Effects of Grazing Animals on Upland/Montane Lichen Vegetation in Great Britain

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Summary

The effects of grazing animals on montane lichen vegetation was shown to be both quantitative and qualitative, and to decrease with increasing elevation. There was a significant decrease in biomass of fruticose lichens, which were also fragmented so that colonies were smaller and did not form luxuriant cushions. There was an increase in the influence of the substratum due to the destruction of the deep vascular plant and bryophyte layer. There was also an increase in the number of crustose species, due to reduced competition from vascular plants and exposure of additional habitats. Lichen species diversity was shown to be inversely related to the height of the vascular-plant vegetation.

Key words: Moorhouse, Snowdon, Inchnadamph, Red deer, Sheep, Exclosure, Biodiversity, Montane, Lichen.

Introduction

It has long been known that grazing animals have a considerable effect on the terricolous lichen vegetation in boreal/Arctic regions (Skjennenberg & Slagsvold, 1968). Reindeer/caribou (*Rangifer tarandus* L.) rely heavily on them for food, particularly in winter, and their increasing numbers over the past few decades has also lead to serious damage, due to trampling, during the summer months (Evans, 1996). This overstocking has resulted in serious degradation of the lichen-rich heaths in Lapland (northern Norway and Finland) that is visible from satellites orbiting the earth (FORUT, 1990; Pedersen, Johansen & Tommervik, 1993). At Dvorefjell National Park, Norway the natural east-west migration of reindeer was interrupted by the construction of a railway and a road through a valley in 1921. At this time the reindeer population was low (*c.* 1500 animals) and little damage resulted, but the cessation of hunting during World War II resulted in a population explosion to not less than 15,000 beasts. This increase went unchecked until 1956 when the population crashed. Thirty years later, with the reindeer population back to near its pre-war level, significant recovery had taken place in the lichen heath but the differences between the sides of the valley were still readily discernible (D. Mardon, unpublished data).

Thompson, Galbraith. & Horsfield (1987) considered over-grazing by sheep and red deer (*Cervus elaphus* L.) to be one of the main threats to montane vegetation in the British Isles. Grazing by sheep has been recognised as causing considerable damage to *Racomitrium lanuginosum* heaths in the English Lake District and Wales (Thompson & Brown, 1992) but the effects on lichens within

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montane vegetation are less well studied, although these are likely to be less widespread as most grazing animals leave the higher altitudes in winter when lichens become a more important food source. However, sheep have been observed browsing the thalli *of Sphaerophorus globosus* from the tops of boulders, and in other cases there is assumed evidence of damage (A. Fryday, unpublished data).

The main effects of over-grazing on upland vegetation have been outlined by Thompson *et al.* (1987). These are the removal of primary production and woody vegetation, an increase in peat-erosion by deer, local nutrient enhancement from urine and dunging, local association with large-patch burning extending from upper fringes of sub-montane heaths, and may be accompanied by local large-patch burning of woody species. The only positive effect identified was that diversity of species-rich types may be maintained by trampling.

The principal grazing animal in the Scottish Highlands is the red deer although in some areas (*e.g.* Ben Lawers) sheep are also numerous. Sheep are also the main grazing animal in other montane areas of the British Isles. Smaller mammals (*e.g.* rabbits (*Oryctolagus cuniculus*), voles (*Microtus agrestis*)) may also damage the vegetation but the effects of these are insignificant unless the larger animals are excluded.

Materials and Methods

Exclosures at Moor House, northern England (GR 35/70-5,31-3; 2°26′W, 54°43′N), Snowdon, North Wales, (GR 23/62,55; 4°34′W, 53°4′N) and Inchnadamph, north-west Scotland (GR 29/26,19-20; 5°57′W, 55°9′N) were visited and comparisons made of the vegetation inside and outside the exclosures. In addition, a newly erected exclosure on Ben Lawers, south-central Highlands of Scotland (GR 27/63,41; 4°15′W, 56°35′N) also was sampled for future reference and the permanent quadrats on the *Nephroma arcticum* (Arctic kidney lichen) colony on Beinn Eighe, north-west Scotland (GR 18/9760; 5°23′W, 57°36′N) briefly inspected.

Subjectively determined, representative areas within each exclosure, and from a comparable area outside, were selected and sampled with 4×4 m quadrats. All species of vascular plants, bryophytes and lichens were recorded and assigned a value on the Domin scale, except for saxicolous lichens that were given a DAFOR value.

The total lichen vegetation was then removed from a 20×20 cm area of the densest lichen cover in each relevé for biomass determination. Each sample was cleaned of all soil and other vegetative matter, air-dried and then weighed. The lichen biomass in each relevé was estimated by dividing this figure by the percentage cover of lichen in the sample and multiplying by 400, to give a theoretical value for 100% lichen cover in the relevé. This figure was then multiplied by the percentage lichen cover in the relevé to give a figure for the total lichen biomass in the relevé. The increase in lichen biomass inside each exclosure was then calculated by dividing the biomass from the relevé inside the exclosure by that from the relevé outside.

Soil samples were taken from the centre of each relevé and, where possible, the sample was extended down to the underlying bed-rock so that any pH gradient could be detected. However, in most cases there was very little soil, the vegetation growing almost directly on rock with just a thin layer of litter or humus. pH was determined, using an electronic pH meter and glass electrode, by suspending 2 g of sample in 20 ml of distilled water.

'Montane' is used in preference to 'Alpine' as the former portrays a much more accurate picture of the British mountains, which although above the tree-line are largely snow-free for much of the year. Similarly, 'submontane' is used in preference to subalpine as this reflects the distinctive nature of this zone in the British Isles where the subalpine scrub common in European mountains is totally lacking.

Lichen nomenclature follows Purvis, Coppins & James (1994). When later names have been used the former name is given as a synonym. Bryophyte nomenclature follows Blockeel & Long (1998) and vascular plants Stace (1991).

Sites Visited

Unfortunately, the only long-established exclosures in Scotland are at a relatively low altitude (500-600 m) and at these elevations the cessation of grazing leads to a dominance by vascular plants. Only those exclosures on the Inchnadamph NNR in Sutherland can be considered in any sense 'montane' as, although they are situated at only 250 m altitude, they are far enough north and west to be in the submontane zone characterised by dwarf willows (*Salix* spp.). However, the presence of the typical subspecies of *Empetrum nigrum* (subsp. *nigrum*), rather than the more montane *E. nigrum* subsp. *hermaphroditum*, indicates that the vegetation is not 'montane'. Outside Scotland there is an excellently positioned exclosure at 900 m in Snowdonia in Wales that, unfortunately, has not been properly maintained, and several at Moor House NNR in the northern Pennines in England. Nowhere are there any exclosures erected primarily to investigate changes in the lichen vegetation and very few are situated on potentially lichen-rich areas.

Moor House NNR Moor House NNR in the northern Pennines includes some of the highest ground in England outside the Lake District. True montane ground is restricted to the summit of Cross Fell at 893 m, the rest of the terrain being submontane grasslands and heather moors. The highest exclosures, reaching 840 m on Little Dun Fell, are long-established, most were erected in 1954. They cover a range of vegetation types (acidic and calcareous grassland, blanket bog and lichen-rich heath) and are readily accessible as a well-maintained road runs to the summit of Great Dun Fell at 850 m.

Most of the exclosures surveyed were situated on heavily grazed, high altitude grassland in the vicinity of Great Dun Fell (GR 35/70-2,31-3). A further series of exclosures, located on somewhat lower ground around the main house (GR 35/75,32-3), were, in general, sited in areas with a poor, or non-existent, lichen vegetation (*i.e. Nardus* grassland, *Calluna* heath, etc.) and were, consequently, of little relevance to the present project. However, two exclosures in this latter group were located on limestone and supported considerable lichen growth. These were also surveyed. The details of these exclosures are given in Table 1 and the species recorded from them in Table 2.

Table 1. Details of relevés at Moor House NNR.

		Habitat	Grid ref.	Altitude
Q1	Little Dun Fell (D43, inside)	Acid grassland	35/705,331	840 m
Q2	Little Dun Fell (D43, D42, outside)	Acid grassland	35/705,331	840 m
Q3	Little Dun Fell (D42, inside)	Acid grassland	35/705,331	840 m
Q4	Knock Fell (D14, inside)	Limestone grassland	35/718,313	745 m
Q5	Knock Fell (D14, outside)	Limestone grassland	35/718,313	745 m
Q6	Trout Beck Head (D31, inside)	Blanket bog	35/722,318	685 m
Q7	Trout Beck Head (D31, outside)	Blanket bog	35/722,318	685 m
Q8	Silverband (D13, inside)	Blanket bog	35/711,310	685 m
Q9	Silverband (D13, outside)	Blanket bog	35/711,310	685 m
Q10	Hard Hill (D40, inside)	Lichen-rich heath	35/725,332	685 m
Q11	Hard Hill (D40, outside)	Lichen-rich heath	35/725,332	685 m
Q12	Tree Exclosure (D16, inside)	Limestone grassland	35/757,330	550 m
Q13	Tree Exclosure (D16, outside)	Limestone grassland	35/757,330	550 m
Q14	Limestone Gorge (D19, inside)	Limestone grassland	35/756,328	550 m
Q15	Limestone Gorge (D19, outside)	Limestone grassland	35/756,328	550 m

Numbers of the exclosures (*e.g.* D43, D14) are those used by Rawes 1981, 1983.

The exclosures at Moor House have been used extensively by ecologists studying upland vegetation, most importantly by Rawes (1981, 1983) and these publications should be referred to for a more detailed description of the site, the exclosures and the vascular-plant vegetation.

Snowdon The high level exclosure on Snowdon is at an altitude of 850 m immediately to the south of the low point (bwlch) of the ridge at the western end of Crib Goch (GR 23/621,551). It is on steeply sloping ground (30°) which is approximately two-thirds covered with short grasses – the other third being bare soil with small, unstable pebble scree.

The more densely vegetated area of the exclosure had a vegetation cover of 99% with a height of 5 cm. Unfortunately, the ground adjacent to the western perimeter fence has been worn down by hill-walkers using the fence as a support when descending to Glas-Llyn with the result that, for some time, sheep have been able to enter the exclosure. Not withstanding this, the vegetation inside the exclosure is more luxurious than that outside; although it is still only a few centimetres high.

Terricolous lichens were largely absent from the exclosure, the only area where they were consistently present being on the boundary between the vegetated and non-vegetated areas. To either side of this, lichens were almost completely absent with only a few isolated thalli of *Cladonia uncialis* subsp. *biuncialis* being present in the grassland (although other species were usually present on the few bare areas of soil at the edge of banks) and none at all on the scree. Consequently, a relevé was taken at the vegetation boundary.

The vegetation over the whole vegetated area (inside and outside the exclosure) is dominated by coarse grasses with abundant *Galium saxatile* and frequent *Polytrichum commune. Racomitrium lanuginosum* was also frequent in the areas of the quadrats although it was almost totally absent elsewhere. This

Table 2. Species recorded from relevés at Moor House NNR.

Relevé (quadrat)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Inside/Outside exclosure	**In**	**Out**	**In**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Total cover (%)	80	80	98	100	99	100	95	90	70	100	90	100	100	100	100
Rock (%)	20	20	2	0	1	0	0	0	0	0	10	0	0	0	0
Peat (%)	0	0	0	0	0	0	5	10	30	0	0	0	0	0	0
Lichen cover (%)	20	5	2	1	1	1	<1	3	1	40	10	70	<1	40	2
Height of vegetation (cm)	8	2	12	15	2	17	5	12	6	25	2	1.5	3	4	2
Vascular Plants															
Equisetum ?arvense	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Selaginella selaginoides	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Achillea millefolium	.	.	.	3	.	.	.	.	.	.	.	.	.	1	2
Anemone nemorosa	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.
Calluna vulgaris	.	.	.	.	.	4	2	.	.	.	.	.	.	.	.
Campanula rotundifolia	.	.	.	.	3	.	.	.	.	.	.	.	.	.	1
Cardamine pratensis	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.
Cerastium fontanum															
subsp. *holosteoides*	.	.	.	.	1	.	.	.	.	.	.	.	2	.	1
Cirsium palustre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
C. ?vulgare	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Cochlearia ?pyrenaica	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Empetrum nigrum	.	.	.	.	.	4	2	5	1	2	.	.	.	.	.
Euphrasia officinalis aggr.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
Galium saxatile	.	3	1	2	2	.	.	.	.	4	4	3	4	4	4
G. sterneri	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Minuartia verna	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
Oxalis acetosella	.	.	.	1	.	.	.	.	.		.	.	.	.	.

Table 2. Species recorded from relevés at Moor House NNR – *continued.*

Relevé (quadrat)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Inside/Outside exclosure	**In**	**Out**	**In**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Potentilla erecta	.	.	.	2	.	.	.	.	.	.	.	.	.	1	.
Ranunculus acris	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.
Rubus chamaemorus	.	.	.	.	.	3	1	3	1	.	.	.	.	.	.
Rumex acetosa	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.
Thymus polytrichus	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
Trifolium repens	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Vaccinium myrtillus	5	4	3	3	4	3	.	4	1	4	3	1	.	1	.
V. vitis-idaea	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.
Viola lutea	.	.	.	.	2	.	.	.	.	.	.	.	.	1	.
V. riviniana	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.
Agrostis capillaris	.	2	.	4	5	.	.	.	.	.	.	4	5	4	3
Anthoxanthum odoratum	.	.	.	.	.	.	.	.	.	.	.	2	1	.	1
Carex bigelowii	4	1	8	3	.	.	.	.	.	.	.	.	.	.	.
C. caryophyllea	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
C. nigra	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.
C. pilulifera	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Danthonia decumbens	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Deschampsia cespitosa	.	.	.	4	1	.	.	.	.	.	.	.	2	.	.
D. flexuosa	8	1	8	2	.	5	5	.	.	.	2	.	.	.	.
Eriophorum angustifolium	.	.	.	.	.	3	3	3	3	.	.	.	.	.	.
E. vaginatum	.	.	.	.	.	8	9	7	8	.	.	.	.	.	.
Festuca rubra	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
F. ovina	3	9	.	8	8	.	.	.	.	.	7	9	8	8	10
Juncus squarrosus	.	.	.	.	.	.	.	.	.	.	4	.	.	1	.

Luzula campestris	.	.	.	.	3	.	.	.	.	.	.	4	3	.	2
Nardus stricta	.	.	.	.	.	.	.	.	.	.	4	.	.	1	2
Narthecium ossifragum	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.
Trichophorum cespitosum	.	.	.	.	.	.	1	3	1	.	.	.	.	.	.
Total Vascular Plants	4	6	4	11	20	7	6	7	6	5	6	9	10	10	10
Bryophytes															
Aulacomnium palustre	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Campylopus ?atrovirens	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.
C. flexuosus	1	.	.	.	.	2	.	1	3	.	.	.	.	.	.
Ctenidium molluscum	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Dicranum scoparium	3	4	4	1	.	1	1	.	1	.	.	.	1	1	2
Fissidens taxifolius	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Hylocomium splendens	.	.	.	.	.	.	.	.	.	.	.	3	3	.	.
Hypnum cupressiforme	.	.	.	2	1	.	.	.	.	.	1	.	.	.	3
Mnium hornum	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
Pleurozium schreberi	.	.	2	2	.	.	.	.	.	4	2	1	1	5	4
Pohlia nutans	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Polytrichum alpinum	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.
P. commune	.	.	2	.	.	.	.	.	.	2	.	.	1	4	4
P. formosum	.	2	.	.	1	.	1	.	.	.	.	.	.	.	.
P. piluliferum	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
P. strichum	3	2	2	.	1	.	.	.	.	.	.	.	.	.	.
Racomitrium lanuginosum	1	1	.	.	1	.	.	.	.	.	1	.	.	.	.
Rhytidiadelphus squarrosus	.	.	.	2	1	.	.	.	.	1	1	2	4	.	.
Tortella tortuosa	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Barbilophozia floerkei	.	.	.	1	1	.	.	.	.	.	.	2	.	3	2
Calypogeia azurea	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.

Table 2. Species recorded from relevés at Moor House NNR – *continued.*

Relevé (quadrat)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Inside/Outside exclosure	**In**	**Out**	**In**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Ou**
C. fissa	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.
Cephaloziella sp.	1	1	.	.	.	1	.	.	.	.	.	.	.	.	.
Diplophyllum albicans	.	.	.	.	1	2	1	1	1	.	.	.	.	.	.
Frullania tamarisci	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Lophocolea bidentata	.	.	.	.	2	.	.	.	1	.	.	.	.	1	.
Lophozia ventricosa	.	1	1	1	.	3	.	1	.	.	.	.	.	.	.
Mylia taylorii	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Ptilidium ciliare	1	1	2	1	.	.	.	.	.	.	.	.	.	.	.
Total Bryophytes	6	8	6	8	13	6	5	4	6	3	4	5	5	7	7
Terricolous Lichens															
Baeomyces rufus	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
*Cetraria aculeata**	1	1	.	.	1	.	.	2	.	.	3	2	.	1	.
C. islandica	5	1	2	.	.	.	.	1	.	.	.	2	1	4	1
Cladonia arbuscula	1	.	.	.	.	.	.	1	.	2	1	1	.	.	.
C. bellidflora	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.
C. chlorophaea	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
C. ciliata	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
var. *tenuis*	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.
C. diversa	1	2	.	.	2	.	1	3	2	.	1	.	.	.	.
C. floerkeana	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
C. furcata	2	1	1	.	1	.	1	.	1	3	1	1	.	2	.
C. pocillum	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
C. portentosa	2	1	1	1	1	1	.	2	.	5	4	8	1	5	.
C. pyxidata	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1

C. uncialis	2	1	1	.	1	1	.	1	.	.	2	.	.	.	2
Micarea cinerea	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
M. lignaria	1	1	.	.	1	.	.	1	.	.	.	.	.	.	.
Ochrolechia frigida	.	1	.	.	.	.	.	1	.	.	1	.	.	.	.
Omphalina ericetorum	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.
O. hudsoniana	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.
Peltigera membranacea	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Placynthiella uliginosa	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.
Thelocarpon epibolum	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Trapeliopsis gelatinosa	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
T. granulosa	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.
Total Terricolous Lichens	9	12	5	1	11	2	2	12	4	5	7	5	2	7	7
Saxicolous Lichens															
Baeomyces rufus	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Clauzadea monticola	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Fuscidea cyathoides	.	R	.	.	.	.	.	.	.	.	R	.	.	.	.
F. kochiana	D	D	D	.	.	.	.	.	.	.	D	.	.	.	.
Gyalecta jenensis	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Lecanora intricata	R	R	R	.	.	.	.	.	.	.	R	.	.	.	.
L. soralifera	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lecidea lithophila	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.
L. plana	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
L. pycnocarpa	R	R	R	.	.	.	.	.	.	.	.	.	.	.	.
Micarea coppinsii	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.
Ochrolechia androgyna	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Opegrapha saxatilis aggr.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Parmelia saxatilis	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Parmeliopsis ambigua	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.

Table 2. Species recorded from relevés at Moor House NNR – *continued.*

Relevé (quadrat)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Inside/Outside exclosure	**In**	**Out**	**In**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Pertusaria aspergilla	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.
Porpidia crustulata	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. macrocarpa aggr.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. tuberculosa	O	O	.	.	R	.	.	.	.	.	R	.	.	.	.
Protoblastenia rupestris	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Rhizocarpon geographicum	R	R	R	.	.	.	.	.	.	.	.	.	.	.	.
R. lecanorinum	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
R. obscuratum aggr.	R	O	.	.	.	.	.	.	.	.	.	.	.	.	.
R. umbilicatum	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Rimularia furvella	O	O	O	.	.	.	.	.	.	.	.	.	.	.	.
Tephromela aglaea	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Toninia aromatica	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Trapelia involuta	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Trapeliopsis granulosa	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Verrucaria hochstetteri	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Total Saxicolous Lichens	14	14	7	0	8	0	0	0	0	0	6	0	0	0	0
Total Lichens	23	26	12	1	19	2	2	12	4	5	13	5	2	7	7

* syn. *Coelocaulon aculeatum*

clearly puts the vegetation in the typical sub-community of the *Festuca ovina-Agrostis capillaris-Galium saxatile* community (NVC U4).

The exclosures have been fully surveyed and reported recently (Hill, Evans & Bell, 1992) and, consequently, only enough vascular plant information was recorded to establish the NVC communities present.

OTHER EXCLOSURES Four other exclosures at a lower altitude were also visited but found to contain only very isolated lichen growth and, consequently, these were not sampled. Exclosures 5 and 1 (Hill *et al.*, 1992) near Pen-y-pass were totally dominated by *Erica cinerea* and *E. tetralix* and contained only two clumps of *Cladonia uncialis* subsp. *biuncialis* and two clumps of *C. portentosa* respectively, although these were well developed. These lichens were equally well represented outside the exclosure and were even better developed where associated with rock outcrops. The other two exclosures (at the western end of Llyn Llydaw) were even more devoid of lichens. Exclosure 4, which was dominated by ericaceous shrubs but also had a good cover of grasses and some *Vaccinium myrtillus*, contained one clump of *C. uncialis* subsp. *biuncialis* and one of *C. bellidiflora.* Exclosure 9 supported a more varied vascular plant flora being dominated by grasses but also with much *Achillea millefolium*, *Cerastium palustre* and *Luzula sylvatica* but contained no lichens whatsoever!

It would appear that the only appreciable effect these exclosures are having on the lichen flora of the area is in providing a substratum for lignicolous species as the posts used to fence the exclosure (and sub-dividing posts within them) often supported a luxuriant growth of lichens. *Hypogymnia physodes* and *Parmelia saxatilis* were immediately obvious but *Fuscidea lightfootii*, *Lecanora conizaeoides*, *L. symmicta* and *Trapeliopsis granulosa* were also frequent; the last two were also found on the stems of *Erica* spp.

Inchnadamph NNR The Inchnadamph NNR in west Sutherland is located on Durness Limestone but, due to high precipitation in the area, the soils are mostly deeply leached and peaty. Much of the flatter ground is covered with blanket peat overlaying glacial drift with a similarly calcifuge vegetation (*e.g. Calluna vulgaris* heath) covering the slopes. Limestone is visible only as rocky outcrops and this supports a strongly calcicole vegetation that contrasts sharply with the terricolous vegetation.

Two long-established exclosures are situated towards the north of the reserve at an altitude of *c.*250 m. The lower of the two (GR 29/263,205) is largely densely vegetated with dwarf *Salix* spp., tall grasses, and large bryophyte and lichen hummocks. The vegetation in the upper exclosure (GR 29/265,199) is less well developed being largely composed of coarse grasses with bryophyte and lichen hummocks. Two relevés were taken from the lower exclosure and one just outside it for comparison but only one relevé was taken from the upper exclosure (with none outside) due to rapidly deteriorating weather conditions.

A series of four other small exclosures, situated on a high-level limestone grassland on Cnoc Eilidh Mhathain towards the south of the reserve (GR 29/27.18) were also visited but these had only recently been erected and, as they supported no lichens, they were not sampled.

Ben Lawers NNR Ben Lawers is the highest of the base-rich, mica-schist Breadalbane Mountains of Central Perthshire. These mountains are botanically very rich with the greatest concentration of important areas being contained within the Ben Lawers NNR. The lichen vegetation is of international importance (Gilbert, Coppins & Fox, 1988) with the great majority of the significant species and communities being concentrated on the base-rich crags. The terricolous vegetation is, in contrast, composed mostly of widespread montane lichens of acid soils, particularly at intermediate altitudes (<800 m).

Four exclosures are present on the NNR, two are on Creag an Lochain (GR 27/5940) (E1 & 2) and have been in position since 1987, one is on the south side of the bealach between Meall Garbh and Meall Greigh (GR 27/6443) and was erected in 1989 (E3) and one encloses a large area of the Edramucky Burn (GR 27/6138-9) and was erected in 1990 (E4). In addition two 1 m exclosure cages have been in position below Creag Loisgte since 1987 for monitoring *Gentiana nivalis*, although these are no longer in position. Unfortunately, all these exclosures are on lichenologically dull vegetation.

The two exclosures on Creag an Lochain, although the longest established, are at a relatively low altitude (550 m) and dominated by higher plants. As no terricolous lichens were present either inside or outside these exclosures, they were not sampled. Similarly, the *G. nivalis* cages, although at over 1000 m, contained no lichens and so they were not sampled. The Meall Garbh-Meall Greigh exclosure was not visited due to lack of time, adverse weather conditions and its remote location. It was also considered unlikely that it would yield any useful data (D. Mardon, pers. comm.). The Edramucky Burn exclosure although at only 625 m at its highest point did contain areas of significant terricolous lichen growth. Consequently, although it had been in position for only three years, it was sampled (at its highest point) as a reference point to monitor future changes of reduced grazing pressure.

Beinn Eighe NNR Beinn Eighe in Wester Ross is composed mainly of Cambrian Quartzite and Torridonian Sandstone. Most of the high ground is bare rock that supports a species-poor, largely unremarkable lichen vegetation. However, the rocks of the Moine Thrust, which include the base-rich fucoid-beds, are exposed on the very highest summits of Còinneach Mhór, Ruadh-stac Mór and Ruadh-stac Beag and these areas support a well vegetated grass-heath in stark contrast to the rest of the mountain.

The area of grass-heath on Ruadh-stac Beag (GR 18/972614) is the principal locality in the British Isles for *Nephroma arcticum* (Arctic kidney lichen) and the only one where it has been seen in recent years. The plants are poorly developed and apparently under a great deal of stress. Permanent quadrats were set up around the colonies in 1991 and re-surveyed in 1998 – along with the rest of the colony. Small exclosure cages were also placed over some of the plants to assess the effects of a complete removal of grazing pressure (A. Fryday, unpublished data).

Results and Discussion

In the present study effects of grazing were assessed by comparing the vegetation

Table 3. Lichen biomass increase inside exclosures.

Relevé	Air-dry lichen biomass (g)	% Cover in sample	% Cover in relevé	Lichen biomass in relevé	Relative increase in lichen biomass
Moor House NNR					
Ql	27.76	100	20	2220.8	94.5
Q2	0.94	80	5	23.5	
Q3	45.32	100	2	362.6	15.4
Q4	46.87	100	1	187.5	9.7
Q5	4.27	90	1	19.0	
Q6	14.84	100	1	59.4	>27.0
Q7	0.33	60	<1	<2.2	
Q8	10.89	100	3	130.7	8.4
Q9	3.09	80	1	15.5	
Q10	37.43	100	40	5988.8	20.48
Q11	7.31	100	10	292.4	
Q12	36.96	100	70	10348.8	>17248.0
Q13	0.12	80	<1	<0.6	
Q14	39.95	100	40	3692.0	
Q15	0.79	80	2	7.9	467.3
Snowdon (Crib Goch)					
Outside exclosure	1.81	50	2.0	35.95	
Inside exclosure	3.37	75	2.0	26.96	1.33
Inchnadamph NNR					
Ql (inside lower)	23.7	100	15	355.5	87.55
Q2 (inside upper)	44.69	100	8	357.5	88.05
Q3 (outside)	2.03	50	<1	<4.06	

inside exclosures with that in the immediately vicinity. No attempt was made to apportion the effects to any of the possible causes outlined above but, as the main grazing animal is sheep and given the nature of the British uplands, it is most likely that grazing is the major cause.

The methods used for assessing the changes in the lichen vegetation brought about by grazing are subject to a considerable amount of error. The placement of the quadrats on a 'representative' area of vegetation is largely subjective and liable to be biased in favour of lichen-rich areas whereas the assessment of percentage lichen cover, in both the specimen removed for biomass determination and the relevé, is susceptible to a considerable degree of interpretation. However, these will be the same for both sets of relevés (*e.g.* inside and outside the exclosure) and will be, to some extent, self-compensating.

The overall results are so clear-cut that concerns with the objectivity of the methods are inconsequential. At Moor House there is a biomass increase inside the exclosures of 467.3 and 17248 fold at low altitude and between 8.4-94.5 fold at higher altitudes, whereas at Inchnadamph the increase is around 87 fold (Table 3). These figures are largely related to degree of montanicity, the low-level site at Moor House being upland in character whereas the high-level site and

Inchnadamph are sub-montane. This is supported by the results from Snowdon, the only true montane site, which yielded an increase of 1.33 fold; although taken in isolation even this increase (33.3%) is far from inconsequential. The increase at this site is also probably low because of the ineffective nature of the exclosure.

There is also a possible positive correlation between an increase in lichen biomass and lichen-rich vegetation. That is, there is a greater increase in lichen biomass inside exclosures on lichen-rich heaths. In the high-altitude exclosures at Moor House the increase in biomass is, to some extent, associated with the percentage lichen cover inside the exclosure (Table 3). This is to be expected as outside the exclosure the lichen vegetation will be grazed down to a similarly low figure whether it was originally lichen-rich or not. As none of the exclosures were specifically placed on lichen-rich vegetation this suggests that the results obtained are, if anything, under-estimates and further emphasise the need for exclosures erected on lichen-rich vegetation.

The effects on species diversity are less clear. Many of the changes in species number and individual cover values are not significant, falling well within the range of chance occurrences. However, there is a clear, inverse relationship between species diversity and height of vegetation. This is most pronounced in the exclosure at Moor House NNR erected over limestone (Table 4) but is also apparent in the other heathland exclosures. At the first low level exclosure at Moor House (Table 1, Q12 & 13) where the vegetation is lower inside the exclosure, possibly due to grazing by rabbits, the lichen species diversity increases from two species outside the exclosure to five species inside, whereas at the high level exclosures on Little Dun Fell, where the vegetation outside the exclosures is 2 cm tall and that inside 8 and 12 cm tall, the lichen species diversity falls from 12 outside to 9 and 5 respectively inside.

This decrease in lichen species diversity with increase in height of vegetation is due to the structure of the vegetation inside the exclosure. This is a closed sward of tall grasses (or other monocotyledons) and tussock-forming bryophytes with which most lichens, especially crustose ones, are unable to compete successfully. This is especially true of saxicolous species as low-lying rocks and pebbles are completely covered by the vegetation (Fig. 1). The only lichens that can compete are the fruticose species that grow up with the vascular plants (*i.e. Cetraria islandica* and *Cladonia* subgenus *Cladina* spp.).

There are exceptions to this trend, most noticeably in the exclosures on blanket peat where the structure of the vegetation is very different and a closed sward is not formed inside the exclosure. Although the height of the vegetation increased significantly in both exclosures sampled, the lichen species diversity remained at the same low figure in one (although different species were involved) and increased significantly (from four to twelve) in the other.

Results from the other two sites from which data were gathered were less conclusive. At Crib Goch (Snowdon) there was an increase in the number of lichen species inside the exclosure from 14 to 20 but no change in the height of vegetation. This suggests that at higher altitudes, where vascular plant growth is less vigorous, grazing does not have the beneficial effect on species diversity observed at Moor House NNR and may actually reduce it. At Inchnadamph

Table 4. Correlation between height of vegetation and lichen species diversity from exclosures at Moor House NNR.

Substratum	**Acid grass-heath**			**Limestone**		**Blanket-peat**				**Lichen-rich heath**		**Calcareous grass-heath**			
Relevé (quadrat no.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Inside/Outside exclosure	In	Out	In	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Height of vegetation (cm)	8	2	12	15	2	17	5	12	6	25	2	1.5	3	4	2
Terricolous lichens	9	12	5	1	11	2	2	12	4	5	7	5	2	7	7
Saxicolous lichens	14	14	7	0	8	0	0	0	0	0	6	0	0	0	0
Total lichens	23	26	12	1	19	2	2	12	4	5	13	5	2	7	7

Fig. 1. Large exclosure on Little Dun Fell, Moor House NNR – showing the effects on the vegetation of the removal of grazing animals.

changes in both species diversity and height of vegetation were both small and variable.

Cetraria islandica and *Cladonia* subgenus *Cladina* spp. were the lichens most favourably affected by the reduction in grazing. Not only did their biomass and percentage cover increase but the plants were also much better formed, often occurring as large, rounded tussocks. The situation in the Snowdon exclosure was rather different with *Cetraria islandica* not occurring and only one thallus of the subgenus *Cladina* (*Cladonia arbuscula*) being seen. Here the main change in the vegetation was the presence of *Stereocaulon condensatum* inside the exclosure. It seems that this species is absent from either extreme due to grazing pressure at one end of the continuum and competition from higher plants at the other. The other notable difference inside the exclosure is the increased number of *Cladonia* spp., which is significant with regards to the climax vegetation as these are usually the most numerous lichens in ungrazed grass-heaths.

The data also show that grazing can have a qualitative effect on the lichen vegetation in addition to the expected quantitative one. This is best illustrated from the relevés on limestone at Moor House, especially the high altitude ones (Table 1, Q4 & Q5). Here the lichen vegetation inside the exclosures is very different from that outside; having much more in common with that inside the exclosures on nearby acidic grassland (Table 1, Q2 & Q3). This convergence is brought about by the lush growth of vascular plants and bryophytes inside the exclosure that form a cushion 10-20 cm thick and this isolates the lichens from the limestone substratum. The surface of this cushion has a pH of 4.5 compared with the litter layer outside the exclosure with a pH of 5.5-5.7. Consequently, with reduced grazing, an acid layer builds up and the substratum becomes less of a factor in determining the composition of the lichen vegetation enabling normally calcifuge species (*i.e.* *Cetraria islandica*, *Cladonia* subgenus *Cladina* spp.) to grow over limestone. This effect was also seen at Inchnadamph NNR where limestone boulders and outcrops are prominent features outside the exclosures whereas inside they are submerged beneath a luxuriant cover of predominately calcifuge vegetation.

There is clear evidence of an adverse quantitative effect by grazing animals on the lichen vegetation of upland/submontane heaths (Fig 1). However, the evidence for a detrimental effect on montane lichen vegetation is largely circumstantial, being an extrapolation from data obtained from lower altitudes supported by evidence from one site (Crib Goch). The limited information obtained from Crib Goch, the one truly montane area from which it was possible to obtain data, suggests that grazing has less of an impact at higher altitudes but as these data were obtained from a lichen-poor heath, and the exclosure was not securely fenced, more direct evidence is required before reliable conclusions can be reached.

The potential decrease in lichen species-diversity upon the cessation of grazing must be taken into account when exclosures are to be erected in areas important for their lichen vegetation (*e.g.* Ben Lawers NNR). It has been shown (Fryday, 1996) that, at low to intermediate altitudes, tall-herb communities outcompete the lichen vegetation with the result that the latter is considerably impoverished. With the cessation of grazing, it is possible that the tall-herbs will become dominant around the base of some crags and have a serious adverse effect on the internationally important lichen vegetation.

In order to assess the effects of grazing on montane lichen vegetation more exclosures are required on areas of lichen-rich vegetation. The area most suitable for these would be the Cairngorm Mountains, which has by far the best-developed terricolous lichen vegetation in the British Isles (A. Fryday, (in press). The lichen-rich summit heath of Beinn a'Bhuird would be an ideal location for exclosures for general monitoring but a further possibility would be the Northern Spurs which are the main locality of the prostrate *Calluna vulgaris-Cladonia arbuscula* heath (NVC U13). One of these, Creagan Dubh, supports a substantial colony of *Alectoria ochroleuca*. This species forms a major component of lichen-rich heaths in Scandinavia and the erection of exclosures or small exclosure cages over part of the colony would yield invaluable information on the effects of grazing, and also help ascertain whether its absence elsewhere in the British Isles is due to over-grazing.

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