APPENDIX 4A.1

PWLLPEIRAN SYSTEM STUDY

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ABSTRACT

Increases in sheep numbers in the UK uplands have resulted in degradation of semi-natural heathlands, with replacement of dwarf shrubs by grasses such as *Nardus stricta*. Altered grazing regimes to restore vegetation will need to be economically viable. This study assessed the effects on vegetation and livestock performance of four grazing regimes (1.0 or 1.5 ewes ha^{-1} for 10 months per year, cattle at 0.5 heifers ha^{-1} for 2 months in summer and 0.5 ewes ha^{-1} plus cattle) in a 71 ha replicated plot experiment on a *N. stricta* grassland during 2003-2006. There was a small grazing treatment effect on the overall plant community but no significant effects on cover or frequency of any individual species except *Molinia caerulea*, which was scarce in the sward but selectively grazed by cattle. Significant year effects suggested that annual variation in productivity influenced grazing intensity on *N. stricta*, which declined overall in 2006. *Vaccinium myrtillus* was grazed widely by sheep and cattle but its cover and frequency did not change. *Calluna vulgaris* was scarce in the sward and not heavily grazed. Daily liveweight gain of cattle was inadequate to achieve adequate condition to calve at 2 years of age and tended to be lower in the mixed than cattle only treatment. Ewe and lamb performance did not differ significantly between treatments but tended to be better at the lower stocking rate, and with lamb performance tending to improve over time especially in the mixed grazing treatment. The study showed that cattle could be grazed for short periods in addition to sheep with potentially beneficial effects for livestock performance but at additional costs to compensate for reduced cattle growth rates. Results would need to be confirmed over a longer period of time and the desired change in vegetation will also take longer to achieve.

INTRODUCTION

Semi-natural plant communities in the uplands of the UK provide significant grazing for domestic stock and are of international importance in terms of their ecological and environmental value. Economic pressures, agricultural subsidies and the introduction of the Less Favoured Areas Directive in 1975 resulted in major increases in the numbers of sheep being kept in upland areas. As a result, semi-natural plant communities became overgrazed with a decline in the quality and quantity of dwarf shrubs such as *Calluna vulgaris* (Felton & Marsden, 1990; Bardgett et al., 1995; Tudor & Mackey, 1995). Where dwarf shrubs declined, they have often been replaced by grasses including *Nardus stricta*, *Agrostis capillaris* and *Festuca ovina* (Welch & Scott, 1995). The increase in *N. stricta* has also been attributed to the replacement of wether sheep by ewes (Grant et al., 1985). The objectives of implementing reduced stocking rates as part of agri-environment scheme prescriptions were to stop this decline, and under even lower stocking rates to enhance dwarf shrub heath. A number of studies have been carried out which investigated the impact of reducing sheep numbers on vegetation change (Hill et al., 1992; Anderson & Radford, 1994; Nolan et al., 1995; Hulme et al., 2002) as well as studies investigating animal performance on semi-natural vegetation (Griffiths et al., 1997; Common et al., 1998; Davies et al., 2000; Merrell et al., 2001). Cattle consume more *N. stricta* than sheep and could be beneficial in restoring *N. stricta* dominated swards (Common et al., 1998). However, the effects on both vegetation and the physical and financial performance of extensive grazing systems using sheep and cattle alone or together in mixed grazing systems has not been studied.

This paper reports on a study to investigate the impact of different grazing regimes on vegetation and animal performance on *N. stricta* dominated swards.

METHODS

Study Site and Grazing Regimes

The 4 year study was sited on 71 ha of *N. stricta* grassland at an elevation of 305-625 m above sea level, with annual rainfall well in excess of 2000 mm, on the Cambrian Mountains in Mid Wales. Soils consisted of Stagnopodzols with peaty top soils of the Hiraethog and Hafren series, or shallow soils of the Powys series with bedrock at 30 cm. The site had been part of a 300 ha hill grazing experiment (MAFF projects MS1508, BD1211 and LS1509) grazed by sheep for at least 6 years at a maximum stocking density of either 1.5 or 1.0

ewes per ha. The site was formerly dwarf shrub heath, degraded by past heavy grazing. The main objective was to reduce the abundance of *N. stricta,* to restore dwarf shrubs such as *Vaccinium myrtillus* and *C. vulgaris*, and maintain the diversity of other plant species. The vegetation most closely resembled the U5 *Nardus stricta* – *Galium saxatile* grassland, with vegetation similar to the U5a species-poor and U5b *Agrostis canina* – *Polytrichum commune* sub-communities represented (Rodwell 1992).

The area was divided into three blocks which were subdivided into four plots (12 plots in total). Four treatments were allocated randomly to plots, replicated over the three blocks. Treatments included low sheep (1.0 ewes per ha for 10 months per year + lamb from May to August); high sheep (1.5 ewes per ha for 10 months per year + lamb from May to August) cattle (0.5 heifers per ha for 2 months in summer only) and mixed grazing (low sheep + cattle).

Vegetation

For vegetation assessments, a grid of 125 1 x 1 m quadrats at 75 m spacing was superimposed on the 12 plots 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 and bare ground present at the cross-wire intersection. The presence of all plant species in each quadrat was also recorded. Presence and top cover of all plant species, litter and bare ground was recorded pre-treatment in 2002 and at the end of the experiment in 2006. Top cover was also recorded in 2004. Local shoot frequency (presence in each 10 cm cell) and a grazing index (proportion of occupied cells in which grazed shoots were present) of four key species (*N. stricta*, *V. myrtillus*, *C. vulgaris*, *Molinia caerulea*) were recorded annually from 2003. Overall sward height was measured from five random locations within each quadrat. All records were made in September-October.

Treatment effects on the overall plant community were analysed by partial redundancy analysis (PRDA) with 999 Monte Carlo permutations on 2006 log-transformed mean cover and plot frequency data, in which blocks were treated as covariables and the four grazing treatments as nominal variables. Treatment, temporal and spatial (block) effects on cover, frequency and grazing indices (all subjected to arcsine $\sqrt{x}$ transformation), vegetation height and log-transformed species richness m^{-2} were assessed by repeated-measures analysis of variance (with the Greenhouse-Geisser adjustment where more than two years' data were analysed) using the General Linear Model procedure in Statistica 6.0 (Statsoft Inc, 2001).

Animal performance

Welsh Mountain ewes were used in low sheep, high sheep and mixed treatments. Welsh Black 2 year old heifers were used in the cattle and mixed treatments. Liveweight and body condition scores were recorded for all heifers when turned onto and removed from the plots. Liveweights and body condition scores were recorded for ewes when turned onto and removed from plots as well as at specific points during the sheep year such as tupping, shearing and weaning. Ewes were removed from plots for tupping (November) and lambing (April). Only ewes with single lambs were returned to the plots. Lambs were weighed at birth, shearing and weaning.

Treatments started in June 2003, cattle data was recorded over four summers and lamb performance was recorded over three sheep years (tupping to weaning).

All animal data were analysed using the method of residual maximum likelihood (REML; GENSTAT 5). The model used comprised fixed effects for block, treatment and year and the interactions between treatment and year for all variables.

RESULTS

Vegetation

In total, 48 species were recorded in 2002 and 54 in 2006. *F. ovina*, *Galium saxatile*, *V. myrtillus*, *N. stricta*, *A. capillaris* and *Pleurozium schreberi* were recorded most frequently (Annex 1). Grazing treatment had a significant effect on both cover and frequency of the overall plant community in the PRDAs (Table 1), with treatments well dispersed in ordination space by the first two axes (Figure 1). The effect on cover was primarily attributable to the low sheep only treatment, which was just outside the limits of statistical significance (*P*=0.05; Table 1). Frequency was affected by both low sheep only and low sheep plus cattle, there being no significant difference between the other two treatments. Species more associated with low sheep only than high sheep only (cover and frequency) included *F. ovina*, *A. capillaris*, *Carex binervis* and *Juncus squarrosus*. *N. stricta* cover, but not frequency, was more associated with high sheep only than low sheep only. *C. vulgaris* cover and frequency was associated with cattle only. Treatments with cattle, especially sheep plus cattle (Figure1a,b) tended to have more bare peat and less litter was exposed under low sheep only.

Table 1 **PRDA results of 2006 species cover and frequency. LS = low sheep only; HS = high sheep only; SC = sheep plus cattle. The fourth treatment (cattle only) was the final nominal variable after forward selection and was not significant. ** *P*<0.01, * *P*<0.05, ns not significant**

	Cover		**Frequency**	
Treatment	**Lambda**	**F**	**Lambda**	**F**
LS	0.12	1.62 ns	0.13	1.57 *
HS	0.10	1.31 ns	0.08	0.97 ns
SC	0.09	1.35 ns	0.12	1.72 *
All treatments	Eigenvalue	F	Eigenvalue	F
Axis 1	0.137	1.38 ns	0.133	1.25 ns
Overall	0.313	1.50 *	0.326	1.46 **

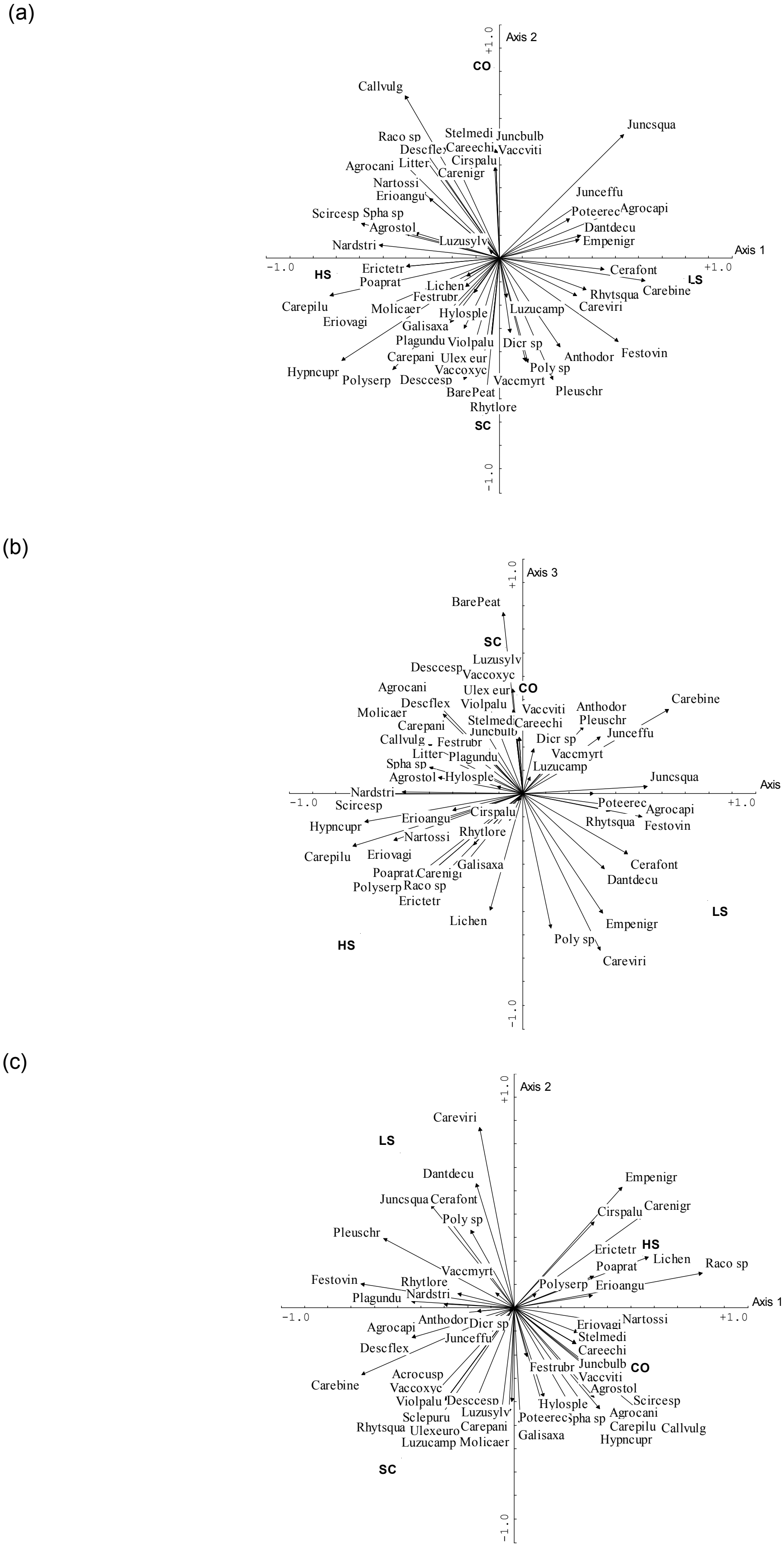

Figure 1 PRDA biplots of species and grazing treatments in 2006 for (a) cover, axes 1 & 2; (b) cover, axes 1 & 3; frequency, axes 1 & 2. For abbreviated species names see Annex 1; treatment codes as Table 1 plus cattle only (CO)

Overall mean species richness m^{-2} was 13.4 ±0.26 SE in 2002 and 13.8 ±0.19 in 2006, with no significant change ($F_{1,6}$=3.02, P=0.13) or treatment effect ($F_{3,6}$=0.57, P=0.65) detected. There were no treatment effects on cover, local frequency or grazing index of any individual species or other variables analysed with the exception of *M. caerulea*, nor were there any significant treatment x year interactions. However, there were temporal and spatial effects. Cover of *N. stricta* declined after 2004 from 21% to 16% (Table 2) as did its frequency (47% to 37%; Table 3). The grazing index was very low, albeit significantly higher in 2006 (4%) than previous years (0.2-1.2%) (Table 3). *F. ovina* cover was slightly higher in 2004 (14%) than in other years (11%) as was that of *A. capillaris*. *M. caerulea* cover showed a similar trend that was just non-significant (P=0.05). *M. caerulea* cover and frequency were very low (1-2% and 3-4% respectively). However, the grazing index differed among treatments, being lowest in the high sheep only treatment (7.1 ±3.75%), with an increasing trend from low sheep only (22.9 ±10.63%) to cattle only (45.6 ±8.10%) and low sheep plus cattle (62.7 ±7.40%). Therefore, *M. caerulea* was selectively grazed, especially when cattle were present, and despite being relatively scarce in the sward. The index was also significantly lower in 2004 than in other years, mirroring the trend in top cover. Cover of *J. squarrosus* and *C. binervis* showed the reverse temporal pattern to *F. ovina*, *A. capillaris* and *M. caerulea*, being lower in 2004. *V. myrtillus* had relatively low cover (8-9% overall year means) but high frequency (67-72%), neither of which changed significantly over time. *V. myrtillus* was widely grazed (15-17%) and significantly more so in 2003 (27%). *C. vulgaris* was scarce in the sward (cover 1-2%, frequency 3%) and not heavily grazed (3-10%). *Carex panicea* cover was low and it declined from 3.5 to 1.4%. Bare ground was significantly more frequent in 2003 (3.5%) than in other years, when frequency was negligible. Vegetation height tended to be lower in 2006 (15.7cm) than 2005 (19.1cm), this being just outside the limits of statistical significance (P=0.06). Significant year x block interactions for several species indicated that the magnitude of change tended to vary spatially but with no consistent differences among the three blocks.

Table 2 **Mean (±SE) percentage cover of main species and sward height (cm) each year with *F* statistics from ANOVA (Greenhouse-Geisser adjustment applied to year df). Untransformed data presented for clarity. * *P*<0.05, ** *P*<0.01, *** *P*<0.001**

Variable	**2002**		**2004**		**2005**		**2006**			**Year**	**Treatment**
									df	*F*	$F_{3,12}$
Agrostis capillaris	8.1	±0.96	12.1	±1.38	-	-	10.3	±0.91	1.92, 11.52	19.65 ***	0.46
Calluna vulgaris	1.1	±0.63	1.6	±0.89	-	-	0.7	±0.30	1.19, 7.13	1.50	2.79
Carex binervis	7.8	±1.37	5.0	±1.03	-	-	6.4	±1.10	1.98, 11.89	5.53 *	3.36
Carex panicea	3.5	±0.63	2.5	±0.37	-	-	1.4	±0.45	1.99, 11.92	17.51 ***	1.17
Festuca ovina	11.3	±0.65	14.0	±1.07	-	-	10.6	±0.91	1.44, 8.65	10.54 **	1.24
Juncus squarrosus	4.3	±0.89	3.4	±0.62	-	-	4.2	±0.74	1.48, 8.88	5.56 *	1.98
Molinia caerulea	1.4	±0.44	2.3	±0.65	-	-	2.0	±0.58	1.17, 7.03	5.20	1.34
Nardus stricta	21.1	±1.49	20.1	±2.09	-	-	16.0	±1.47	1.92, 11.55	25.35 ***	1.42
Vaccinium myrtillus	8.2	±0.82	9.5	±0.99	-	-	9.0	±0.86	1.92, 11.54	3.54	0.57
Height	-	-	18.1	±1.27	19.1	±0.75	15.7	±0.91	1.35, 8.10	4.42	0.42

Table 3 **Mean (±SE) local frequency (Freq.) and grazing index (GI) of main species each year with *F* statistics from ANOVA (Greenhouse-Geisser adjustment applied to year df). Untransformed data presented for clarity. Tmnt. = grazing treatment; * *P*<0.05, ** *P*<0.01, *** *P*<0.001**

	Variable	**2003**		**2004**		**2005**		**2006**		**Year**			**Tmnt.**
										df	*F*	df	$F_{3,18}$
Freq.	*Calluna vulgaris*	2.8	±1.45	2.9	±1.46	2.5	±1.17	2.7	±1.24	1.96, 11.76	0.54	3, 18	3.14
	Molinia caerulea	4.4	±1.16	3.8	±0.95	4.3	±1.07	3.7	±0.93	2.60, 15.60	0.37	3, 18	2.18
	Nardus stricta	51.4	±5.07	47.4	±5.32	36.8	±3.93	37.1	±3.84	1.80, 10.82	13.22 **	3, 18	0.87
	Vaccinium myrtillus	67.1	±4.41	64.8	±4.41	66.7	±4.02	72.0	±2.83	1.43, 8.57	2.04	3, 18	0.32
	Bare ground	3.5	±1.24	0.4	±0.27	0.0	±0.01	0.0	±0.02	1.05, 6.31	19.22 **	3, 18	1.05
GI	*Calluna vulgaris*	8.3	±5.02	2.7	±2.21	9.5	±6.61	9.7	±8.93	1.89, 7.57	0.38	3, 6	3.83
	Molinia caerulea	41.0	±9.73	16.3	±7.11	43.7	±10.58	49.6	±10.50	2.43, 7.30	10.45 **	3, 3	36.34 **
	Nardus stricta	1.0	±0.27	1.2	±0.97	0.2	±0.13	4.0	±1.14	2.32, 13.95	13.84 ***	3, 6	1.64
	Vaccinium myrtillus	27.3	±3.04	15.2	±2.97	17.1	±1.94	17.1	±2.06	1.89, 11.35	6.33 *	3, 6	0.02

Cattle performance

Cattle were delayed by a couple of weeks in their initial turnout date in 2003, due to adverse weather conditions in early summer delaying completion of fencing of all enclosures. They were eventually put onto the treatment areas on 17 July. In subsequent years, dates on to treatments were 29 June 2004, 30 June 2005 and 27 June 2006. The heifers weighed an average of 531, 461, 416 and 460 kg in years 2003 to 2006 respectively with condition scores of 3.2, 3.1, 2.5 and 2.8 respectively. Over the four years, changes in body condition score were less than a quarter score between the start and end of grazing with overall scores reducing slightly from 2.85 to 2.74 for cattle only treatments and 2.90 to 2.86 for cattle on mixed grazing treatments (P>0.05). The results for daily liveweight changes are given in Table 4.

Table 4 The effect of grazing treatment on cattle daily liveweight changes (kg/day)

						SED		
	2003	**2004**	**2005**	**2006**	**Mean**	**Treat**	**Year**	**Interaction**
Cattle	0.49_{abcd}	0.40_{abc}	0.80_{c}	0.48_{abc}	0.545	0.049	0.069	0.098
Mixed	0.54_{bcd}	0.30_{a}	0.68_{cd}	0.36_{ab}	0.471			
Mean	0.518	0.350	0.742	0.422				

There were some significant year X treatment interactions (P<0.001). With the exception of 2003, heifers from the cattle only treatment had higher daily liveweight gains than from the mixed grazing treatment although due to a high individual animal variation, treatment differences were not significant (P>0.05). In Years 2004, 2005 and 2006, daily liveweight gain of heifers from the mixed grazing treatment was consistently a factor of about 0.75 of that of the heifers from the cattle only treatment. In 2005, heifer performance across both treatments was better than in other years however this may have been a result of the lower weight of animals at the start.

Sheep performance

Weaning weights of ewes and lambs were used as an indicator of animal performance. The weaning weights for ewes in each year are given in Table 3. There was a significant difference in weaning weight between years (P<0.001) but no significant treatment effects. This was despite ewes at the lower stocking rate consistently having higher weaning weights than other treatment groups. Ewes at the lower stocking rate also had slightly higher body condition scores at weaning (2.67, 2.46 and 2.43 for LS, HS and mixed grazing regimes respectively) but again differences were not significantly significant (P>0.05). Ewe tupping weights and condition scores also showed seasonal variation with no significant treatment effects (40.5, 39.5 and 41.0kg; 2.70, 2.62 and 2.50 respectively). Subsequent lamb birth weights were similar for all treatment groups at 3.5, 3.6 and 3.6kg respectively (Table 5).

Table 5 Effect of grazing regime on ewe weaning weight (kg)

	2004	**2005**	**2006**	**Mean**	**SED**		
					Treat	**Year**	**Treat X year**
Low Sheep	37.4_{a}	43.9_{d}	41.0_{c}	40.8	0.81	0.81	1.43
High Sheep	36.8_{a}	43.3_{cd}	38.1_{ab}	39.4			
Cattle & Sheep	36.9_{a}	42.0_{cd}	40.6_{bc}	39.9			
Mean	37.0	43.1	39.9				

Lamb performance as measured by weaning weight (Table 6) was not significantly affected by treatment (P>0.05) despite an average 1kg additional liveweight for lambs from the lower stocking rate. Performance between years was variable but, year on year, lamb performance improved. With the exception of the high sheep treatment, lambs were significantly ($P<0.05$) heavier at weaning in 2006 compared to 2004.

Table 6 Effect of grazing regime on lamb weaning weight (kg)

	2004	2005	2006	Mean	SED		
					Treat	**Year**	**Treat X year**
Age at weaning	153	145	145				
Low Sheep	25.2_{ab}	25.8_{abc}	27.5_{bc}	26.2	0.728	0.730	1.262
High Sheep	23.4_{a}	25.5_{abc}	26.8_{bc}	25.2			
Cattle & Sheep	23.9_{a}	25.2_{ab}	28.0_{c}	25.7			
Mean	24.1	25.5	27.4				

DISCUSSION

Vegetation

There were only small treatment effects at the plant community level and no significant effect on any of the most abundant species was detected individually, including *N. stricta, F. ovina, V. myrtillus* or *A. capillaris*. *N. stricta* is relatively unpalatable to both sheep and cattle and other, broadleaved grasses are selected if they are available (Grant et al., 1985). However, cattle do ingest more *N. stricta* than sheep (Common et al., 1998; Grant et al., 1996a) as they are less able than sheep to select discrete food items at a small spatial scale (Jarman & Sinclair, 1979). Consequently, cattle grazing in single species or mixed grazing systems on hill grasslands can result in a decline in *N. stricta* and a corresponding increase in other grasses (Common et al., 1998; Grant et al., 1996a) due to their superior competitive ability (Grant et al., 1996b). In contrast, sheep-only grazing can result in an increase in *N.*

stricta cover and biomass as they actively avoid grazing it (Grant et al., 1996a). The apparent absence of these effects in the current study might be partly explained by the lower intensity of grazing as a result of the moderate stocking levels applied. In the previous studies of hill grasslands, sward height was reduced to 4-5 cm by grazing or 1-4 cm by cutting, whereas mean sward heights in the current study were 16-19 cm. At the stocking rates applied here, cattle might not have removed enough *N. stricta* biomass to affect its overall cover or frequency. The reduction of lamina extension in *N. stricta* is dependent on the severity and duration of defoliation (Grant et al., 1996b). Under the sheep only grazing treatments, there might have been insufficient offtake of the more palatable grasses to reduce their competitive advantage over *N. stricta*. Even so, there was a minor effect of sheep stocking density on the overall species composition by the fourth year. Another reason for the lack of treatment effects on *N. stricta* might be the low productivity of the site. *N. stricta* is more likely to decline under heavy grazing at more productive sites (Pakeman, 2004), presumably because of the increased competitive vigour of other species in the community.

In 2004, cover of productive species (*F. ovina*, *A. capillaris*, *M. caerulea*) was higher and less productive species (*J. squarrosus*, *C. binervis*) was lower. This suggests a more productive year, supported by the trends in vegetation height. For *M. caerulea* at least, this was also related to reduced grazing intensity. Overall, the results suggest that the decline in *N. stricta* seen between 2004 and 2006 might have been attributable to increased grazing intensity across all treatments, which was dependent on annual variation in the productivity of the more palatable species. Over a longer period of time, treatment effects might become more evident as changes to the *N. stricta* community only occur very slowly. *M. caerulea* had only 1-2% cover, yet was grazed more in treatments with cattle than those with sheep only. Selective grazing of *M. caerulea* by cattle has been widely reported from hill grasslands, blanket bog and heather moor (e.g. Grant et al., 1987; Common et al., 1997).

One objective of the vegetation management was to increase the abundance of dwarf shrubs by reducing the biomass and competitive effect of grasses, but no evidence of this was detected. *V. myrtillus* was widespread across the site and was grazed in all plots, indicating utilisation by both sheep and cattle. However, there was no indication of differential effects of the grazing treatments. *C. vulgaris* was relatively scarce on the site and would probably require more disturbance to create bare ground and allow regenerate from seed (Marrs et al., 2004). Cattle are more likely to create such conditions than sheep, as indicated by the association of bare peat with the cattle treatments. However, *C. vulgaris* was also scarce or absent from the seedbank at this site (Mitchell, unpublished data) and seed addition would probably also be necessary for seedling establishment.

Livestock performance

In the initial year, the swards had all previously been grazed by sheep-only regimes for many years and a vegetation biomass had accumulated. In the first year of this project, cattle performance was similar whether sheep were present or not suggesting that when present, sheep were not competing with cattle for available vegetation. Despite this, daily performance of the cattle was disappointing at only about 0.5kg per day. This contrasts with around 1kg per day for cattle on improved pastures. In subsequent years, cattle performance from the mixed grazing regime was consistently a factor of 0.75 of the growth rate obtained by cattle-only regimes, suggesting that sheep could be competing with cattle for available nutrients. These levels of production would have consequences in the whole farm system. These heifers would not be gaining sufficiently to allow them to reach a sufficient body weight to calve at 2 years of age. For growing cattle destined for finishing, these growth rates would need to be subsequently compensated for by additional feeding which would incur additional costs.

As might be expected, the lower stock rates with sheep resulted in improved sheep performance in terms of improved ewe weights and condition at weaning. 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 rates were about 1 kg heavier and remained 0.2 of a condition score greater than ewes on the higher stocking rate (2.7 vs. 2.5). The target condition score for hill ewes is 2.5 to 3.0 (Henderson, 1995) and hence all groups were well within this target which would explain why no differences were seen in conception rates. Lambing % did not appear to be affected, however ewe numbers in each experimental area were rather low to detect these effects. Ewe body weight was slightly impaired by the addition of cattle, but generally the low stocking plus cattle were no worse than the high sheep only treatment. Indeed there were indications that the performance of ewes on the mixed treatment was improving, although this would need to be investigated over a longer time scale due to the slow changes that take place in hill swards.

Similarly, lamb growth rates appeared to be improving under the mixed grazing regimes. This might be expected if cattle are removing older vegetation and allowing it to be replaced with more palatable and more nutritious new growth. With the relatively small number of animals involved and a high variation between groups, treatment differences were not statistically significant, however the mean changes reported were quite large and would have a substantial effect of farm financial margins. The extra lamb performance may result in a higher proportion of lambs being sold finished off the farm or reduced ages at slaughter reducing grazing pressures on limited improved pastures at weaning.

The results raise potential questions for environmental based prescriptions where levels are in livestock units ha^{-1} regardless of livestock species. This work would suggest cattle could be grazed for short periods in addition to sheep with beneficial effects for livestock performance although the vegetation objectives will probably take longer to achieve.

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ANNEX 1 PLANT SPECIES RECORDED IN 2002 AND 2006

Data are number of quadrats (out of 125) in which each species was recorded, in descending order. Abbreviated names are those used in Figure 1.

2002			**2006**		
Festuca ovina	Festovin	120	*Galium saxatile*	Galisaxa	106
Nardus stricta	Nardstri	111	*Festuca ovina*	Festovin	105
Galium saxatile	Galisaxa	110	*Vaccinium myrtillus*	Vaccmyrt	105
Vaccinium myrtillus	Vaccmyrt	110	*Nardus stricta*	Nardstri	103
Agrostis capillaris	Agrocapi	109	*Agrostis capillaris*	Agrocapi	99
Pleurozium schreberi	Pleuschr	104	*Pleurozium schreberi*	Pleuschr	89
Rhytidiadelphus squarrosus	Rhytsqua	88	*Deschampsia flexuosa*	Descflex	88
Carex pilulifera	Carepilu	86	*Rhytidiadelphus squarrosus*	Rhytsqua	84
Polytrichum sp.	Poly sp	82	*Agrostis canina*	Agrocani	80
Rhytidiadelphus loreus	Rhytlore	80	*Polytrichum* sp.	Poly sp	63
Deschampsia flexuosa	Descflex	79	*Potentilla erecta*	Poteerec	63
Potentilla erecta	Poteerec	64	*Juncus squarrosus*	Juncsqua	59
Juncus squarrosus	Juncsqua	59	*Hylocomium splendens*	Hylosple	57
Agrostis canina	Agrocani	55	*Rhytidiadelphus loreus*	Rhytlore	52
Carex binervis	Carebine	52	*Carex pilulifera*	Carepilu	50
Hylocomium splendens	Hylosple	43	*Carex binervis*	Carebine	47
Dicranum sp.	Dicr sp	39	*Hypnum cupressiforme*	Hypncupr	36
Luzula campestris	Luzucamp	35	*Anthoxanthum odoratum*	Anthodor	33
Danthonia decumbens	Dantdecu	29	*Danthonia decumbens*	Dantdecu	27
Racomitrium sp.	Raco sp	22	*Luzula campestris*	Luzucamp	27
Eriophorum vaginatum	Eriovagi	21	*Carex panicea*	Carepani	26
Molinia caerulea	Molicaer	20	*Festuca rubra*	Festrubr	26
Lichen	Lichen	16	*Racomitrium* sp.	Raco sp	26
Sphagnum sp.	Spha sp	16	*Lichen*	Lichen	24
Eriophorum angustifolium	Erioangu	15	*Carex demissa*	Caredemi	22
Carex panicea	Carepani	14	*Carex nigra*	Carenigr	19
Hypnum cupressiforme	Hypncupr	13	*Dicranum* sp.	Dicr sp	19
Calluna vulgaris	Callvulg	12	*Molinia caerulea*	Molicaer	16
Juncus effusus	Junceffu	12	*Juncus effusus*	Junceffu	13
Empetrum nigrum	Empenigr	11	*Empetrum nigrum*	Empenigr	11
Anthoxanthum odoratum	Anthodor	7	*Calluna vulgaris*	Callvulg	10
Carex echinata	Careechi	5	*Eriophorum vaginatum*	Eriovagi	10
Agrostis stolonifera	Agrostol	4	*Plagiothecium undulatum*	Plagundu	10
Carex nigra	Carenigr	4	*Scirpus cespitosus*	Scircesp	9

2002			2006		
Carex demissa	Caredemi	3	*Sphagnum* sp.	Spha sp	9
Luzula sylvatica	Luzusylv	3	*Eriophorum angustifolium*	Erioangu	8
Cerastium fontanum	Cerafont	2	*Polygala serpyllifolia*	Polyserp	6
Erica tetralix	Erictetr	2	*Agrostis stolonifera*	Agrostol	5
Scirpus cespitosus	Scircesp	2	*Cirsium palustre*	Cirspalu	4
Vaccinium vitis-idaea	Vaccviti	2	*Deschampsia cespitosa*	Desccesp	3
Rosa pimpinellifolia	Rosapimp	1	*Narthecium ossifragum*	Nartossi	3
Deschampsia cespitosa	Desccesp	1	*Luzula sylvatica*	Luzusylv	2
Cardamine hirsuta	Cardhirs	1	*Viola palustris*	Violpalu	2
Cirsium palustre	Cirspalu	1	*Acrocladium cuspidatum*	Acrocusp	1
Festuca rubra	Festrubr	1	*Carex echinata*	Careechi	1
Narthecium ossifragum	Nartossi	1	*Cerastium fontanum*	Cerafont	1
Ulex europaeus	Ulexeuro	1	*Erica tetralix*	Erictetr	1
Vaccinium oxycoccus	Vaccoxyc	1	*Juncus bulbosus*	Juncbulb	1
			Poa pratensis	Poa prat	1
			Pseudoscleropodium purum	Pseupuru	1
			Stellaria media	Stelmedi	1
			Ulex europaeus	Ulexeuro	1
			Vaccinium oxycoccus	Vaccoxyc	1
			Vaccinium vitis-idaea	Vaccviti	1
COUNT		48	COUNT		54