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Persistence of *Carex bigelowii-Racomitrium lanuginosum* moss heath under sheep grazing in the Grampian Mountains, Scotland.

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Abstract

Carex bigelowii-Racomitrium lanuginosum moss heath has been monitored on the summit of Glas Maol since 1990 to assess the impact of herbivores and snow-lie. This vegetation community has high conservation value in Britain, being near-natural and the habitat of some rare arctic-alpine birds. In recent decades it has decreased in extent in British uplands, and changed in composition due to declining *Racomitrium* cover, with the main drivers believed to be heavy grazing and nitrogen deposition.

Permanent plots were established for the monitoring, laid out at fixed distances from a ski corridor built in 1986. Sheep grazing was assessed by pellet-group counts, and botanical composition by point-quadrat analysis. Monitoring was in summer annually between 1990 and 1996, but less frequently since.

The moss heath was found to retain its main characteristics from 1990 to 2008/09, with *Carex bigelowii* Torr. *ex* Schwein dominant and *Racomitrium lanuginosum* (Hedw.) Brid. having much cover. There was a small but significant increase in grasses, and lichens declined, but the community remained species-poor. Some ground experienced increased grazing pressure and suffered a temporary decline of *Racomitrium*, but recovery followed despite continuing substantial grazing. The species experiencing greatest change was *Dicranum fuscescens* Turner, which first increased but later lost most of its cover; its relationships to *Racomitrium lanuginosum* are discussed.

Keywords: Montane heath, *Racomitrium lanuginosum*, Sheep grazing, Snow-lie, Vegetation composition

Introduction

Montane heaths containing *Racomitrium lanuginosum* (Hedw.) Brid. have high conservation value in Britain, being the preferred habitat of the rare dotterel (*Eudromias morinellus*), for which Special Protection Areas (SPAs) are designated under the EC Birds Directive (Galbraith *et al*., 1993; Thompson *et al*., 2003; Thompson *et al*., 2012). The birds nest in the heaths and feed on invertebrates within the *Racomitrium* carpets, e.g. tipulid larvae (Smith *et al*., 2001). However, there is concern that heavy grazing by sheep is causing these heaths to decline in extent and change in composition with loss of *Racomitrium* (Thompson *et al*., 1987; Ratcliffe & Thompson, 1988; Thompson *et al*., 2012). Nitrogen deposition can also damage *Racomitrium* (Baddeley *et al*., 1994; Jones *et al*., 2002; Pearce *et al*., 2003), and moreover helps the spread of graminoids (Armitage, 2010); these are usually introduced into the heaths by sheep. The increased cover of graminoids may then attract more herbivore usage, so the interaction of grazing with nitrogen deposition substantially increases the overall threat to *Racomitrium* (Van der Wal *et al*., 2003, 2011; Armitage *et al*., 2012). Over much of the British range of this community there is monitoring of Special Areas of Conservation and SPAs to assess if conservation targets are being met for habitats and birds respectively (see Van der Wal *et al*., 2011, Thompson *et al*., 2012). However, we lack detailed data on the nature of changes in vegetation and their drivers (e.g. Ross *et al*., 2012).

In 1990 we began detailed studies on a montane heath around the summit of Glas Maol, part of the Caenlochan SPA designated for its dotterel population. This mountain in the eastern Scottish Highlands had long been grazed by sheep and had a substantial breeding population of dotterel (Galbraith *et al*., 1993). Our study was triggered by the construction of a fenced skiing corridor along the edge of the summit plateau in 1986; this 800 m long corridor clearly modified sheep usage on Glas Maol since it prevented sheep from moving directly between favoured grazings on the summit and in an adjacent corrie. The fencing also gave the sheep some shelter, causing greater usage close-by. Furthermore, the fencing was designed to intercept drifting snow, increasing the depth and duration of snow-lie within the corridor and immediately outside, and *Racomitrium* is adversely affected by snow-lie (Rodwell, 1992). We therefore monitored vegetation composition, sheep usage and snow-lie in zones near the ski corridor, our aim being to determine the threshold impacts that *Racomitrium* could tolerate, to aid the conservation of the heaths.

Loss of cover by *Racomitrium* close to the ski corridor from 1990 up to 2002 due to the increased sheep usage and snow-lie has previously been described (Welch *et al*., 2005; Scott *et al*., 2007). Now we report on the zone distant from the fencing, recording trends in cover up to 2008/09. In the earlier papers, and a detailed study on the patterns of sheep grazing that ran from 1990 to 1996 (Welch & Scott, 2001), the fencing was found to have a negligible effect in increasing usage in this distant zone, which runs parallel to the corridor 19 to 45 m away.

Study area

Glas Maol is a mountain rising to 1068 m (56º53'02" N, 03º22'02" W) that has a very large summit plateau of c. 100 ha. This plateau is surrounded by steep escarpments and crags, and the ski corridor was built along the top of one of these escarpments to connect an uplift tow to downhill ski runs (Figure 1).

The climate is wet and cold, having been assigned by Birse (1971) to his hemi-oceanic, extremely humid, lower oro-arctic type (defined as having 0 mm annual potential water deficit and receiving yearly 300-500 day degrees C). The plateau is very exposed, which much reduces snow-lie. The yearly deposition of total nitrogen has been estimated at 14-20 kg ha^{-1} (Pearce *et al*., 2003; Armitage, 2010; Armitage *et al*., 2011).

The vegetation of the plateau is mainly *Carex bigelowii-Racomitrium lanuginosum* moss heath typical sub-community, which is U10b in the National Vegetation Classification for Great Britain (Rodwell, 1992). The soils are well-drained rankers, and the underlying rocks are graphitic schists or slates, with all rock outcrops and scree areas uniformly acidic.

Glas Maol is grazed by many sheep, some mountain hares (*Lepus timidus*) and infrequently by red deer (*Cervus elaphus*). The sheep visit during the summer, mainly from June to September, as reported in Welch & Scott (2001). In the early years of that study they came from three different flocks which grazed in three separate glens radiating away from the mountain, but the flocks from the south-east and south were removed respectively in the autumns of 1995 and 2001. This caused little reduction in usage on the summit plateau, confirming our belief that most of the sheep grazing there came from Glen Clunie, which runs north from the mountain. This flock had a much easier route to the plateau, since broad tracts of grassland run down escarpments on its north face.

The ski corridor erected in 1986 blocked the main access to Glas Maol summit from the north, and in its early years could not be crossed by sheep (Welch & Scott, 2001). However in 1992 the sheep made several gaps in the fence palings, and so could move between their favoured grazings, of *Carex bigelowii* Torr. ex Schwein on the plateau and grass swards in the corrie below, with much less detour. The fence was repaired in summer 1996, but soon gaps again appeared, the fence palings having weakened with age. From 2000 to 2009 the fence was not a barrier to sheep movement although it still gave shelter.

Methods

Fixed plots were used to monitor sheep use and vegetation composition. They were placed separately and in a set pattern along transects that extended at right angles from the ski corridor. These transects were spaced at random distances along the corridor, 15 on the plateau side and 3 on the escarpment side. Additionally, snow drifts were mapped during site visits in May and June for six years (1991 to 1996), enabling days of late snow-lie to be estimated for the monitoring areas.

To monitor sheep use, we counted and cleared pellet groups from 10 m x 2 m plots whose long axes ran parallel to the ski corridor; they were positioned at 23-25 m and 43-45 m distance from the corridor. Visits were made at three-week intervals, ensuring that there would be no losses from decomposition. Monitoring began in early July 1990, when the plots were set out, extended to October 1990, and continued from May to October each year from 1991 to 1996 and again in 2004. Indirect assessment of herbivore usage from dung deposition is a technique frequently used by surveyors, and pellet-group counting was reviewed by Neff (1968). We chose long narrow plots to minimise errors in searching by having a plot width that gives a single observer a full view across the plot, but is not so narrow as to increase the edge/area ratio (which increases the error due to pellet groups that straddle the edges), and to be of sufficient size that zero counts were few. Pellet groups straddling plot edges were counted only if most pellets lay within the plots. Herbivore species were distinguished by the shape, size and texture of their dung.

Botanical composition was assessed using 50 point-quadrats in 1 m x 0.5 m areas. The merits and weaknesses of various forms of assessment using point quadrats are considered in Greig-Smith (1983), and our chosen method of permanent positions at random distances along the ski corridor enables change to be measured precisely. These areas were positioned away from the dung plots to avoid trampling damage and any effect of cleared dung, their distances from the ski corridor being 19-20 m and 39-40 m. Hence, with two recording areas on each transect, there were 1500 point-quadrats on the plateau and 300 on the escarpment. We used a 5-pin frame with the pins 10 cm apart, and in each 1 m x 0.5 m area we placed the frame in 10 positions 10 cm apart along the transect line; we recorded all plant species touched by a pin. Recording was first done in early July 1990, timed to coincide with the annual peak in shoot growth of *Carex bigelowii*. Recording in later years took place within the same 15-day period, for the plateau in the Julys of 1991-1996, 2002 and 2008, and for the escarpment in the Julys of 1991, 1993, 1997, 2003 and 2009.

To find significant changes in 1) pellet-group counts between recording periods and 2) species cover between main recording years, we did paired t tests separately and combined for the 6 escarpment and 30 plateau recording areas. For the dung recording periods, annual counts were aggregated between the initial and final July observations that fitted most closely to the timings of the July botanical recordings, then a mean count per year was calculated to allow comparison between periods and also to the 2004 totals. We then compared escarpment and plateau deposition by one-way ANOVA. For *Racomitrium lanuginosum* we searched for relationships between its cover trends and both pellet-group counts and days of late snow-lie, pairing in linear regressions each point-quadrat area (n=36) with the dung plot 3 m further along the transect.

Results

Sheep usage, as measured from counts of pellet groups, was much lighter on the plateau than the escarpment, the differences in yearly deposition rate being highly significant in each of the four recording periods (Table 1). On the plateau, the deposition rate was significantly greater in the 1994-1996 period than in the two preceding periods or in 2004 ($P<0.001$ in paired t tests). On the escarpment, a similar pattern of sheep use was recorded with deposition much reduced in 2004, but the between-period differences were not significant probably because there were just six plots. A few pellet groups were judged to be from red deer, chiefly in 2004, but at most they would have added 2 pellet groups 100 m^{-2} to the reported rates if they actually were from sheep.

The botanical composition of the moss heath in the zone distant from the ski corridor was very poor in species and changed little since *Carex bigelowii* stayed dominant and *Racomitrium lanuginosum* had much cover in all analyses (Table 2, Figure 2). Some subsidiary species did show definite trends over the 18/19-year study period, particularly grasses, lichens and *Dicranum fuscescens* Turner. Grasses more than doubled in cover whereas lichens declined, their losses being significant on the plateau (Table 2) and also for the combined sectors. On the escarpment *Deschampsia flexuosa* (L.) Trin. increased markedly (Figure 2), but was very patchy, never being hit in three of the six recording areas in any analysis. However, this species together with *Agrostis capillaris* L. and *Nardus stricta* L. contributed to the significant overall increase of the combined grass group on the escarpment (Table 2). Also both *Agrostis* and *Deschampsia* showed significant increase ($P<0.05$) when the plateau and escarpment data were combined.

Racomitrum declined in the early years of monitoring and then recovered, this trend being much more pronounced on the escarpment (Figure 2). It also occurred patchily, exceeding 70% cover in every analysis in four recording areas but being absent or with cover less than 5% in five recording areas that experienced prolonged snow-lie (see Figure 1 in Welch *et al*. (2005) for distribution of snow-lie; the maximum 6-year average for a recording area was 19 days late snow-lie). *Dicranum fuscescens* had peak cover in 1996/97, but then was sharply reduced, the losses over 12-year periods being significant at $P < 0.001$ on the plateau and $P = 0.036$ on the escarpment. By 2008 *Dicranum* had no cover in almost half the plateau recording areas, and much of its cover of 5.5% was contributed by the two areas that had most snow-lie and lacked any *Racomitrium*. For *Polytrichastrum alpinum* there was no clear trend on the escarpment (Figure 2), but a slow rise on the plateau was significant over the 18 years of monitoring (Table 2).

The changes in cover of *Racomitrium* from 1990 to 1996/97 were found to have only weak non-significant relationships to sheep usage and late snow-lie recorded over this period. However, the actual cover of *Racomitrium* in 1990, as in 1996/97, was significantly negatively related to sheep usage and late snow lie from 1990 to 1996, implying that similar pressures exerted before July 1990 had already affected its cover then ($F_{1,34} = 5.29$, $P = 0.028$ for 1990 cover in relation to 1990-1996 dung; $F_{1,34} = 8.85$, $P = 0.005$ for 1990 cover in relation to 1991-1996 late snow lie). For cover changes after 1996/97 we could only calculate a regression value on dung and snow up to 1996/97, but interestingly found a positive relationship between 1996/97-2002/03 cover change and 1992/93-1996/97 dung counts: in a multiple regression that included 1991-1996 late snow-lie the adjusted R^2 was 12.7% ($F_{2,33} = 3.54$, $P = 0.41$), with $P = 0.013$ for dung and 0.082 for snow-lie, this latter factor having its usual negative relationship.

Discussion

Persistence of the *Carex bigelowii-Racomitrium lanuginosum* moss heath on the Glas Maol plateau at present is amply proved by our recordings in 2002 and 2008. *Racomitrium* now has greater cover than in four recordings from 1992 to 1995, and *Carex bigelowii*, with 61% cover in 2008, was still the clear dominant (Table 2). *Carex bigelowii* did have significantly less cover than in 1990, but is much more liable than *Racomitrum* to vary in cover between years due to its growth pattern and the impact of sheep grazing. At the end of winter *Carex bigelowii* has no green shoots, its rhizomes lying within the moss and litter layer, but it then grows rapidly. Our recordings were all made during a 15-day period in early July when we judged that cover peaked before the sheep grazed down the shoots and inflorescences.

The significant increase of grasses observed up to 2008 could have important implications, in attracting more herbivores to the moss heath. However these grasses were usually shorter than *Carex bigelowii* in July and August, and probably it is the development of a substantial standing crop of *Carex* that induces sheep to visit the Glas Maol plateau; in our detailed studies on sheep usage from 1990 to 1996 (Welch & Scott, 2001) we found greater usage in June in a year which had higher mean temperatures in May and June leading to earlier sedge growth. The rate of increase in grass cover on the plateau was somewhat reduced after 2002 and the cover so far attained (13.5%) is well within the range (Domin value up to 6 for two grass species) reported for the *Carex bigelowii-Racomitrium lanuginosum* moss heath typical sub-community (Rodwell, 1992), so is only a minor concern for its conservation. The loss of lichens is noteworthy, but does not influence the phytosociological status of the heath; Rodwell reported that the "limited role" of lichens was a striking feature of the community.

Dicranum fuscescens declined sharply after 1996/97 (Figure 2), this being the greatest compositional change seen during our 19 years of monitoring. Scott *et al*. (2007) showed a significant negative relationship between this species and *Racomitrium* at small spatial scale, having analysed hits at individual point-quadrat pins, and Rodwell (1992) reported that *Dicranum fuscescens* often occurs in NVC U10 moss heath in tiny depressed areas that "hold a little more snow" and hence where *Racomitrium* was less dominant. A broader-scale negative relationship between the two mosses was observed for the zone adjacent to the ski corridor between 1990 and 1996, *Dicranum* significantly increasing and *Racomitrium* significantly declining, due, we considered, to increased herbivore usage and snow-lie (Welch *et al*., 2005). However, the recent *Dicranum* decline on the plateau distant from the ski corridor, cannot be attributed to competition from *Racomitrium* since both species had substantial cover there in 1990 (*Dicranum* 27%, *Racomitrium* 43% (Table 2)) and *Racomitrium* cover was hardly changed in 2008 (42%). We earlier suggested that warmer, drier summers could be partly responsible (Welch *et al*., 2005), and a further reason is very probably reduced total yearly snow-lie since 1996; we were able to measure only spring snow-lie, which may well not have been closely related to total snow-lie on the plateau.

On the escarpment the marked increase in *Racomitrium* from the low point observed in 1991 (Figure 2) shows that it can thrive despite considerable usage from sheep. This is one of the few recorded examples of this heath recovering under grazing pressure. The pellet-group counts on the escarpment were much greater in all periods than on the plateau for this zone distant to the corridor (Table 1), which raises questions as to why *Racomitrium* has not increased on the plateau. Perhaps its cover there is checked by dense tall growth of *Carex* and the presence of rocks, despite exceeding 50% in half the 36 1 m x 0.5 m recording areas in at least one analysis, and reaching 80% in eight of them. Evidence for a negative relationship between *Carex* litter and *Racomitrium* biomass was obtained at sites across Glas Maol summit in August 2002 (Van der Wal *et al*., 2005); the probable mechanism was light extinction since light levels above the moss layer were reduced when graminoid litter exceeded 50% cover, and experiments showed that *Racomitrium* had poor tolerance of shade.

The recovery of *Racomitrium* on the escarpment and the positive relationship between the 1996/97-2002/03 increment and 1992/93-1996/97 dung deposition could have other explanations. Perhaps more niches were available for *Racomitrium* growth where it had lost considerable cover, but had still presence, than in normal mature carpets; in all four recording areas that had cover ranging from 6 to 44% in 1991 it had gained cover by 1993 and thereafter cover averaged almost double its 1991 amounts. Also when sheep usage was heavy we perhaps under-recorded *Racomitrium*, its living stems appearing dead or obscured in the litter due to trampling, Moreover it has now been found that *Racomitrium* growth is enhanced when nitrogen availability is greater (Armitage *et al*., 2012), as probably resulted from the heavy grazing in the early 1990s. A definite conclusion for the escarpment is that sheep grazing had quickly affected the vegetation and reduced *Racomitrium* after the ski corridor`s construction in 1986. Indeed, we believe that *Racomitrium* had quite similar cover on the escarpment to the plateau prior to 1986, but have no measurements to prove this.

That sheep were the main herbivore rather than red deer on a high Scottish mountain may cause surprise, but their thick wool coats give them good resistance to the severe windy climate and red deer prefer more-sheltered situations being originally forest dwellers. We earlier reported (Welch & Scott, 2001) on the patterns of sheep and deer usage for the district around Glas Maol, and referred to a previous study on the grazing of the mountains around Ben Lawers, Perthshire (Colquhoun, 1970) that similarly found greater usage by sheep than deer on high-level *Carex* swards. We suggested that an additional reason for the greater sheep usage of these swards could be that they are more able than red deer to secure satisfactory intake from low-height swards. In our visits to Glas Maol from 1990 to 2000 we almost always saw herds of c. 200 hinds in the corries north of Glas Maol (Welch & Scott, 2001), and this regular occupancy has continued up to 2013. Doubtless there has been similar heavy usage by red deer in Caenlochan Glen to the south-east of Glas Maol (Figure 1), hence the Caenlochan SSSI management plan stating that deer grazing is a serious problem.

The effect of the fencing condition in controlling sheep behaviour and occupancy was examined in Welch & Scott (2001). The poorer performance of *Racomitrium* on the plateau compared to the escarpment from 1991 to 1995 (Figure 2) can be partly explained by the increasing number of fence gaps allowing more sheep visits to the plateau then, and fewer sheep being held back on the escarpment below. Then the 1996 fence repairs led to a higher dung deposition rate on the escarpment for the July 1995-July 1997 period (Table 1) and the small decline in *Racomitrium* cover (Figure 2). Using a conversion factor of 17 pellet groups deposited by a sheep per day (Welch, 1982), the estimated annual sheep stocking experienced in the 1990s, and survived by *Racomitrium*, was roughly 1 sheep ha^{-1}, rather more on the escarpment and rather less on the plateau.

The persistence of *Racomitrium* on Glas Maol since 2000 could have benefited from the removal of the Glen Shee sheep flock in 2001 (Figure 1). More importantly, the flock summered in Glen Clunie was reduced by roughly 100 sheep from its previous size of c. 700 sheep in 2003, this being encouraged by Invercauld Estate in the interests of grouse shooting, and we have observed sheep in that glen for shorter total time in recent years. Unfortunately we could not maintain the three-weekly monitoring on Glas Maol, except in 2004, but the pellet-groups counts were significantly reduced that year (Table 1). A count in early July 2009 found deposition had been 50% less than the average for the same period in 1993-1996 on these distant-zone plots. Further visits to Glas Maol in the summers from 2010 to 2013 confirmed that sheep pressure was reduced and *Racomitrium* remained in good condition in our study area.

This study will continue to monitor changes in the Glas Maol heath and hopefully provide pointers to how other heaths and protected areas may change in response to environmental factors. South of the Highlands, where historically these montane heaths have deteriorated so much that nesting dotterel have been lost (Thompson *et al*., 1987, 2003, 2012), there is now evidence of sheep grazing pressure declining and heaths recovering (Van der Wal *et al*., 2011, pers obs). Our study at Glas Maol provides one of very few pointers to the timescale of potential recovery of the heath.

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Captions to figures

Figure 1. Map (4.5 x 4.5 km) showing Glas Maol, the three main glens radiating north, south-east and south, contours at 200 m intervals, the ski tow and corridor running north from the tow top, and areas of crag or scree (stippled). The monitored plots lay immediately east (plateau) and west (escarpment) of the corridor.

Figure 2 Trends in percentage cover of three main moss species and a grass measured by point-quadrat analysis in two sectors of the summit of Glas Maol (plateau - dotted line), escarpment - solid line).

Figure1.

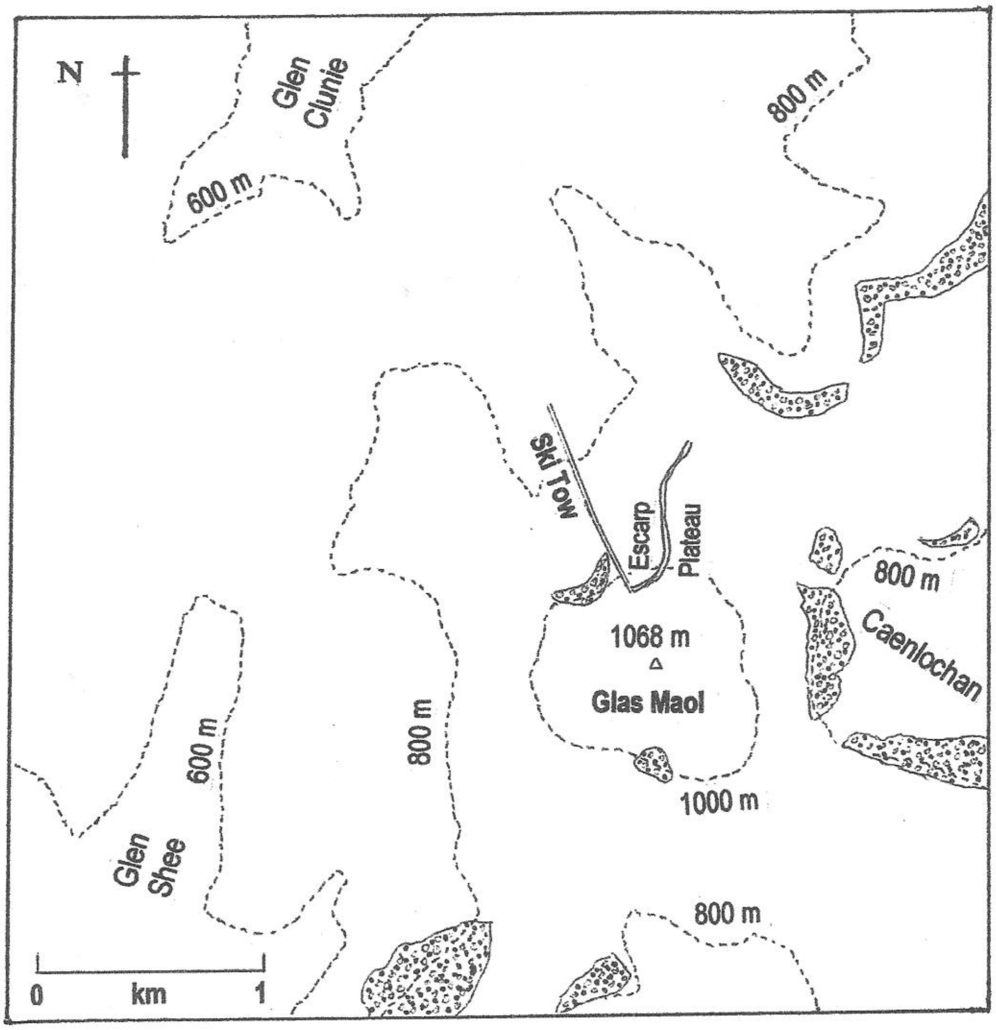
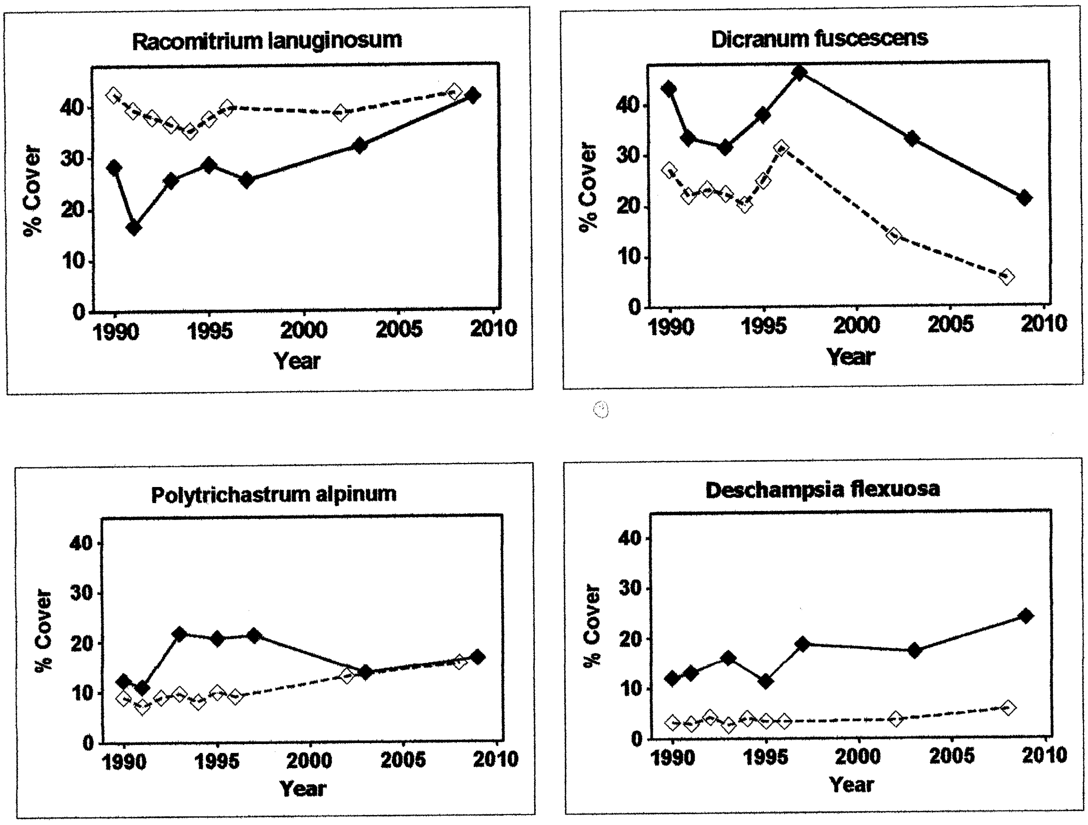


Figure 2.



Racomitrium lanuginosum
Dicranum fuscescens
Polytrichastrum alpinum
Deschampsia flexuosa
% Cover
Year
0
10
20
30
40
1990
1995
2000
2005
2010

Table 1 Trends in sheep usage distant to the ski corridor for two sectors of Glas Maol summit, as estimated by pellet-group counts (groups 100 m^{-2} yr). All periods but 2004 start and end at the July count nearest to the time of vegetation recording. Standard errors are given, together with F-ratios ($F_{1,34}$) and *P* values for comparisons between plateau and escarpment.

Plateau		Escarpment		F-ratio	*P* value
Period	Pellet Groups	Period	Pellet Groups		
1990-92	26.4±3.9	1990-93	74.2±12.5	21.92	0.000
1992-94	25.5±3.6	1993-95	54.6±11.9	9.45	0.004
1994-96	36.2±3.9	1995-97	81.3±24.1[1]	11.01	0.002
2004	18.0±1.9	2004	48.3± 9.3	47.14	0.000

[1] for 1997, pre-July usage was assumed the same as pre-July usage in 1996.

Table 2 Changes in vegetation composition since 1990 in two sectors of the summit of Glas Maol. Includes all species with cover >1% in a recording. Significant changes from 1990 to 2008/9 in paired t tests for the 30 plateau and 6 escarpment 1 m x 0.5 m recording areas are shown: +/- P<0.05, ++/-- P<0.01, +++/--- P<0.001.

	% mean cover									
	Plateau					Escarpment				
	1990	1996	2002	2008	90-08 Sig.	1990	1997	2003	2009	90-09 Sig.
Agrostis capillaris	0.5	1.3	3.3	2.9		7.0	8.7	11.7	10.3	
Deschampsia flexuosa	3.2	3.3	3.6	5.7		12.0	18.7	17.3	24.0	
Festuca ovina	1.3	1.7	3.3	4.9	+	1.7	1.0	0.7	0.3	
Nardus stricta	0.7	0.0	0.7	0.9		0.0	0.0	1.0	2.7	
All Grasses	5.5	6.1	10.4	13.5	++	20.3	27.7	28.7	35.7	+
Carex bigelowii	69.1	52.7	58.1	61.3	-	51.0	43.7	44.3	46.0	
Galium saxatile	1.7	0.3	1.7	1.3		0.0	1.0	1.3	1.3	
Vaccinium myrtillus	0.9	0.2	0.0	0.3		1.7	1.7	1.0	1.0	
Dicranum fuscescens	27.3	31.4	13.8	5.5	---	43.3	46.3	33.0	21.0	
Pleurozium schreberi	0.5	0.8	1.6	3.1	+	0.0	0.0	0.0	0.0	
Polytrichastrum alpinum	8.9	9.1	13.0	15.6	+	12.3	21.3	13.7	16.7	
Ptilidium ciliare	1.2	0.9	1.5	0.4		0.0	2.0	0.0	0.3	
Racomitrium lanuginosum	42.5	39.9	38.7	42.3		28.3	25.7	32.3	41.7	+
Cetraria islandica	5.7	5.1	2.9	1.3	--	3.0	4.0	4.0	2.0	
Cladonia rangiformis	2.5	2.1	1.7	1.1	-	3.0	0.3	1.3	0.0	
Cladonia uncialis	6.9	5.0	3.3	1.3	---	1.7	4.0	2.3	1.0	
Rock	0.7	0.2	0.3	0.3		0.7	1.0	0.0	0.0	
Total Number of species	16	20	21	21*		12	17	17	16	
Higher plants	7	7	7	8		5	7	7	7	
Bryophytes	5	7	7	6		3	5	4	5	
Lichens	4	6	7	6		4	5	6	4	

* total includes 1 lycopod, *Huperzia selago*