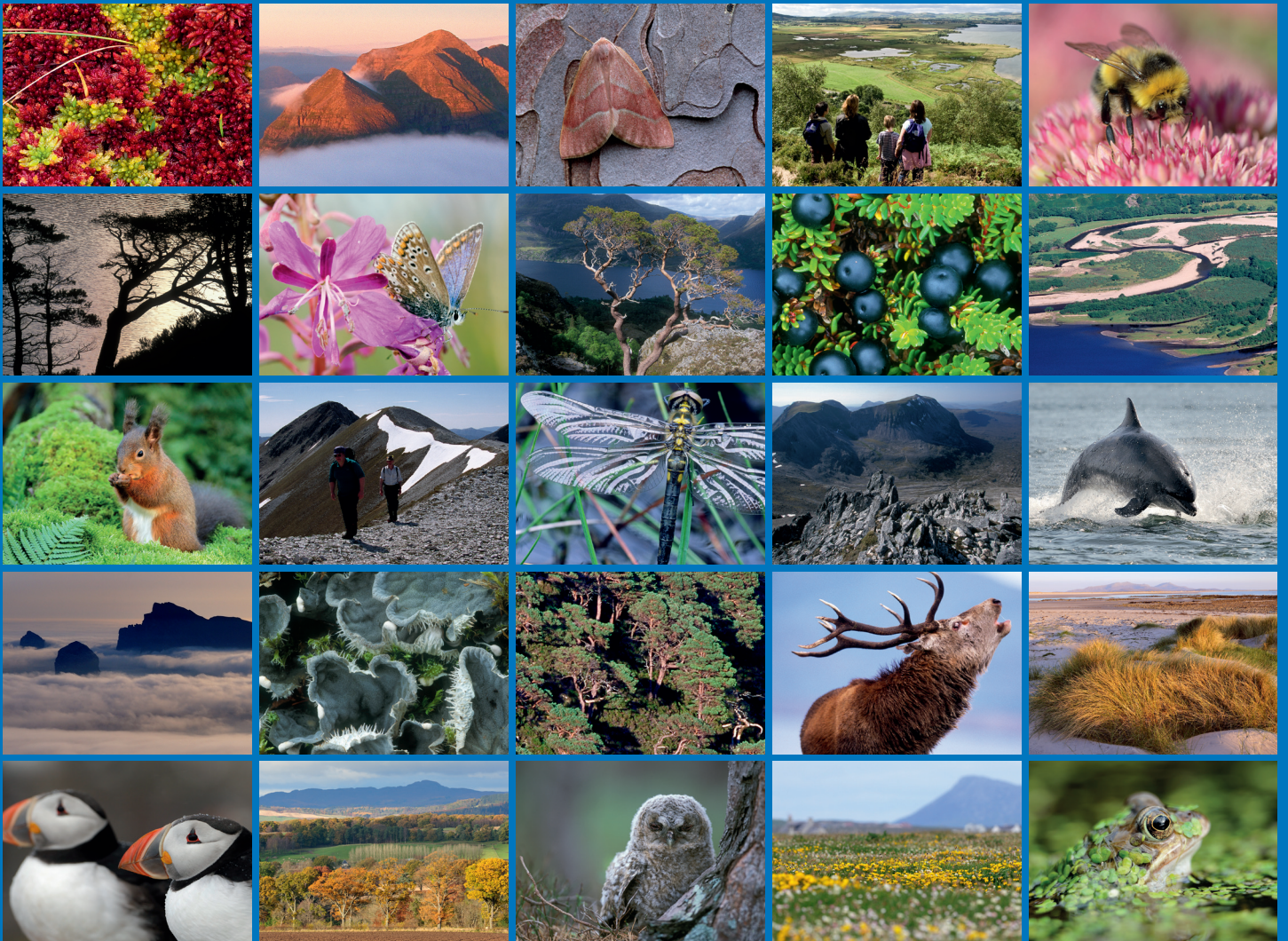


# Geographical variation in the density of grazing mammals on montane sites in the Highlands of Scotland



**Geographical variation in the  
density of grazing  
mammals on montane sites in the  
Highlands of Scotland**

Report No. F99AC402A

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## COMMISSIONED REPORT

# Summary

### **Geographical variation in the density of grazing mammals on montane sites in the Highlands of Scotland**

Report No: F99AC402A

Contractor : David McLeod

#### **BACKGROUND**

This report presents the results of counts conducted of sheep, red deer *Cervus elaphus*, and mountain hare *Lepus timidus* in the summers of 1987 - 1999 on 47 sites in the montane zone of the Highlands of Scotland. Sites ranged from Lochnagar in the eastern Grampians, to Aonach Mor/Aonach Beag in the western Grampians to Seanna Bhragh in the northwest Highlands.

#### **MAIN FINDINGS**

- Based on studies of sheep grazing similar heathland habitats in Iceland, it is suggested that only three sites were probably overgrazed by sheep, so that degradation of the vegetation may occur: Aonach Mor/Aonach Beag, A'Mharconaich and Glas Maol. It is recommended that numbers of sheep that use these sites should be reduced if the habitat is to be maintained in favourable conservation status.
- It was more difficult to judge whether densities of red deer were adversely affecting montane vegetation. However, local damage may be occurring on Ben Avon in the east Cairngorms, but reducing the high density of deer on Moine Mhor should be the highest priority if montane habitats are to be safeguarded. Away from the Cairngorms, the large herds of red deer that use east Drumochter may be causing degradation of montane vegetation, although the recent removal of sheep from this area may have alleviated problems of overgrazing. The apparently high densities of red deer across a large area of the south Grampians may represent a problem of overgrazing, and the locally high density of deer in the Ben Alder also deserves further study. Overall, however, it was apparent that many sites are probably not experiencing levels of grazing that represent a threat to the future of protected montane plant communities.

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Table 5. Mean annual densities (maximum daily count/day/km<sup>2</sup>) of sheep, red deer and mountain hare on sites in the western Grampians, Nevis range, Monadhliaths and northwest Highlands. - = no count recorded.

Fig. 1. The relationship between density of sheep on a site and density of mountain hare on a site (32 sites: P < 0.001).

## INTRODUCTION

The montane zone (low and middle alpine zone), the area above the former tree-line, covers just 3% of Britain's land surface but is an extremely important component of the uplands as it is the only substantial area of near-natural habitat left in Britain (Thompson *et al.* 1987, Thompson & Brown 1992). Annex I of the EU Habitats and Species Directive (92/43/EEC) lists many montane/alpine habitats as requiring protection through the classification of Special Areas of Conservation (SACs). As a signatory to the Directive the UK Government has classified several SACs for montane habitats in the Highlands of Scotland which must be maintained in a favourable conservation status under conditions of the Directive.

A short growing season coupled with thin soils, frequently subjected to freeze-thaw conditions, makes montane plant communities particularly sensitive to grazing by sheep and red deer (Thompson *et al.* 1987, Thompson & Brown 1992). Despite this sensitivity and the conservation value of montane plant communities, very little has been published about the ecology of grazing mammals in the montane zone of Scotland.

This report presents results of counts of grazing mammals gathered across several years on a large number of montane sites in the Highlands of Scotland. Principally it seeks to address two objectives:

- To describe any regional and local variation in the density of grazing mammals;
- To provide a preliminary assessment of whether densities of grazing mammals on any site may be having an adverse effect on montane vegetation communities through overgrazing.

## METHODS

Twenty-two montane (i.e. low/middle alpine zone, altitudes above the former tree line) sites were studied with a regime of several visits during a single field season, for at least one year. These are known as 'intensive' study sites. The number of years that intensive study sites were studied varied between sites (Whitfield 2001). Several other sites were visited only for one or two days during the course of a season, some being visited in more than one year and in some years intensive study sites were visited only once or twice (Whitfield 2001). The study period was the years 1987 to

1999 inclusive. The boundaries of all study sites were digitised in a Geographical Information System (GIS) (ArcView) allowing the area of each site to be calculated.

On intensive study sites, during each summer, a single fieldworker visited the study area on approximately one third to two thirds of days from May until the middle of August, the number of visits being determined primarily by the occurrence of suitable weather. On all sites, observers did not usually visit sites on days with strong winds and heavy rain or low cloud for safety reasons. Timing of arrival and departure from the site was recorded by the observer and varied according to the weather and the remoteness of the site. Typically, observers arrived on a site between 0900 and 1100 hours (British Summer Time: BST) and left between 2000 and 2200 hours BST.

Observers recorded all mammalian herbivores seen during the course of a visit, usually when they were first seen. If the observer considered that a herbivore had already been recorded earlier in a visit, it was not recorded again. Exceptions were when groups (flocks or herds) made substantial movements, which were recorded but with a note referring to the previous sighting to ensure there was no 'double-counting'. Sheep were usually recorded as ewes or lambs, red deer *Cervus elaphus* as hinds, calves, stags or 'knobbers' (young stags), and mountain hare *Lepus timidus* as adults or leverets.

Records of herbivores are presented as an average density per season (number per day per km<sup>2</sup>) as numbers varied both daily and seasonally (Whitfield 2001). Records of red deer from Moine Mhor in 1990 and 1991 were taken as a maximum count over each five-day period of the field season. Applying this method to data gathered using the more typical method when all counts were recorded suggested that it doubled the estimate of density. Hence, density estimates were halved when derived by the 'maximum' count method to make them comparable with other density estimates. Mountain hares were far more difficult to see than sheep or deer, and so an annual estimate of density on a site was taken as the maximum count on any day per km<sup>2</sup>.

## **RESULTS**

Estimates of herbivore densities are presented on a regional basis. Sheep, red deer and mountain hare constituted the vast majority of observations, and so only records from these three species are presented. Single roe deer *Capreolus capreolus* were seen rarely and without sufficient frequency to discern any local or regional patterns

in abundance so records are not presented. A herd of reindeer *Rangifer tarandus* was hefted on the Cairn Gorm - Cairn Lochan - Ben Macdui plateau of the central Cairngorms in some years and records are presented by Whitfield (2001).

### **Cairngorms massif**

By the end of the study period there appeared to be no sheep on any of the sites in the Cairngorms (Table 1). A small flock of up to 28 animals was present on the Cairn Gorm - Cairn Lochan - Ben Macdui plateau until 1990 but apart from observations of a stray flock of four animals in 1996, no sheep were present 1991-1999. No sheep were seen on other Cairngorms sites not visited by this study (D.P. Whitfield unpubl. data). The Cairngorms massif was unusual for the lack of sheep over such a large area.

Red deer densities were very variable from site to site but, in general, densities appeared to be low (Table 1). The striking exception to this was Moine Mhor in the western Cairngorms, where large numbers of deer were seen in most years when the site was visited. Although the maximum count in 1994 was only 140, maximum counts in other years varied from 2,500 (1990) to 670 (1992). The most recent maximum count was 818 in 1997. Herds on this site came from daytime feeding grounds in south Feshie and west Mar Lodge. The only other study sites in the Cairngorms where any large herds of red deer were seen were Ben Avon (maximum count of 331 on a 1.5 km<sup>2</sup> study plot in 1990) and Beinn a' Bhuird (maximum count of 257 in an area south of the summit in 1998), neighbouring sites in the eastern Cairngorms. Use of Beinn a' Bhuird by red deer appeared to be less than use of Ben Avon, and did not appear to be regular.

Density of mountain hare appeared to be similarly low across all the Cairngorms study sites, at around 1 animal for every 2.5 km<sup>2</sup> (Table 1). No site stood out as being particularly good or poor for this species.

Table 1. Mean annual densities (maximum daily count/day/km<sup>2</sup>) of sheep, red deer and mountain hare on sites in the Cairngorms. - = no count recorded.

Site	Grid reference	Year	Density (count/day/km <sup>2</sup> )		
			Sheep	Red deer	M hare
Moine Mhor	NN902956	1989	0	52.1	0
Moine Mhor	NN902956	1990	0	97.7	0.7
Moine Mhor	NN902956	1991	0	59.0	0.2
Moine Mhor	NN902956	1992	0	54.9	-
Moine Mhor	NN902956	1994	0	7.6	0.3
Moine Mhor	NN902956	1997	0	23.3	0.3
Carn Ban Mor	NN894972	1990	0	0	0.2
Carn Ban Mor	NN894972	1991	0	0	-
Carn Ban Mor	NN894972	1997	0	0	-
Braeriach	NN937991	1989	0	0	-
Braeriach	NN937991	1990	0	0	-
Braeriach	NN937991	1991	0	0	-
Braeriach	NN937991	1997	0	0	0.3
Cairn Toul	NN963972	1991	0	0	-
Cairn Toul	NN963972	1997	0	0	-
Monadh Mor	NN938942	1991	0	2.4	-
Monadh Mor	NN938942	1997	0	0	-
Cairn Gorm	NJ005041	1987	0.6	0	0.3
Cairn Gorm	NJ005041	1988	0.3	0	0.6
Cairn Gorm	NJ005041	1989	1	0	0.3
Cairn Gorm	NJ005041	1998	0	0	1.2
Cairn Lochan	NJ005041	1987	1	0.1	0.3
Cairn Lochan	NJ005041	1988	1.6	0	0.4
Cairn Lochan	NJ005041	1989	0.7	0.1	0.3
Cairn Lochan	NJ005041	1990	0.9	0	0.4
Cairn Lochan	NJ005041	1991	0	0	0.4
Cairn Lochan	NJ005041	1992	0	0	0.2
Cairn Lochan	NJ005041	1993	0	0	-
Cairn Lochan	NJ005041	1994	0	0	0.4
Cairn Lochan	NJ005041	1996	0.1	0	0.2
Cairn Lochan	NJ005041	1997	0	0.1	0.4
Cairn Lochan	NJ005041	1998	0	0.1	0.4
Cairn Lochan	NJ005041	1999	0	0	0.7
Etchachan	NJ007003	1998	0	-	-
Ben Avon	NJ132019	1990	0	5.2	-
Ben Avon	NJ132019	1993	0	21.3	-
Beinn a' Bhuid	NJ092006	1993	0	0.4	-
Beinn a' Bhuid	NJ092006	1994	0	0	-
Beinn a' Bhuid	NJ092006	1998	0	4.1	0.4

## **Drumochter Hills, central Grampians**

Sheep were ubiquitous in the Drumochter Hills west of the A9, but their density varied across sites, being highest on the small montane area of Meallan Buidhe and the whaleback west of A' Mharconaich summit, where 100-150 sheep grazed in some years (Table 2). Densities were lowest on Sgairneach Mhor, between Meallan Buidhe and A' Mharconaich, and intermediate on Beinn Udlamain, the highest plateau in the locale, and on Geal Charn, the lowest of the west Drumochter tops. East of the A9, up until 1998 sheep densities on the extensive plateau from Carn na Caim in the north to A' Bhuidheanach Bheag in the south were comparable with those on Beinn Udlamain and Geal Charn (Table 3). Prior to the 1998 summer sheep were no longer hefted on to the hills east of the A9.

West of the A9 herds of red deer were only occasionally seen on montane areas, and then usually at lower altitudes (confirmed by the low densities of their dung at the higher altitudes) (Table 2). The only exception to this was Sgairneach Mhor when large herds were seen feeding across the whole site in the earlier years of the study (maximum count of 420 in 1991). None were seen in the later years of the study period, however, although deer probably still continued using the site judging by the presence of dung, albeit at lower frequency and numbers. By contrast with much of the western Drumochter Hills, red deer were very common on the plateau east of the A9, with maximum annual counts on the Carn na Caim site ranging from 276 in 1993 to 1,630 in 1997 (Table 3). Typically herds would spend the day in the extensive montane bogs east of the study sites during the day and moved across the site in the evening to feed on the slopes between the plateau and the A9 during the night. Densities were only slightly less than those observed on Moine Mhor in the western Cairngorms, although Moine Mhor seemed to be more frequently used as a feeding ground than east Drumochter.

Mountain hare densities were lower on the west Drumochter Hills than the plateau east of A9 (Tables 2 & 3). West of the A9 densities were typically 1 or 2 records per km<sup>2</sup>, and were highest on Geal Charn and lowest on Sgairneach Mhor. Densities on the eastern sites were high (often 6 animals per km<sup>2</sup>), probably due to the presence of montane bog where most animals were seen.

Table 2. Mean annual densities (maximum daily count/day/km<sup>2</sup>) of sheep, red deer and mountain hare on sites in the Drumochter Hills, west of the A9. - = no count recorded.

Site	Grid reference	Year	Density (count/day/km <sup>2</sup> )		
			Sheep	Red deer	M hare
Meallan Buidhe	NN611715	1990	74.1	11.0	-
Meallan Buidhe	NN611715	1991	65.0	0	-
Sgairneach Mhor	NN599731	1990	6.9	33.7	-
Sgairneach Mhor	NN599731	1991	3.6	38.9	0
Sgairneach Mhor	NN599731	1992	9.3	18.5	0
Sgairneach Mhor	NN599731	1993	8.2	0	-
Sgairneach Mhor	NN599731	1994	0.5	0	-
Sgairneach Mhor	NN599731	1995	5.9	0	-
Sgairneach Mhor	NN599731	1999	3.0	0	0.4
Beinn Udlamain	NN579740	1990	24.9	15.9	-
Beinn Udlamain	NN579740	1991	3.5	15	2.1
Beinn Udlamain	NN579740	1992	20.2	0	0
Beinn Udlamain	NN579740	1993	15.0	0	-
Beinn Udlamain	NN579740	1994	1.3	0	-
Beinn Udlamain	NN579740	1995	15.0	0	-
Beinn Udlamain	NN579740	1999	3.7	0	1.9
A'Mharconaich	NN600750	1990	60.1	6.5	1.7
A'Mharconaich	NN600750	1991	42.8	0	2.5
A'Mharconaich	NN600750	1992	31.7	32.3	2.5
A'Mharconaich	NN600750	1993	60.6	0	3.3
A'Mharconaich	NN600750	1994	24.4	0	1.7
A'Mharconaich	NN600750	1995	68.3	0	1.7
A'Mharconaich	NN600750	1996	66.7	0	1.7
A'Mharconaich	NN600750	1997	45.6	4.3	1.7
A'Mharconaich	NN600750	1998	39.8	0.8	-
A'Mharconaich	NN600750	1999	51.7	0	2.5
Geal Charn	NN596783	1990	20.8	0.9	-
Geal Charn	NN596783	1991	11.63	0	1.1
Geal Charn	NN596783	1992	23.8	3.2	4.3
Geal Charn	NN596783	1993	17.6	0	-
Geal Charn	NN596783	1994	5.0	0	-
Geal Charn	NN596783	1995	43.2	0	-
Geal Charn	NN596783	1999	21.6	3.2	6.5

Table 3. Mean annual densities (maximum daily count/day/km<sup>2</sup>) of sheep, red deer and mountain hare on sites in the Drumochter Hills, east of the A9. - = no count recorded.

Site	Grid reference	Year	Density (count/day/km <sup>2</sup> )		
			Sheep	Red deer	M hare
Carn na Caim	NN677822	1987	-	45.4	-
Carn na Caim	NN677822	1988	21.8	59.5	-
Carn na Caim	NN677822	1989	21.4	28.9	-
Carn na Caim	NN677822	1990	25.5	93.4	6.5
Carn na Caim	NN677822	1991	22.7	25.8	6.3
Carn na Caim	NN677822	1992	21.4	25.9	7.5
Carn na Caim	NN677822	1993	25.1	11.4	4.3
Carn na Caim	NN677822	1994	11.9	37.6	3.8
Carn na Caim	NN677822	1995	-	-	5.3
Carn na Caim	NN677822	1996	-	23.5	-
Carn na Caim	NN677822	1997	29.5	69.1	-
Carn na Caim	NN677822	1998	0.4	22.8	-
Carn na Caim	NN677822	1999	0	22.1	7.8
A'Bhuidheanach	NN658791	1991	-	-	3.6
A'Bhuidheanach	NN658791	1992	65.8	9.0	1.8
A'Bhuidheanach	NN658791	1999	0	34.2	8.1
A'Bhuidheanach Bheag	NN661776	1991	-	-	4.0
A'Bhuidheanach Bheag	NN661776	1992	37.3	-	0.7
A'Bhuidheanach Bheag	NN661776	1999	0	-	-

### South-central and east Grampians

Several of the many small montane tops in the south-central Grampians, mainly from Gaick (east of Drumochter) east to Atholl, were visited, but only in one year and usually for only 1-3 days. This limited sampling should temper the results, especially with regard to red deer that showed large day-to-day variation in use of montane sites (Whitfield 2001). Some patterns do emerge, however, including the generally low densities of sheep and densities of mountain hare that were probably comparable with those on west Drumochter (Table 4). Observations of red deer were noteworthy on some sites (maximum of 330 on Sron Bhuirich in Gaick) suggesting large herds were present in at least parts of this region, and yielded the highest estimates of red deer density for the study.

Table 4. Mean annual densities (maximum daily count/day/km<sup>2</sup>) of sheep, red deer and mountain hare on sites in the south central Grampians (S Feshie, Gaick, to Atholl) and east Grampians (Glen Shee to Lochnagar). - = no count recorded.

Site	Grid reference	Year	Density (count/day/km <sup>2</sup> )		
			Sheep	Red deer	M hare
Beinn Bhreac	NN868820	1995	0	0	1.4
Beinn Mheadhonach	NN880758	1995	0	0	1.3
An Sgarsoch	NN933836	1995	0	0	0.3
Sron a' Chleirich	NN784769	1995	0	267.8	-
Leathad an Taobhain	NN822858	1995	0	110.6	-
Sron Bhuirich	NN751805	1995	0.9	143.5	-
Carn an Fhidhleir	NN905842	1995	0	0	0
Beinn a' Ghlo	NN970732	1993	0.5	2.4	0.8
Carn a' Gheoidh	NO107767	1993	24.4	12.0	16.5
Glas Maol	NO167766	1988	61.3	49.0	3.5
Glas Maol	NO167766	1989	44.6	28.4	3
Glas Maol	NO167766	1990	48.9	4.3	6.5
Glas Maol	NO167766	1991	24.2	16.6	-
Glas Maol	NO167766	1993	37.6	6.3	-
Glas Maol	NO167766	1994	68.8	54.2	-
Glas Maol	NO167766	1996	64.4	13.1	14.4
Glas Maol	NO167766	1997	61.5	0	12.8
Glas Maol	NO167766	1999	63.5	0	24.6
Garbh Choire	NO175778	1999	44.9	0	12.9
Druim Mor	NO190772	1999	16.1	0	9.7
Cairn of Claise	NO186789	1999	16.9	0	5.8
Carn an Tuirc	NO174804	1999	15.5	0	4.9
Fafernie	NO220830	1996	0	17.3	0.3
Carn an t-Sagairt Mor	NJ212840	1996	3.8	0	2.5
White Mounth	NJ240840	1996	2.0	4.1	0.3

Further east of Atholl, in the hills west of Glen Shee (represented by Carn a' Gheoidh), there was a noticeable increase in the density of both sheep and mountain hares (Table 4). This was mirrored on Glas Maol, east of Glen Shee, the site of the highest recorded densities of sheep and mountain hares of the study. North of Glas Maol, on the rolling plateau extending up to Cairn Tuirc, sheep and hare densities declined. Red deer densities in this area of the southeastern Grampians were moderate compared to other regions of the Grampians further west. Typically, deer herds that used montane areas stayed on lower elevations or used sites as routes between glens. Numbers could be substantial, nevertheless, with a maximum count of 665 deer on Glas Maol in 1994. The area of the Mounth, from Fafernie in the southwest to Lochnagar in the northeast, had low densities of sheep (those that were seen may have been strays), low-moderate densities of red deer and low densities of hares that were probably most similar to those of the Cairngorms massif.

## **The western Grampians, Creag Meagaidh and the Monadliaths**

Sheep densities were moderate on Creag Meagaidh and Carn Liath when the sites were visited (Table 5). In recent years sheep numbers on these two sites are substantially lower due to management agreements (P.Duncan pers. comm.). Densities of both red deer and hare were low. Records were collected on only two other sites in the Monadliaths, on the southeastern fringe of the massif. Sheep densities were moderate here, but hare densities were high, probably through the presence of montane bog (as on east Drumochter).

To the south of Meagaidh, the large hills of the Ben Alder range northwest of Loch Ericht typically had no sheep and moderate to locally high densities of red deer: the Ben Alder plateau appeared to be favoured by hinds for calving. Hare densities probably varied from site to site, being very low on Aonach Beag, intermediate on Ben Alder and Beinn Bheoil (similar to densities on west Drumochter to the east), and highest on Beinn a' Chlachair.

To the southwest, The Aonachs north of Glen Nevis appeared to support no hares or red deer but high densities of sheep. Subjective impressions were that this typified other hills in the Mamores to the south and The Grey Corries to the east.

## **The northwest Highlands**

Records were collected from only three sites in the northwest Highlands. Red deer densities were lower than on most sites in the Grampians to the south, with hare densities low but locally moderate on Am Faochagach (Strathvaich). Sheep grazed only on Ben Wyvis.

Table 5. Mean annual densities (maximum daily count/day/km<sup>2</sup>) of sheep, red deer and mountain hare on sites in the western Grampians, Nevis range, Monadhliaths and northwest Highlands. - = no count recorded.

Site	Grid reference	Year	Density (count/day/km <sup>2</sup> )		
			Sheep	Red deer	M hare
Carn an Fhreiceadin, Monadhliaths	NH730074	1995	1.1	0	3.6
A'Chailleach, Monadhliaths	NH669031	1992	13.0	0	7.9
Creag Meagaidh	NN423876	1993	19.0	0.2	0.2
Creag Meagaidh	NN423876	1994	12.1	0.4	0.2
Carn Liath	NN472903	1993	14.2	7.2	0.1
Carn Liath	NN472903	1994	7.2	3.4	0.1
Ben Alder	NN498719	1993	0	7.9	0.6
Beinn Bheoil	NN517718	1993	0	0	1.8
Aonach Beag	NN451753	1993	0	23.4	0
Beinn a' Chlachair	NN471781	1993	0	18.5	3.7
Aonach Mor/Beag, Nevis Range	NN196715	1992	43.1	0	0
Aonach Mor/Beag, Nevis Range	NN196715	1993	46.2	0	0
Am Faochagach	NH304795	1992	0	12.0	0
Am Faochagach	NH304795	1993	0	4.2	0.6
Am Faochagach	NH304795	1994	0	0	1.4
Ben Wyvis	NH464700	1993	11.2	0.6	0.2
Seanna Bhraigh	NH289873	1993	0	-	0

## DISCUSSION

Identifying the factors responsible for the geographical patterns of grazer abundance will require a multivariate analysis that is beyond the scope of the present report. Clearly for sheep and deer, land management practices such as stocking and culling rates respectively will bear heavily on montane abundance and all animals involved probably spent some of the year grazing on lower altitude ground. Subjectively it is apparent that low ground areas where Deer Commission for Scotland counts suggests high red deer densities are close to montane areas where the present study also suggests high deer densities. Although this is not surprising, it does tend to confirm that maintaining high red deer densities leads to an additional grazing pressure on montane plant communities, even if deer only use montane sites as a refuge against biting insects (Whitfield 2001) or when moving between alternative

feeding grounds. The montane results indicate that there are probably high densities of red deer extending across a large area of the southern Grampians from east Drumochter to Atholl. Other areas of high density appeared more localised, such as around Ben Avon and, particularly, the south of Moine Mhor in the eastern and western Cairngorms respectively. Deer herds in the glens and corries around Glas Maol did not seem to use montane ground with regularity, although large numbers of animals were involved when use did occur. Deer densities were probably lower in the central and western Grampians and northwest Highlands than in the southern and eastern Grampians, although locally there were probably large herds, such as around Sgairneach Mhor of west Drumochter. Even so, these herds did not seriously challenge those seen on east Drumochter and Moine Mhor, for example, in numbers of animals.

Sheep density will be especially conditional on decisions by landowners and tenants, rather than intrinsic environmental influences. Where areas are stocked with sheep, densities on montane sites may also be influenced by the availability of forage at lower elevations. On A'Mharconaich, east Drumochter and Glas Maol, montane densities in June and July exceeded those on surrounding moorland (D.P. Whitfield & S. Holt unpubl. data), although sheep increasingly used higher elevations as the season progressed (see also Whitfield 2001). One very noticeable pattern was the absence of sheep across large areas, such as the Cairngorms and the Ben Alder/Aonach Beag range, and the localised high sheep densities on some sites.

Mountain hare distribution and abundance was probably most likely to be related to environmental influences, and subjectively there appeared to be a within-region relationship with underlying geology. The results provide support to the arguments of Watson & Hewson (1973 and Watson et al. (1973) that underlying geology influences hare density, whereby higher densities occur on sites with more base-rich rocks than on sites with underlying granite, probably through associated nutritional influences on forage. Between-site differences in estimated densities are very similar to those described by Watson & Hewson (1973) although site estimates were usually lower in the present study, probably because Watson & Hewson (1973) used dogs to flush hares. The relationship with geology would be worth examining objectively while accounting for other possible factors such as altitude and geography. It was noticeable that densities within a site were much higher in areas of montane bog, and so the occurrence of this habitat may also have affected differences in density between sites. Simple correlations suggested no relationship between deer density

and hare density, but a positive correlation between sheep density and hare density (Fig. 1). Superficially this suggests that red deer and sheep did not have a marked detrimental effect on mountain hare density.

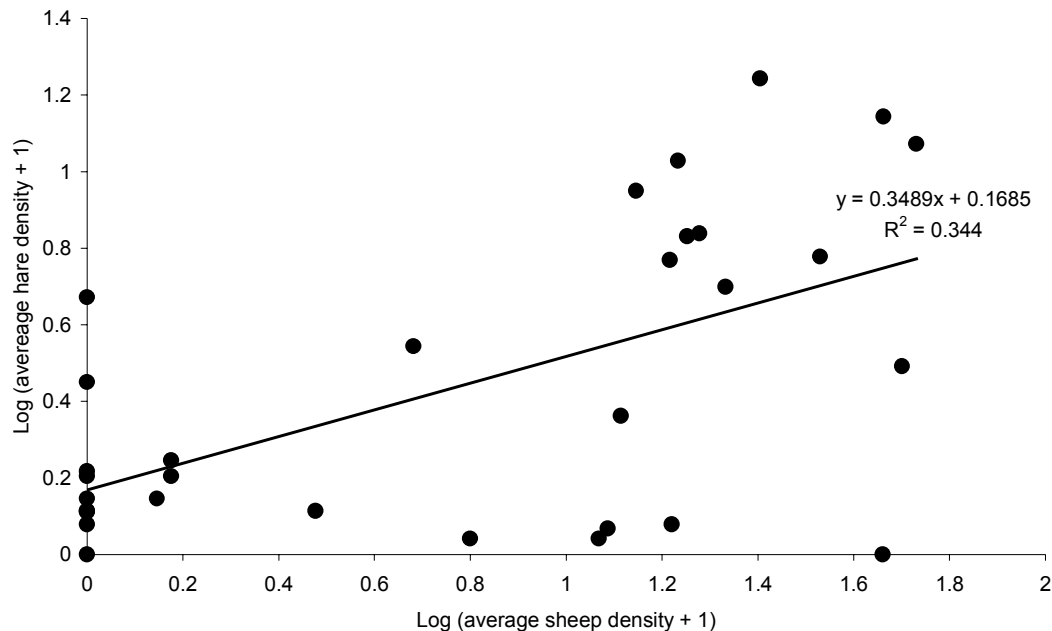


Fig. 1. The relationship between density of sheep on a site and density of mountain hare on a site (32 sites:  $P < 0.001$ ).

Given the generally low densities of hares compared with sheep and/or red deer it seems very unlikely that this species on its own had a marked effect on the montane plant communities. Nevertheless, very few studies have been conducted on the effects of grazing on montane plant communities in Scotland. Experimental research has been conducted on the effects of sheep grazing on heathlands in Iceland, however (Magnússon & Magnússon 1992). The communities studied in Iceland are not exactly the same as those found in montane Scotland and, in general, are more species-rich. The Icelandic communities are probably most similar to those found on the lower altitude sites such as Drumochter (where *Racomitrium lanuginosum* heath dominates) and least similar to the communities in the high Cairngorms, that have a closer affinity with some plant communities in the arctic. The Icelandic results, nevertheless, provide some useful pointers as to whether sheep densities on montane areas of Scotland may be degrading the Annex I habitats.

The study of Magnússon & Magnússon (1992) had three experimental levels of sheep grazing: light (7.4 - 16.7 ewes/km<sup>2</sup>), moderate (25.0 - 35.7 ewes/km<sup>2</sup>) and heavy (38.5 - 62.5 ewes/km<sup>2</sup>). There was no evidence of any difference in the vegetation between the light and moderate grazing treatments, or between these treatments and a treatment where grazing had been removed for eight years. The heavy grazing treatment, however, showed marked signs of damage and change to the vegetation such as a severe drop in the cover of *Racomitrium lanuginosum* moss and an increase in the amount of bare ground. Although additional grazing pressure caused by red deer makes it difficult to draw comparisons with the present results, the Icelandic study suggests that A'Mharconaich (west Drumochter), Glas Maol (east Grampians) and Aonach Mor/Aonach Beag (west Grampians, Nevis range) were overgrazed by sheep. This is supported by the results of Welch & Scott (1996) which also point to local degradation of the habitat on Glas Maol through overgrazing. While not the most heavily sheep-grazed area, sheep densities on east Drumochter were locally high in the early years of the study. Hence, the removal of sheep from east Drumochter prior to the 1998 field season was a helpful measure for the long-term future of the montane vegetation, especially given the high deer densities in this area. The absence of sheep from all of the high altitude sites in the Cairngorms also undoubtedly safeguarded many of the especially vulnerable montane plant communities found in the massif. For example, late-snow bed communities that are nationally rare and are extremely vulnerable to physical damage appeared to be strongly selected by grazing sheep (D.P. Whitfield unpubl. data). Although the results of the present study suggested many sites were probably managed appropriately with regard to sheep stocking, reductions of sheep on A'Mharconaich and Glas Maol should be a management aim, given the importance of these EU Directive sites.

High sheep densities also cause additional problems through trampling nests of dotterel *Charadrius morinellus*, an Annex 1 species on the EU Birds Directive (SNH unpubl. data). Indeed, trampling of nests occurs at lower sheep densities than those densities that appear to result in obvious habitat damage and was a major contributor to management that has reduced sheep numbers on Creag Meagaidh and Carn Liath. A reduced cover of *Racomitrium lanuginosum* at the expense of grasses in *Racomitrium* heath, a favoured habitat of dotterel, is also probably detrimental as dotterel avoid grass-dominated habitat (Galbraith et al. 1993). Moreover, Magnússon & Magnússon (1992) also found that lambs of ewes in their heavy grazed plots had the lowest weight (lambs in the light grazed plots were heaviest) and so reductions in density also has an economic benefit through increasing the selling value of lambs.

The lack of any experimental study of the effects of red deer grazing on montane vegetation makes it more difficult to identify sites where red deer are probably damaging montane vegetation. Surveys of habitat condition on many montane sites in the Cairngorms for signs of deer damage according to the criteria of MacDonald et al. (1998) found evidence of widespread damage only on Moine Mhor and more localised damage on Ben Avon (Gill & Scott 1996; Pearce 1997; Gill et al. 1998). These results correspond with those of the present study that showed these two sites had the highest montane densities of red deer in the Cairngorms with Moine Mhor experiencing the highest. It is difficult to envisage how the extremely high densities of red deer on Moine Mhor do not have an influence on the vegetation. Certainly, trampling rates of dotterel can be as high as 25% of nests on this site (SNH unpubl. data) and reductions in the numbers of red deer that use Moine Mhor is a clear priority.

Extrapolating these results to other sites suggests degradation of montane vegetation through red deer grazing may be widespread across a large area of the southern Grampians from east Drumochter to Atholl, and that localised overgrazing may occur on Aonach Beag and Beinn a' Chlachair in the Ben Alder range. With the exception of east Drumochter that was visited frequently, however, definitive conclusions on these sites should probably await further study.

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