($F_{4,25}$=3.10, P<0.05). In the LSC paddock a downward trend in frequency (P=0.08) accompanied the reduction in cover and the index was higher in 2004 than other years. A significant interaction showed that frequency declined in the Cv type in HSC but no change in the index or height was detected. In all paddocks, *C. vulgaris* height was significantly less in the Mc type than the Cv or CvMc types (LS $F_{2,26}$=20.4; HS $F_{2,28}$=20.3; LSC $F_{2,27}$=25.3; HSC $F_{2,21}$=17.1; all P<0.001). The grazing index was highest in the Mc type in the LSC paddock ($F_{2,16}$=15.1, P<0.001) but no differences were detected in grazing levels on *C. vulgaris* between Cv, CvMc and Mc vegetation types in the other paddocks.

M. caerulea frequency increased in the CvMv type after 2001 in LS and the grazing index was significantly higher in 2003 (0.30) and 2004 (0.37) than in other years (0.04-0.10) (Figure 2b). Frequency also increased in HS, especially after 2004, although no change was detected in the index. These trends in frequency corresponded to the overall increases in cover in sheep only paddocks and contrasted with those in the mixed grazing paddocks. In LSC, frequency declined between 2003 and 2004. This was one year later than the change in cover. The grazing index increased substantially after introduction of cows, from 0.14 to 0.66-0.78 in following years. In HSC, the temporal trend in frequency was just outside the limits of statistical significance (P=0.054) and reflected the change in cover. As in LSC, the index increased when cows were introduced (from 0.25 to 0.76-0.87). In both mixed grazing paddocks, the *M. caerulea* grazing index was higher in the Mc type than the Cv type (LSC $F_{2,25}$=26.2, P<0.001; HSC $F_{2,16}$=10.3, P<0.01) but no differences were detected in the sheep-only paddocks.

Heather seedlings were counted in quadrats but were too sparse for analysis. Distribution of seedlings tended to be clumped but relatively few appeared to survive from one year to the next. Most were in mixed grazing paddocks (e.g. 52 and 43 in 2006 in LSC and HSC respectively) in Cv and CvMc types, i.e. where heather already most abundant. Only one was recorded in HS and not refound subsequently. More (25) were found in low sheep only in 2004, all in the CvMv vegetation type but they did not survive.

Table 4 **Mean (±SE) percentage cover of main species and vegetation variables and sward heights (cm) each year with *F* statistics from ANOVA in (a) LS, (b) LSC, (c) HS and (d) HSC paddocks. Untransformed data presented for clarity. * *P*<0.05, ** *P*<0.01, *** *P*<0.001**

(a) Low sheep (LS) (n = 48)

Variable	2001	2003	2004	2005	2006	Year $F_{4,39}$	Year x veg. type $F_{20,130.3}$
C. vulgaris	20.8 ±4.48	18.0 ±4.45	17.5 ±4.38	18.3 ±4.40	18.2 ±4.37	2.46 ns	0.56 ns
C. nigra	4.8 ±1.26	6.9 ±1.97	4.8 ±1.64	4.4 ±1.51	4.7 ±1.63	5.09 **	0.55 ns
E. vaginatum	6.3 ±1.69	6.6 ±1.85	8.5 ±2.43	7.2 ±2.10	6.2 ±1.81	1.00 ns	1.18 ns
Juncus spp.	9.0 ±3.42	9.5 ±3.75	8.5 ±3.57	8.9 ±3.62	9.5 ±3.88	2.89 *	2.55 ***
M. caerulea	24.0 ±3.87	32.8 ±4.98	32.3 ±4.91	32.6 ±4.95	33.0 ±4.90	4.08 **	0.89 ns
N. stricta	3.5 ±1.23	2.8 ±1.26	4.2 ±1.78	3.2 ±1.32	3.6 ±1.72	9.03 ***	2.38 **
All mosses	8.4 ±1.48	3.5 ±0.72	4.5 ±0.98	3.9 ±0.87	5.4 ±1.04	12.67 ***	1.28 ns
Plant litter	1.4 ±0.32	0.4 ±0.11	0.6 ±0.17	1.0 ±0.27	2.3 ±0.36	9.64 ***	1.16 ns
Height	22.9 ±1.68	36.2 ±2.48	39.0 ±2.67	41.9 ±2.68	37.2 ±2.29	55.6 ***	1.67 *

(b) Low sheep plus cows (LSC) (n = 47)

Variable	2001	2003	2004	2005	2006	Year $F_{4,38}$	Year x veg. type $F_{20,127.0}$
C. vulgaris	19.9 ±4.66	20.0 ±4.71	19.7 ±4.57	15.3 ±3.85	13.2 ±3.56	9.09 ***	2.53 ***
C. nigra	8.0 ±2.06	6.7 ±1.59	5.5 ±1.47	7.7 ±1.83	8.5 ±1.79	5.01 **	1.03 ns
E. vaginatum	1.7 ±0.77	1.8 ±0.73	2.3 ±1.09	2.5 ±1.04	3.3 ±1.15	1.91 ns	1.49 ns
Juncus spp.	7.4 ±3.03	6.3 ±2.41	5.3 ±2.08	8.5 ±3.57	7.5 ±3.02	8.17 ***	3.53 ***
M. caerulea	29.3 ±4.23	17.6 ±2.55	20.4 ±3.08	20.7 ±2.69	20.9 ±2.69	3.79 *	3.58 ***
N. stricta	4.5 ±1.45	4.9 ±1.63	6.4 ±1.90	5.5 ±1.73	5.3 ±1.65	3.73 *	1.28 ns
All mosses	6.9 ±1.23	8.7 ±1.34	9.3 ±1.37	8.8 ±1.20	10.4 ±1.18	3.00 ns	1.99 *
Plant litter	1.2 ±0.23	8.0 ±1.59	2.4 ±0.55	4.1 ±1.03	5.6 ±0.82	13.43 ***	1.76 *
Height	22.1 ±1.31	20.3 ±1.59	22.4 ±1.15	27.8 ±2.13	22.0 ±1.11	10.38 ***	3.87 ***

(c) High sheep (HS) (*n* = 54)

Variable	**2001**	**2003**	**2004**	**2005**	**2006**	**Year** $F_{4,45}$	**Year x veg. type** $F_{20,150.2}$
C. vulgaris	12.3 ±3.11	8.1 ±2.63	9.3 ±2.85	9.5 ±2.88	8.2 ±2.20	6.36 ***	3.35 ***
C. nigra	12.1 ±2.17	7.5 ±1.52	5.3 ±1.39	7.9 ±1.94	8.5 ±2.14	8.71 ***	1.29 ns
E. vaginatum	3.0 ±1.01	5.1 ±1.43	4.8 ±1.38	3.6 ±1.04	2.9 ±0.89	3.27 *	1.30 ns
Juncus spp.	11.0 ±3.02	12.0 ±3.32	11.9 ±3.35	12.2 ±3.62	12.4 ±3.51	0.44 ns	1.02 ns
M. caerulea	30.3 ±3.70	29.8 ±3.75	34.0 ±4.10	39.6 ±4.31	42.7 ±4.38	4.82 **	1.06 ns
N. stricta	6.3 ±1.81	6.9 ±2.24	6.1 ±1.94	5.4 ±1.89	5.7 ±1.92	2.14 ns	1.44 ns
All mosses	7.0 ±1.35	9.9 ±1.44	9.4 ±1.52	7.2 ±1.46	5.9 ±1.00	3.76 *	1.27 ns
Plant litter	0.8 ±0.16	0.9 ±0.29	0.2 ±0.07	1.0 ±0.18	2.9 ±0.46	11.07 ***	1.05 ns
Height	22.4 ±1.50	30.8 ±2.29	38.6 ±2.37	40.7 ±2.48	39.2 ±1.92	23.33 ***	1.78 *

(d) High sheep plus cows (HSC) (n = 47)

Variable	2001	2003	2004	2005	2006	Year $F_{4,38}$	Year x veg. type $F_{20,127.0}$
C. vulgaris	14.7 ±3.68	15.1 ±3.94	16.1 ±4.01	14.1 ±3.60	12.1 ±3.13	2.29 ns	1.32 ns
C. nigra	11.0 ±2.15	5.1 ±1.03	5.5 ±1.44	9.7 ±1.82	10.7 ±2.06	11.30 ***	1.65 ns
E. vaginatum	2.8 ±0.85	3.4 ±1.30	3.5 ±1.52	3.2 ±1.05	3.0 ±0.91	0.16 ns	0.93 ns
Juncus spp.	11.2 ±4.12	10.2 ±3.94	11.9 ±4.11	12.4 ±4.13	13.9 ±4.26	4.74 **	1.37 ns
M. caerulea	27.1 ±4.51	11.0 ±1.86	11.1 ±2.10	13.6 ±2.35	14.9 ±2.45	15.26 ***	3.72 ***
N. stricta	10.1 ±2.67	10.6 ±2.78	13.4 ±3.61	10.1 ±2.72	10.3 ±2.87	2.59 ns	3.00 ***
All mosses	4.4 ±1.13	13.1 ±2.03	12.0 ±1.93	11.3 ±1.81	11.0 ±1.80	12.57 ***	2.15 **
Plant litter	0.2 ±0.06	6.6 ±1.25	3.6 ±0.71	4.1 ±0.81	4.7 ±0.82	20.40 ***	2.09 **
Height	26.7 ±2.24	22.5 ±2.39	26.7 ±2.88	29.0 ±2.92	28.9 ±2.54	6.80 ***	2.14 **

Table 5 **Mean (±SE) local frequency of *C. vulgaris* and *M. caerulea* and grazing index for types Cv, CvMc and Mc each year with *F* statistics from ANOVA in (a) LS, (b) LSC, (c) HS and (d) HSC paddocks. Untransformed data presented for clarity. * *P*<0.05, ** *P*<0.01, *** *P*<0.001**

(a) Low sheep (LS)

	2001	**2003**	**2004**	**2005**	**2006**	**d.f.**	**Year**	**d.f.**	**Year x veg. type**
C. vulgaris									
Frequency	-	22.6±5.20	24.4±5.24	26.6±5.40	26.8±5.34	3,40	4.97 **	15,110.8	1.22 ns
Grazing	-	0.00	0.05±0.024	0.00	0.02±0.011	1,16	2.07 ns	2,16	4.26 *
M. caerulea									
Frequency	38.1±5.78	42.1±6.13	42.2±6.02	42.9±6.11	42.4±6.10	4,39	2.02 ns	20,130.3	1.82 *
Grazing	0.04±0.017	0.30±0.054	0.37±0.051	0.09±0.026	0.10±0.026	4,17	18.9 ***	8,34	1.61 ns

(b) Low sheep plus cows (LSC)

	2001	2003	2004	2005	2006	d.f.	Year	d.f.	Year x veg. type
C. vulgaris									
Frequency	-	27.0±5.71	24.9±5.33	24.4±5.25	23.1±5.07	3,39	2.24 ns	15,108.1	1.55 ns
Grazing	-	0.13±0.057	0.28±0.062	0.13±0.062	0.21±0.063	3,14	10.07 ***	6,28	1.53 ns
M. caerulea									
Frequency	53.0±5.95	51.6±5.68	48.2±5.51	49.4±5.56	52.9±5.74	4,37	7.62 ***	20,123.7	1.44 ns
Grazing	0.14±0.037	0.78±0.040	0.74±0.040	0.66±0.055	0.77±0.045	4,22	89.66 ***	8,44	0.66 ns

(c) High sheep (HS)

	2001	2003	2004	2005	2006	d.f.	Year	d.f.	Year x veg. type
C. vulgaris									
Frequency	-	14.8±3.76	15.3±3.71	16.4±3.88	16.8±3.95	3,31	0.62 ns	9,75.6	1.63 ns
Grazing	-	0.22±0.072	0.23±0.073	0.24±0.060	0.25±0.056	3,12	0.09 ns	6,24	0.56 ns
M. caerulea									
Frequency	54.6±5.36	53.6±5.27	53.3±5.30	56.7±5.42	57.4±5.37	4,45	4.69 **	20,150.2	0.64 ns
Grazing	0.41±0.053	0.60±0.056	0.40±0.050	0.32±0.047	0.38±0.059	4,22	1.80 ns	8,44	1.66 ns

(d) High sheep plus cows (HSC)

	2001	2003	2004	2005	2006	d.f.	Year	d.f.	Year x veg. type
C. vulgaris									
Frequency	-	22.4±5.20	22.2±5.02	21.8±5.09	21.6±4.77	3,26	2.90 ns	9,63.4	3.05 **
Grazing	-	0.27±0.087	0.22±0.069	0.14±0.044	0.18±0.056	3,10	1.94 ns	6,20	2.46 ns
M. caerulea									
Frequency	39.7±5.80	36.5±5.45	37.3±5.54	37.4±5.76	39.8±5.76	4,37	2.57 ns	20,123.7	1.13 ns
Grazing	0.25±0.052	0.85±0.050	0.87±0.035	0.76±0.046	0.77±0.042	4,13	40.12 ***	8,26	1.83 ns

Livestock Performance

Cattle Performance

Daily liveweight changes (DLC; kg day^{-1}) were calculated for cattle based on weights at turn out and removal, and number of days grazing in the paddocks (Table 6). There was a significant effect of paddock ($P<0.05$) on cow performance and a small but significant interaction between paddock and year ($P<0.05$). With the exception of 2005, cattle from the HSC paddock had lower DLC than cattle on the LSC paddock. Cattle DLC in the HSC paddock was decreased by an average of 0.24 kg day^{-1} weight change. There was considerable variation between years and in 2006, cattle in the LSC paddock had DLC of 1.19 kg day^{-1} compared to those on the HSC with a DLC of 0.64 kg day^{-1}.

Table 6 Daily liveweight changes (kg day^{-1}) of mature, dry, crossbred cows. No of days grazing in parentheses; * $P<0.05$, ns = not significant

	2003 (64)	**2004** (68)	**2005** (42)	**2006** (28)	**Treat mean**	**SED**	**Treat X year SED**
LSC	0.84	0.81	0.70	1.19	0.88	0.104*	0.208*
HSC	0.69	0.61	0.76	0.64	0.67		
Year mean	0.76	0.71	0.73	0.92		0.147 ns	

Ewe Performance

Liveweight and body condition score at tupping for adult ewes were used as performance indicators (Table 7). There were significant differences between paddocks ($P<0.001$) and between years ($P<0.001$) but no significant paddock X year interaction ($P>0.05$). Sheep stocking rate had a significant effect on ewe tupping weight in all years with an average reduction of about 6 kg per ewe from the higher stocking rate. Differences between mixed grazing and sheep only paddocks were small overall but there were indications that ewe performance was improving with time when grazing with cattle. Condition scores did not differ significantly between paddocks ($P>0.05$) but there was a trend for higher scores in the paddocks with lower stocking rates (group means 2.88, 2.89, 2.70 and 2.70 for LS, LSC, HS and HSC respectively). Paddock effects on liveweight and condition score were still apparent at subsequent scanning (52.7, 52.2, 47.8, 48.3kg ($P<0.001$) and 2.64, 2.67, 2.46, 2.48 ($P<0.05$) respectively).

Table 7 Ewe tupping weights (kg) during 2003-2006. *** $P<0.001$; ns = not significant; means with same letter not significantly different

	2003	2004	2005	2006	Treat mean	SED	Treat X year SED
LS	55.6_{def}	56.0_{def}	57.8_{fg}	60.9_{g}	57.6	0.68***	1.35 ns
LSC	53.9_{cde}	56.3_{ef}	58.6_{fg}	61.4_{g}	57.5		
HS	49.6_{ab}	51.7_{ac}	52.6_{acd}	53.1_{bcde}	51.8		
HSC	49.4_{a}	50.9_{ac}	53.0_{acde}	53.9_{cde}	51.8		
Year mean	52.1	53.7	55.5	57.3		0.68***	

Lamb Performance

There were no significant paddock effects on lamb birth weight (4.11, 4.00, 4.01, 4.17 kg) or lambing percentage (119, 131,121 and 119 lambs per 100 ewes) for paddocks LS, LSC, HS and HSC respectively.

Lambs were weaned at an average of 127 days. Weaning weights (Table 8) were significantly higher for lambs from the paddocks with lower sheep stocking rates whether cattle were present or not. Growth rates from birth to weaning were 236, 222, 208 and 211g day^{-1} for paddocks LS, LSC, HS and HSC respectively ($P<0.001$). Daily liveweight gain from birth to marking at an average 25 days of age (361, 336, 316 and 299 g day^{-1} respectively; $P<0.001$) suggested that much of this difference was due to increased milk yields of ewes. The inclusion of cattle had little effect on lamb performance with the exception of 2006 when there was an apparent reduction in performance when grazing at the lower stocking rate.

Table 8 Lamb weaning weights (kg) with age of weaning (days) in parentheses. * *P*<0.001; ns = not significant; means with same letter not significantly different**

	2004 (118)	**2005** (132)	**2006** (129)	**Treat mean** (127)	**SED**	**Treat X year SED**
LS	33.3_{def}	34.0_{ef}	34.7_{f}	34.0	0.67***	1.15 ns
LSC	33.0_{cdef}	34.0_{ef}	30.8_{abc}	32.6		
HS	28.7_{a}	31.5_{bcd}	30.0_{ab}	30.1		
HSC	29.2_{a}	32.2_{bcde}	30.8_{abc}	30.7		
Year mean	31.1	32.9	31.6		0.58***	

DISCUSSION

Vegetation dynamics

The most notable effect was the increase in grazing of *M. caerulea* and the reduction in its cover immediately after cows were introduced to the mixed grazing paddocks. This resulted in exposure of the litter and moss layer. Once exposed, the thick litter layer disintegrated but then gradually built up again slightly, following a partial recovery of *M. caerulea* that might have resulted from the shorter period of grazing by cows in 2005 and 2006. Differences among vegetation types in grazing indices showed that cows grazed *M. caerulea* and reduced its cover most where it was dominant or co-dominant in the sward. Localised interactions between herbivores and vegetation commonly occur on upland heathland (Palmer et al., 2003) and selective grazing of *M. caerulea* by cows has been reported in hill grasslands (Common et al., 1997; Grant et al., 1996) and blanket bog and heather moor (Grant et al., 1987). Grant et al. (1996) showed that at 33% utilisation rates, *M. caerulea* was retained in the sward but it declined at 66% utilisation. Using the equivalence of 33% utilisation at lamina lengths 10-12 cm and 66% at 5-6 cm

(Common et al., 1997), this suggests overall utilisation of *M. caerulea* of around 33% in the LSC paddock and slightly higher in the HSC paddock. Given that grazing intensity varied among vegetation types, it is probable that utilisation exceeded 33% in the Mc and CvMc types, suggesting that grazing levels in both mixed grazing paddocks could have been high enough to reduce *M. caerulea* in the longer-term. However, this assumes that the tolerance of *M. caerulea* to grazing is similar in wet heath and hill grassland. In the current study, sheep were also present during the remainder of the year (unlike the studies on hill grassland) but would have little direct effect on *M. caerulea* during autumn and winter when its leaves had senesced.

M. caerulea grazing indices were higher than those of *C. vulgaris* in all paddocks, indicating that it was grazed preferentially in summer by both sheep and cows. Grazing of *C. vulgaris* in the mixed grazing paddocks would be attributable primarily to sheep because cows were removed at the first signs of their feeding on *C. vulgaris*. *M. caerulea*, along with other grasses and sedges, is also preferred to *C. vulgaris* by both sheep and cows in blanket bog and heather moorland (Grant et al., 1987). However in the current study, sheep grazing, even at the higher stocking rate, did not reduce *M. caerulea* cover or frequency. Sheep grazing was often manifest as frequent but widely dispersed grazed shoots, in contrast to cows, which removed shoots uniformly across a grazed patch.

Despite the reduction in *M. caerulea* in the mixed grazing paddocks, there was no evidence that *C. vulgaris* or any other species were increasing. The DCA results suggested that the species composition of some vegetation types was becoming less characteristic of heathland. Cows can damage *C. vulgaris* by removing large quantities of live and dead shoots (Grant et al., 1987) but in this study it was avoided by removing cattle before damage could occur. Therefore, despite suitable conditions having been created under mixed grazing regimes, there was no evidence that the desired restoration of heathland vegetation was taking place over the four-year period. Restoration probably requires much longer timescales; for example heathland restoration by grazing exclusion was only partially successful at a number sites over periods of up to 13 years (Littlewood et al., 2006). Cows also affect moorland vegetation by trampling and dunging (Welch & Scott, 1995). In this study, the reduction of *C. vulgaris* in the LSC paddock was attributable to localised trampling of older *C. vulgaris*, as revealed by grazing indices and records of dead *C. vulgaris*. However, disturbance by trampling could also stimulate regeneration from seed (Marrs et al., 2004). *C. vulgaris* was present in the seedbank at this site (R.J. Mitchell, unpublished data) but the few *C. vulgaris* seedlings found were concentrated in areas with established parent plants. More positive measures such as mechanical disturbance and seed addition can also aid restoration (Marrs et al., 2004; Mitchell et al., in prep.) although success rates on a large scale are variable (Littlewood et al., 2006).

In the HS paddock, the increase in *M. caerulea* was accompanied by a decline in *C. vulgaris* cover. Despite this, *C. vulgaris* was becoming taller, suggesting light competition between the two species. This contrasts with other studies where *C. vulgaris* relative frequency increased slightly at a similar site with 1.4 sheep ha^{-1} $annum^{-1}$ (Hulme et al., 2002) and its utilisation declined and frequency increased at stocking densities up to 1.9 sheep ha^{-1} $annum^{-1}$ in dry heathland (Pakeman et al., 2003). Part of the *C. vulgaris* decline in the HS paddock was attributed to the earlier outbreak of heather beetle. This also illustrates the frequently reported variability in response among sites (e.g. Welch & Scott, 1995; Vandvik et al., 2005).

C. vulgaris was spreading slowly in the LS paddock (frequency increased), despite the increase in *M. caerulea*. Grazing levels were very low in the Cv, CvMc and Mc vegetation types, sheep tending to graze elsewhere on more palatable grasses. Heathland vegetation can recover from heavy grazing by reducing sheep stocking densities to low levels (Hulme et al., 2002; Pakeman et al., 2003) or by complete cessation of grazing (Hope et al., 1996) as long as the component species are still present.

Only minor changes were detected in the Cn, Ns or Ju vegetation types. Some changes might have been expected in the paddocks where cows were introduced, because cows eat more *N. stricta* than sheep (Common et al., 1998) and ingest sedges and rushes in *M. caerulea* grassland (Common et al., 1997). This suggests that there was sufficient forage for cows in the preferred Mc and CvMc vegetation types. *N. stricta* cover appeared to respond to high rainfall and cooler temperatures, *E. vaginatum* to cooler temperatures and *C. nigra* to higher temperatures. In contrast, annual variation in *N. stricta* biomass was related to higher temperatures across England and Wales (Milne et al., 2002). These variations in temperature and rainfall might therefore account for some annual variation although the exact relationships are not well established. *Juncus* spp. increased in the HSC paddock, possibly as a result of localised disturbance from trampling, since viable seed of *Juncus* spp. (including *J. effusus*) occurs in the seedbank of upland habitats (Miller & Cummins, 2003). Invasion by *Juncus* spp. on a large scale would be undesirable although here the increase was relatively small.

Livestock performance

For the initial two years, the swards were sufficient to sustain the cattle for the two month grazing period. During their time on the heathland, cows gained an average in excess of 0.70 kg day^{-1}, which would have been sufficient to allow animals to regain their body condition prior to calving. Fraser et al. (2007) also reported satisfactory performance of Limousin-cross suckler cows grazed on *M. caerulea* grassland at 0.5 cows ha^{-1} during June to mid-August. However, in the current study vegetation biomass, and *M. caerulea* in particular, was decreasing each year. By year 3, (2005) cattle started to graze *C. vulgaris* after only 42 days on the HSC paddock and were removed. In year 4 (2006) cattle were only sustained for 28 days. This has major implications for cattle grazing of upland wet heathland as cattle would need to be relocated after very short grazing periods to prevent damage to dwarf shrubs, or applied at lower stocking rates, which may negate potentially beneficial sward impacts. The findings would tend to support the need for intermittent cattle grazing of every 3 to 5 years. Cattle DLC was lower in the paddock with the higher sheep stocking rate, particularly in 2006 when cattle had substantially reduced number of grazing days compared to other years. If sustained, the lower weight gain from the HSC paddock would require a change of management to ensure cows regained their body weight by the time of subsequent calving.

This could be achieved by providing supplementary feed in late pregnancy but would have financial implications.

As might be expected, there was improved performance in terms of ewe weights and condition at both tupping and at scanning in paddocks with lower sheep stocking rates. The trends observed were in general agreement with previous work (Davies et al., 2000; Merrell et al., 2001). At tupping, ewes from the lower stocking rate paddocks were about 6 kg heavier and there was some indication that condition scores were higher than those from the higher stocking rate paddocks (2.7 vs 2.9). The target condition score for hill ewes is 2.5 to 3.0 (Henderson, 1995) and hence all groups were well within this target. This might explain why no differences were seen in lambing percentages, although ewe numbers were rather low to detect these effects. Lamb performance was significantly improved at the lower sheep stocking rate. The improvement in the first few weeks of life indicated a response in milk production in the ewe, and the extra weight gain at weaning would have helped to offset the financial impact of reducing stocking rates. The addition of cattle at either stocking rate appeared to have little effect on lamb performance, which suggests that the two species were not competing for feed but were consuming different vegetation. Cattle showed a preference for *M. caerulea* whilst sheep preferred fine grasses. This suggests that agri-environment schemes should avoid prescribing stocking levels in livestock units ha^{-1} regardless of livestock species.

CONCLUSIONS

The vegetation responses cannot be attributed unequivocally to the stocking regimes imposed because it was not practicable to replicate treatments at the system scale. However, the effect on *M. caerulea* by cows in the mixed grazing paddocks was very apparent. Similarly, livestock performance in each paddock might not have been attributable to the stocking regime but to the prevailing environment in each paddock. However, care was taken to ensure that each paddock had comparable areas of each vegetation type and a similar altitudinal range and aspect. The study showed that cows can be used in mixed grazing systems with sheep for short-term reduction in *M. caerulea* above-ground biomass in degraded wet heathland. Sheep-only regimes did not reduce *M. caerulea*. There was no evidence that wet heathland vegetation was being restored after four years, despite suitable conditions being created in the mixed grazing paddocks. Restoration might be achieved by mixed grazing over longer timescales if plant propagules are present. At the stocking densities used in this study, cows can only be grazed for short periods and both cow and sheep performance appeared to be affected by sheep stocking density. Cows preferred areas with abundant *M. caerulea* so sites with less *M. caerulea* are likely to support fewer cows. It is necessary to monitor grazing effects on the vegetation and remove cows when *C. vulgaris* is being browsed. At the farm scale therefore, alternative foraging areas will be required for the rest of the year.

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ANNEX A SPECIES RECORDED IN THE SIX VEGETATION TYPES

Data are species top cover from 2001 with additional species present in quadrats also listed (P). Additional cover accounted for by plant litter, bare peat and dung. Species with 3% cover or more in bold. Vegetation types: Cv *Calluna vulgaris*; Cv-Mc *Calluna vulgaris – Molinia caerulea*; Mc *Molinia caerulea*; Cn *Carex nigra*; Ns *Nardus stricta*; Ju *Juncus* spp.

CV		CvMc		Mc		Cn		Ns		Ju	
Calluna vulgaris	**73.3**	Molinia caerulea	**39.1**	Molinia caerulea	**62.9**	Carex nigra	**30.1**	Nardus stricta	**30.0**	Juncus effusus	**49.3**
Molinia caerulea	**8.0**	Calluna vulgaris	**27.9**	Deschampsia flexuosa	**6.3**	Deschampsia flexuosa	**9.6**	Molinia caerulea	**13.8**	Juncus acutiflorus/articulatus	**15.1**
Eriophorum vaginatum	**7.1**	Eriophorum vaginatum	**9.0**	Carex nigra	**5.1**	Molinia caerulea	**8.9**	Juncus effusus	**10.4**	Agrostis sp.	**6.9**
Carex nigra	2.2	Carex nigra	**7.8**	Polytrichum commune	**3.9**	Polytrichum commune	**7.4**	Carex nigra	**9.8**	Agrostis capillaris	**4.0**
Deschampsia flexuosa	2.0	Deschampsia flexuosa	**3.6**	Nardus stricta	2.7	Agrostis sp.	**6.4**	Festuca ovina	**5.7**	Deschampsia cespitosa	**4.0**
Eriophorum angustifolium	1.4	Polytrichum commune	**3.0**	Festuca ovina	2.6	Agrostis capillaris	**5.7**	Agrostis sp.	**4.9**	Nardus stricta	**3.9**
Polytrichum commune	1.0	Vaccinium myrtillus	1.2	Calluna vulgaris	2.2	Anthoxanthum odoratum	**4.5**	Deschampsia flexuosa	**4.8**	Anthoxanthum odoratum	**3.3**
Festuca ovina	0.9	Sphagnum recurvum	0.6	Scirpus cespitosus	1.7	Rhytidiadelphus squarrosus	**4.4**	Anthoxanthum odoratum	**4.7**	Agrostis canina	2.1
Pleurozium schreberi	0.5	Anthoxanthum odoratum	0.5	Rhytidiadelphus squarrosus	1.4	Calluna vulgaris	**3.6**	Juncus squarrosus	2.7	Rhytidiadelphus squarrosus	1.9
Hylocomium splendens	0.5	Sphagnum palustre	0.5	Juncus squarrosus	1.3	Nardus stricta	**3.3**	Agrostis capillaris	2.6	Polytrichum commune	1.7
Sphagnum recurvum	0.3	Festuca ovina	0.5	Eriophorum vaginatum	1.1	Eriophorum vaginatum	**3.3**	Galium saxatile	2.5	Poa trivialis	1.3
Vaccinium myrtillus	0.3	Pleurozium schreberi	0.5	Pleurozium schreberi	1.1	Galium saxatile	**3.3**	Polytrichum commune	1.9	Festuca rubra	1.2
Scirpus cespitosus	0.2	Eriophorum angustifolium	0.5	Juncus effusus	0.8	Festuca ovina	**3.0**	Potentilla erecta	1.8	Deschampsia flexuosa	1.2
Rhytidiadelphus squarrosus	0.2	Galium saxatile	0.4	Galium saxatile	0.7	Juncus squarrosus	2.8	Rhytidiadelphus squarrosus	1.7	Festuca ovina	1.2
Potentilla erecta	0.2	Potentilla erecta	0.4	Sphagnum palustre	0.7	Pleurozium schreberi	1.1	Agrostis sp.	1.3	Holcus sp.	1.1
Hypnum jutlandicum	0.2	Rhytidiadelphus	0.3	Erica tetralix	0.6	Erica tetralix	0.7	Agrostis canina	1.0	Poa	1.0

CV		**CvMc**		**Mc**		**Cn**		**Ns**		**Ju**	
		squarrosus								pratensis/subcaerulea	
Juncus effusus	0.1	Erica tetralix	0.2	Potentilla erecta	0.6	Eriophorum angustifolium	0.7	Pleurozium schreberi	0.5	Sphagnum palustre	0.8
Sphagnum capillifolium	0.1	Agrostis capillaris	0.2	Anthoxanthum odoratum	0.6	Sphagnum recurvum	0.6	Scirpus cespitosus	0.5	Galium saxatile	0.7
Sphagnum palustre	0.1	Agrostis sp.	0.2	Eriophorum angustifolium	0.4	Luzula campestris	0.6	Carex sp.	0.4	Agrostis sp.	0.7
Aulacomnium palustre	0.1	Juncus squarrosus	0.1	Sphagnum recurvum	0.3	Potentilla erecta	0.4	Luzula campestris	0.4	Poa annua	0.6
Plagiothecium undulatum	0.1	Scirpus cespitosus	0.1	Vaccinium myrtillus	0.2	Agrostis sp.	0.4	Carex panicea	0.4	Potentilla erecta	0.6
Agrostis sp.	<0.1	Sphagnum capillifolium	0.1	Agrostis sp.	0.2	Poa pratensis/subcaerulea	0.3	Holcus sp.	0.3	Carex nigra	0.5
Anthoxanthum odoratum	<0.1	Hypnum jutlandicum	0.1	Juncus acutiflorus/articulatus	0.1	Agrostis canina	0.3	Calluna vulgaris	0.2	Juncus squarrosus	0.5
Galium saxatile	<0.1	Luzula campestris	0.1	Hypnum jutlandicum	0.1	Empetrum nigrum	0.3	Hypnum jutlandicum	0.2	Trifolium repens	0.4
Nardus stricta	<0.1	Nardus stricta	<0.1	Sphagnum capillifolium	0.1	Hypnum jutlandicum	0.2	Deschampsia cespitosa	0.2	Carex panicea	0.3
Erica tetralix	<0.1	Dicranella heteromalla	<0.1	Hylocomium splendens	0.1	Aulacomnium palustre	0.2	Festuca rubra	0.1	Molinia caerulea	0.3
Rhytidiadelphus loreus	<0.1	Empetrum nigrum	<0.1	Agrostis capillaris	0.1	Vaccinium myrtillus	0.1	Juncus acutiflorus/articulatus	0.1	Carex pilulifera	0.3
Dicranum scoparium	<0.1	Hylocomium splendens	<0.1	Empetrum nigrum	0.1	Scirpus cespitosus	0.1	Poa pratensis/subcaerulea	0.1	Carex sp.	0.2
Agrostis canina	<0.1	Juncus effusus	<0.1	Agrostis canina	0.1	Cerastium fontanum	0.1	Eriophorum angustifolium	0.1	Dryopteris dilatata	0.2
Agrostis capillaris	P	Plagiothecium undulatum	<0.1	Aulacomnium palustre	0.1	Rumex acetosella	0.1	Poa annua	0.1	Pleurozium schreberi	0.1
Bromus sp.	P	Juncus acutiflorus/articulatus	P	Luzula campestris	0.1	Carex sp.	0.1	Hylocomium splendens	0.1	Rumex acetosa	0.1
Cynosurus cristatus	P	Luzula sylvatica	P	Agrostis sp.	<0.1	Stellaria alsine	<0.1	Pseudoscleropodium purum	<0.1	Cynosurus cristatus	0.1
Deschampsia cespitosa	P	Pseudoscleropodium purum	P	Plagiothecium undulatum	<0.1	Rhytidiadelphus loreus	<0.1	Bromus sp.	<0.1	Pseudoscleropodium purum	0.1

CV		**CvMc**		**Mc**		**Cn**		**Ns**		**Ju**	
Empetrum nigrum	P	Ranunculus repens	P	Rhytidiadelphus loreus	<0.1	Poa annua	<0.1	Cynosurus cristatus	<0.1	Stellaria alsine	0.1
Festuca rubra	P	Rhytidiadelphus loreus	P	Dicranum sp.	<0.1	Poa trivialis	<0.1	Empetrum nigrum	<0.1	Agrostis stolonifera	0.1
Holcus sp.	P	Rumex acetosella	P	Luzula sylvatica	P	Hylocomium splendens	<0.1	Aulacomnium palustre	<0.1	Cerastium fontanum	0.1
Juncus acutiflorus/articulatus	P	Rumex acetosa	P	Pseudoscleropodium purum	P	Luzula sylvatica	P	Cirsium palustre	<0.1	Cirsium sp.	0.1
Luzula sylvatica	P	Stellaria alsine	P	Ranunculus repens	P	Trifolium repens	P	Dicranum scoparium	<0.1	Luzula campestris	0.1
Poa annua	P	Taraxacum officinale	P	Rumex acetosella	P	Thuidium tamariscinum	P	Ranunculus acris	<0.1	Luzula sylvatica	<0.1
Poa pratensis/subcaerulea	P	Thuidium tamariscinum	P	Rumex acetosa	P	Taraxacum officinale	P	Eriophorum vaginatum	P	Ranunculus repens	<0.1
Pseudoscleropodium purum	P	Trifolium repens	P	Stellaria alsine	P	Sphagnum palustre	P	Luzula sylvatica	P	Taraxacum officinale	<0.1
Ranunculus repens	P	Bromus sp.	P	Taraxacum officinale	P	Sphagnum capillifolium	P	Rhytidiadelphus loreus	P	Thuidium tamariscinum	<0.1
Rumex acetosella	P	Cynosurus cristatus	P	Thuidium tamariscinum	P	Rumex acetosa	P	Sphagnum capillifolium	P	Cardamine pratensis	<0.1
Rumex acetosa	P	Deschampsia cespitosa	P	Trifolium repens	P	Ranunculus repens	P	Sphagnum palustre	P	Cirsium palustre	<0.1
Stellaria alsine	P	Festuca rubra	P	Bromus sp.	P	Pseudoscleropodium purum	P	Sphagnum recurvum	P	Ranunculus acris	<0.1
Taraxacum officinale	P	Holcus sp.	P	Cynosurus cristatus	P	Juncus acutiflorus/articulatus	P	Thuidium tamariscinum	P	Eriophorum vaginatum	P
Thuidium tamariscinum	P	Poa annua	P	Deschampsia cespitosa	P	Holcus sp.	P	Ranunculus repens	P	Bromus sp.	P
Trifolium repens	P	Poa pratensis/subcaerulea	P	Festuca rubra	P	Festuca rubra	P	Rumex acetosella	P	Rhytidiadelphus loreus	P
Dicranella heteromalla	P			Holcus sp.	P	Deschampsia cespitosa	P	Rumex acetosa	P	Rumex acetosella	P
Dicranum sp.	P			Poa annua	P	Cynosurus cristatus	P	Stellaria alsine	P	Sphagnum capillifolium	P
Juncus squarrosus	P			Poa pratensis/subcaerulea	P	Bromus sp.	P	Taraxacum officinale	P	Sphagnum recurvum	P
Luzula campestris	P							Trifolium repens	P	Empetrum nigrum	P
								Erica tetralix	P	Erica tetralix	P
								Vaccinium myrtillus	P	Vaccinium myrtillus	P