This article was downloaded by: [Istanbul Universitesi Kutuphane ve Dok]
On: 23 December 2014, At: 09:08
Publisher: Routledge
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

Scottish Geographical Journal
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rsgj20

Seasonal and Spatial patterns in sheep grazing on a high-level plateau in the Grampian Mountains, Scotland

D. Welch [a] & D. Scott [a]
[a] Centre for Ecology and Hydrology , Banchory Research Station , Hill of Brathens, Banchory, Kincardineshire, AB31 4BY
Published online: 27 Feb 2008.

To cite this article: D. Welch & D. Scott (2000) Seasonal and Spatial patterns in sheep grazing on a high-level plateau in the Grampian Mountains, Scotland, Scottish Geographical Journal, 116:4, 299-314, DOI: 10.1080/00369220018737102

To link to this article: http://dx.doi.org/10.1080/00369220018737102

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at http://www.tandfonline.com/page/terms-and-conditions

Seasonal and Spatial Patterns in Sheep Grazing on a High-level Plateau in the Grampian Mountains, Scotland

D. WELCH & D. SCOTT

Centre for Ecology and Hydrology, Banchory Research Station, Hill of Brathens, Banchory, Kincardineshire AB31 4BY

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

Abstract

Sheep usage of part of the summit of Glas Maol was monitored by pellet-group counts to determine impact on *Carex bigelowii-Racomitrium lanuginosum* moss heath. The effects of a fenced skiing corridor in giving shelter and disrupting ranging movements were assessed. Dung deposition was appreciable only from June to September each year, and heaviest in July and August; occupance seemed to depend on the presence of substantial quantities of green herbage. Dung deposition was much greater within 5 m of the fence, probably because of its sheltering effect. The estimated May-October stocking of 1.1 sheep ha^{-1} on the main plateau is surprisingly heavy for the altitude, whereas usage by red deer was negligible.

Key words: sheep, grazing, behaviour, mountains, shelter.

Introduction

The impact of large herbivores on the uplands of Britain has caused considerable concern in recent years (Cadbury, 1992; Thompson *et al.*, 1995). There is worry that even in the montane zone, defined as being above the former tree line (Ratcliffe & Thompson, 1988), grazing pressures from sheep are becoming increasingly severe (Thompson & Whitfield, 1993).

However, there is little published information on sheep densities in the montane zone, and interpretation of agricultural census data is difficult since upland management units generally include much lower-altitude ground besides higher hills. In upland British sheepwalks, shepherding is infrequent nowadays, so the sheep are free to choose where they graze. Hence, even if total populations increase, a parallel change in the usage of the high-level ground does not necessarily follow. Therefore to estimate sheep impact, monitoring is required for the individual sectors of interest within the overall range of a flock. As sheep are highly selective for plant communities (Hunter, 1962; Rawes & Welch, 1969; Abrahamson *et al.*, 1989), such monitoring is best done for discrete blocks of relatively homogenous vegetation.

Glas Maol, a mountain rising to 1068 m in the eastern Scottish Highlands, appeared to be grazed by substantial numbers of sheep in summer, and hence seemed a suitable location for monitoring. Red deer (*Cervus elaphus* L.) are also numerous in the surrounding area, and possibly this species visits the plateau at night or at other times of year, so causing more impact on the vegetation than the sheep. There is a general perception that deer utilise higher ground than sheep in the Scottish Highlands, *e.g.* Jones *et al.* (1993) considered that three sites at 890-990 m in the nearby Braemar district 'lie well above the limit of sheep grazing in the region' but are utilised by deer.

The summit plateau of Glas Maol has high conservation value because of its use by dotterel (*Charadrius morinellus* L.). This rare bird, listed under Annex 1 of the EC Birds Directive, not only feeds and nests there, but uses the plateau as a staging or gathering point for annual migratory movements between north Africa and breeding areas in Norway and more northerly mountains in Scotland (Galbraith *et al.*, 1993b). The vegetation of the plateau, dominated by *Carex bigelowii* Torr. ex Schwein. and *Racomitrium lanuginosum* (Hedw.) Brid., is a preferred habitat of dotterel (Galbraith *et al.*, 1993a), but may well be suffering adverse changes in composition because of the present intensity of grazing.

The Glas Maol plateau is also affected locally by a skiing corridor and tow constructed in 1986 as part of the Glenshee ski area. As the associated fencing gives more shelter than any natural feature on the plateau, it was thought that sheep and deer would be attracted, but the likely extent of such a zone of heavier usage was unknown.

To fill these gaps in knowledge on herbivore distribution and impact, we began a monitoring study on Glas Maol in 1990, assessing each year the occupance (amount of occupation) of sheep and red deer from pellet-group counts and also recording trends in the composition of the vegetation. We here report on the sheep and deer observations, considering particularly the total yearly occupance and seasonal and spatial patterns. In a second paper (Welch, Scott & Thompson, in prep.) we will describe the resulting vegetation changes including sharp declines in *Racomitrium* and lichens where sheep usage was heavy.

Site description

The study area was an elongated 6-ha section of the summit plateau of Glas Maol (Fig. 1), straddling the boundary of Aberdeenshire and Angus. This plateau is a tract of gently sloping ground with average altitude approximately 1000 m almost completely surrounded by steep escarpments. The plateau extends north in a broad ridge falling gradually to 940 m. The skiing corridor runs along one side of this ridge for 750 m before turning downhill and opening out (Fig. 1). Snow fencing at the sides of the corridor consists of vertical palings reaching *c.* 1.3 m above ground level and held close together (paling : gap ratio of 1:2), so being an effective barrier to sheep when there are no snow drifts; red deer, however, can leap the fencing. From 1992 onwards the condition of the palings and their holding wires deteriorated, allowing the sheep to force gaps between the palings, and then create paths across the corridor.

The vegetation of the plateau is *Carex bigelowii-Racomitrium lanuginosum* moss heath, U10b in the National Vegetation Classification (Rodwell, 1992). In places *Dicranum fuscescens* Sm. and *Polytrichum alpinum* Hedw. have greater cover than *Racomitrium lanuginosum*, and thus the community locally fits better with NVC U8 *Carex bigelowii-Polytrichum alpinum* sedge heath, which Rodwell considers experiences longer snow-lie than U10b. However, *Carex bigelowii* is the clear dominant throughout, and calcicolous plant species have negligible

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

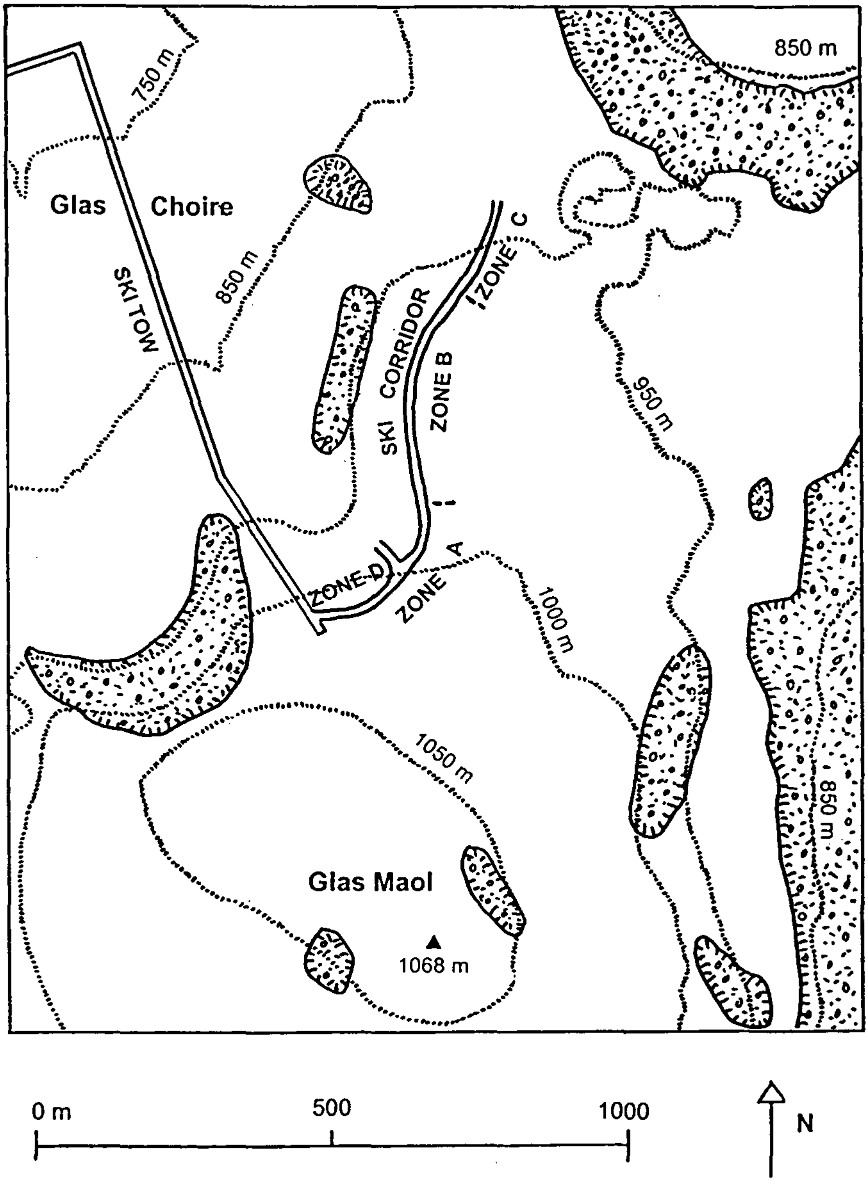

Fig. 1. The study area on Glas Maol, showing the ski corridor and tow, transect positions and zones, contours and areas of crag or scree (stippled).

cover. The shoots of *Carex bigelowii* reached a mean height of 5-7 cm at the peak of growth in late July (measured by a ruler as described in Welch, Scott & Thompson, in prep.).

The plateau is well-drained, and the soils are rankers. In a few places there are small rock outcrops or areas of scree, these last having much *Racomitrium lanuginosum* between the boulders. The rock type is acidic, being classed as

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

graphitic schist or slate on geological maps. Lower down the Glas Maol escarpments, calcareous rocks outcrop, but they have no direct influence on the plateau.

The sheep using Glas Maol came potentially from three flocks which grazed respectively in Glen Clunie, Glen Shee and Caenlochan Glen. These three valleys radiate around Glas Maol (Fig. 2), running respectively north, south west, and south, and their watersheds constitute the county boundaries, Aberdeenshire, Perthshire and Angus meeting on the Glas Maol plateau. Glen Clunie is some 13 km long and the home farm is at Auchallater 11 km north of Glas Maol; Glen Shee extends 7 km to the south-west and the home farm is at Spittal of Glenshee at its foot; Caenlochan Glen had its home farm at Auchavan also 7 km from Glas Maol but this last flock was removed at the end of 1995. The sheep are owned and managed by tenant farmers despite the land belonging to large estates (Glen Clunie and Glen Shee to Invercauld Estate, Caenlochan Glen to Tulchan Estate).

The size and management of the Glen Clunie and Glen Shee sheep flocks changed little in the 1990s: in Glen Clunie *c.* 800 breeding ewes graze approximately 6500 ha from May to October, in Glen Shee *c.* 1400 breeding ewes graze approximately 4500 ha year round (Simon Blackett, pers. comm.). These area extents are approximate because there are no fences to restrict the sheep from further ground that is high and inhospitable and hence rarely visited. The estimated densities for the two areas are quite similar to the overall densities recorded in recent Agricultural Returns for their respective parishes (Braemar and Kirkmichael), the stocking rate for Kirkmichael being roughly six times greater than for Braemar.

Most of the sheep using the Glasmaol plateau are believed to come from the Auchallater flock despite the greater distance of its home farm and the lighter overall stocking density in Glen Clunie. The probable reason is the presence of a large tract of grassy vegetation next to the plateau on its north-west side in Glas Choire (Fig. 1), which gives the Auchallater flock an attractive stepping stone to reach the plateau, whereas the other flocks have to cross less attractive vegetation or precipitous crags and scree. No shepherding was observed on or around the Glas Maol plateau during the study and the sheep groups moved across the plateau without regard to the theoretical boundaries of their home farms; the farmers visit the plateau only to round up sheep for shearing in July and to take them off the hill in autumn. All the sheep encountered on Glas Maol belonged to the Scottish Blackface breed; according to the farmers their normal maximum age is five years.

Methods

Permanent plots for counting pellet groups were set up in July 1990. The northern sector of the plateau was chosen for monitoring, so that the effects of the ski corridor could be studied. To assess the extent of its zone of influence, plots were positioned at distances of 0-1, 3-5, 13-15, 23-25 and 43-45 m from the corridor on 18 transects running normal to it (Fig. 1). The outermost plots were intended as a control, giving an assessment of occupance on the plateau, and it was expected that the 23-25 m distance plots also would be unaffected by the fencing. The corridor actually runs at the top of an escarpment the slope of which starts about 15 m east of the corridor (or south, at its south end) and becomes much

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

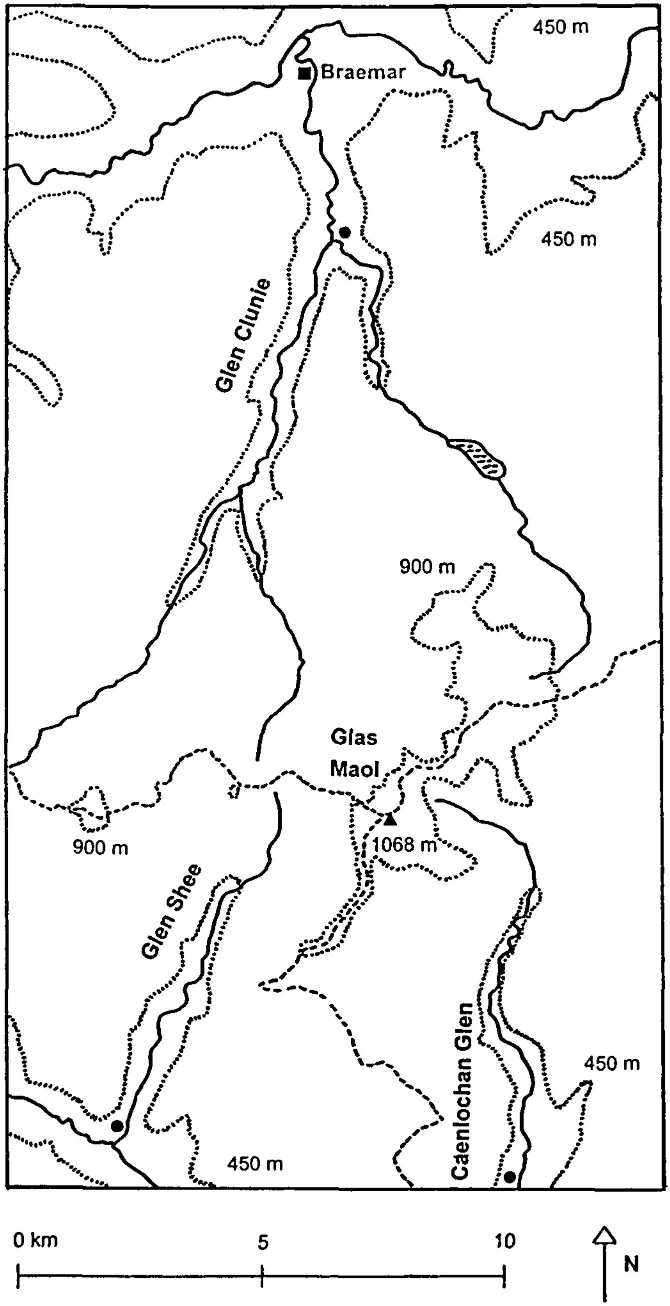

Fig. 2. Topography of the Grampian Mountains around Glas Maol, showing the 450 and 900 m contours (dotted), the three glens with the home farms (filled circles) of the three sheep flocks, and the county boundaries (dashed). Aberdeenshire is in the north, Perthshire in the south west, and Angus in the south east.

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

steeper to its west or north. Thus the 23-25 m and 43-45 m plots lie higher than the corridor and are exposed in all directions. Along the corridor the transects were randomly positioned. During the first year of observations differences in sheep occupance between groups of adjacent transects became apparent, hence subsequent analyses are based on three plateau zones (A = transects 1-6, B = transects 7-12, C = transects 13-15) as well as a zone (D) for the escarpment transects (16-18) below the corridor (Fig. 1).

Plot size was 10 × 2 m except at the 0-1 m position (10 × 1 m), the plots' long axes being parallel to the fencing so that each distance band was monitored precisely. Initially all sheep and deer dung was cleared off the plots, then counts of pellet groups were made at roughly three-week intervals. Dung deposited by resting or ruminating sheep was not separated from dung deposited during grazing, hence the counts assessed all impact not just grazing impact. Lamb groups were not distinguished from adult-sheep groups, but sheep and deer groups were counted separately being recognised from their characteristic pellet shapes. All the dung from sheep and deer was removed, but hare pellets were left on the plots. Counts took place from May to October, the final dates each year being affected by weather conditions. At the first spring counts, fresh pellet groups and older weathered groups were separated; some occupance could have occurred in winter during periods when the plateau was not snow covered, but almost all the old groups were highly weathered and hence had been deposited in the autumn after the last monitoring visit. These older groups were therefore included in the previous years' totals.

For statistical analyses the transect yearly totals of pellet groups, obtained in the six complete years of observation 1991 to 1996, were treated as coming from a Poisson distribution and subjected to an analysis of deviance, with transect, zone, year and zone-year interaction as factors. Variation between zones was split into variation between the plateau (zones A-C) and the escarpment (zone D), and variation within the plateau (zones A v B v C). Significance tests were made by dividing the zone mean deviances by the residual between-transect mean deviance and assessing these ratios using F-tables.

In later years sheep were able to enter the corridor, and to assess its occupance seven plots of 10 × 2 m were employed, placed centrally at regular intervals along it.

Results

Variation in occupance between years and seasons

The total number of sheep pellet groups counted rose yearly from 1991 to 1995, the plots on the plateau being largely responsible (Table 1). But in 1996 deposition fell back to 1991 levels both on the plateau and escarpment. Variation between years in total deposition was highly significant ($P < 0.001$). Occupance by red deer was negligible, only 40 pellet groups being counted during the whole study, almost all on the escarpment.

Seasonal patterns in sheep occupance were very marked (Fig. 3, Table 2). Deposition rates were greatest in July and August each year, and continued moderately great into September. There was more variation between years in the

Table 1. Total numbers of sheep pellet groups deposited each year on the monitoring plots

	Escarpment	Plateau	Both sectors
1991	239	387	626
1992	198	586	784
1993	184	694	878
1994	209	724	933
1995	301	749	1050
1996	211	431	642
Total area of monitoring plots (m^2)	270	1350	1620

Table 2. Seasonal estimates of sheep occupance on the east plateau in relation to weather and spring snow-lie

	Rates of deposition (groups ha^{-1} day^{-1})			Mean no. snow-lie	Mean temperature† (degrees)		
Year	June	July-Aug.	Sept.	days*	May-June	July-Aug.	Sept.
1991	5	30	26	10	9.4	14.5	10.7
1992	17	56	11	1	11.7	11.1	9.9
1993	16	64	22	3	10.0	11.2	8.5
1994	4	68	32	7	9.2	12.5	9.4
1995	10	53	53	1	10.0	15.1	10.1
1996	5	39	17	5	9.1	13.7	10.8

Deposition rates were calculated assuming a constant daily rate within the observation periods.
* After 30 April, for the monitoring plots.
† For Braemar.

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

June and September rates than the July-August rates. Deposition in September 1995 was particularly great, and this resulted in the large total for deposition in 1995, since the rates in June and July-August that year were only average (Table 2).

Variation between years in the seasonal rates of dung deposition appeared to be related to spring snow-lie recorded at the site and to mean temperatures at Braemar, the nearest meteorological station situated 14 km north of the site (Table 2, Fig. 2). Low occupance in June, observed in 1991, 1994 and 1996, was associated with longer spring snow-lie and lower May-June mean temperatures; snow drifts lasted until June on some plots in 1991, 1994 and 1996, but completely thawed away during May in the other years. The lowest September occupance, observed in 1992, was associated with low mean temperature both in July-August and September, and the highest September occupance, for 1995, followed a particularly warm July-August period. The August mean maximum for that year (22.1 °C) was 3.5 °C greater than the next warmest August in the 1988-1996 period, and 6.3 °C greater than the nine-year August mean.

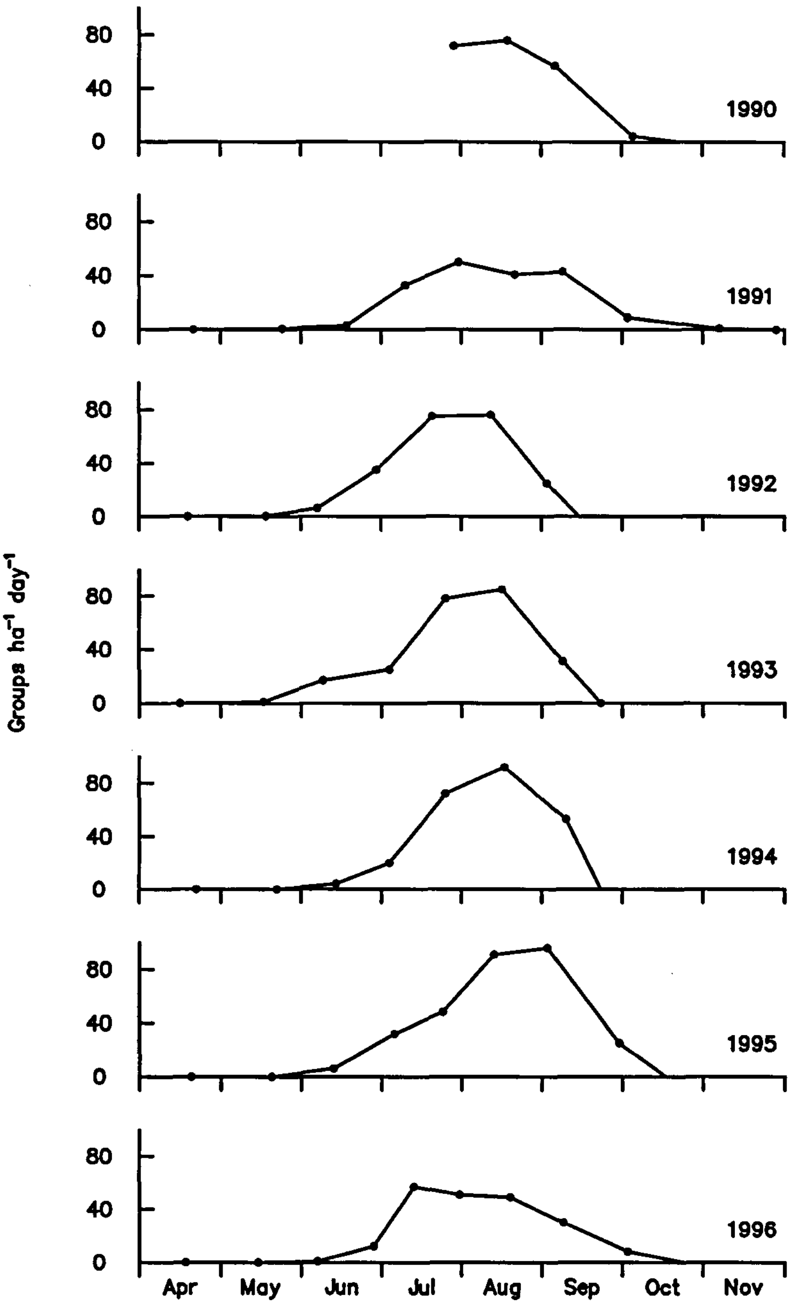

Fig. 3. Seasonal pattern in the rate of deposition of sheep pellet groups, based on all monitoring plots at Glas Maol. In 1992-1995 a few more pellet groups were deposited after the last autumn recording, the mean rate being 5 groups ha^{-1} day^{-1} assuming a 21-day period; in 1990 monitoring began on 16 July when the plots were cleared of all dung.

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

Table 3. Total yearly deposition of pellet groups by sheep on the 18 transects (no. groups 90 m^{-2})

Transect	1990†	1991	1992	1993	1994	1995	1996
1	37	41	96	89	75	99	72
2	61	60	99	96	95	75	55
3	33	45	41	55	52	46	27
4	34	31	45	57	58	51	36
5	36	17	30	33	43	37	16
6	41	27	35	39	68	36	19
Mean Zone A	40	37	58	62	65	57	38
7	17	20	29	34	50	37	12
8	16	12	28	41	36	18	11
9	13	12	25	20	25	31	17
10	12	11	12	35	27	72	53
11	15	6	10	27	24	78	30
12	15	5	27	29	26	36	18
Mean Zone B	15	11	22	31	31	45	24
13	29	20	25	36	43	41	16
14	62	48	55	68	69	54	28
15	45	32	29	35	34	38	21
Mean Zone C	45	33	36	46	49	44	22
16	125	120	104	64	103	161	116
17	64	65	44	71	65	80	57
18	46	54	50	49	41	60	38
Mean Zone D	78	80	66	61	70	100	70
Signif. of differences							
Zones A + B + C v D	***	***	*	n.s.	n.s.	*	*
Zones A v B v C	**	**	*	*	*	n.s.	n.s.

† Curtailed year of monitoring.
*** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$.

Spatial patterns in sheep occupance

On the plateau much more dung was deposited in the transects of the south and north zones (A and C respectively) than in the middle zone (B) (Fig. 1, Table 3). This pattern was clear in the first season of monitoring and corresponded with differences in vegetation composition, hence the transect groupings into zones were set up. These groupings have been retained even though in later years some transects of zone B, *e.g.* 10 and 11, received more pellet groups than transects in the end zones. The analyses of mean deviance showed that transect, zone and year were all highly significant ($P < 0.001$) in accounting for variation in the yearly transect dung totals, and there was also a significant ($P < 0.01$) interaction between zone and year, showing that the distribution pattern changed during the study.

Changes in sheep distribution, as reflected in the mean occupance of the three plateau zones and the escarpment, appear to be related to the condition of

Table 4. Sheep distribution in years 1990 to 1996 in relation to the condition of the ski-corridor fencing. For the condition to be classed as good there were no broken palings along the whole length of the corridor

Year	Corridor fencing condition	Corridor mean occupance (groups 100 m^{-2} yr^{-1})	West escarpment mean occupance as % of mean plateau use	Zone B mean occupance as % of mean plateau use
1990	good	0	252	47
1991	good	0	309	43
1992	few gaps	26	169	56
1993	some gaps	30	133	67
1994	some gaps	58	144	65
1995	many gaps	66	201	91
1996	gaps closed in July but fencing weak	25	245	82

the ski-corridor fencing (Table 4). Initially the wood-paling fence prevented sheep entering the corridor or crossing it, and the proportionate occupance of the escarpment was high, and of zone B low. During 1992 and 1993 a few gaps appeared in the fence where the sheep could squeeze between the palings, and the occupance of zone B more than doubled (Table 3), this contributing to the increase in total usage on the plateau in those years (Table 1). The escarpment proportionate occupance fell markedly in 1992 and 1993 (Table 4) but the decline in absolute deposition was small (Table 3), there being an overall increase in sheep usage. Between-zone differences were much less significant in 1992 and 1993 than in 1990 and 1991 (Table 3).

In 1994, sheep occupance had a very similar pattern to 1993, but during the summer a trampled path developed across the corridor between a gap at the east end of zone D and a gap in the middle of zone A. By this year a distinct path had appeared immediately east of the fence particularly in zones A and C; this seemed to reflect the sheep choosing the shortest lowest route round the outside of the corridor curves when moving along the plateau ridge. As ground was being bared on these paths, with a threat of erosion, the Ski Company deliberately made more gaps in the fencing in spring 1995, and in two places positioned gaps immediately opposite each other in the upper and lower fence. Summer 1995 proved to be particularly warm and sheep occupance increased overall, as previously described, and rather than the trampling damage diminishing, it increased. There was greater occupance inside the corridor (Table 4), and the sheep inside often chose to group with those outside, either lying on both sides of the fence or walking along it together; cross-corridor paths appeared where the pairs of gaps had been made, and zone B received greater proportionate occupance than in any previous year (Table 4), with some transects having large increases in deposition (Table 3). In 1996, as a result of the 1995 trampling damage, the Ski Company changed their tactics and closed all fence gaps in early July, using lengths of new palings.

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

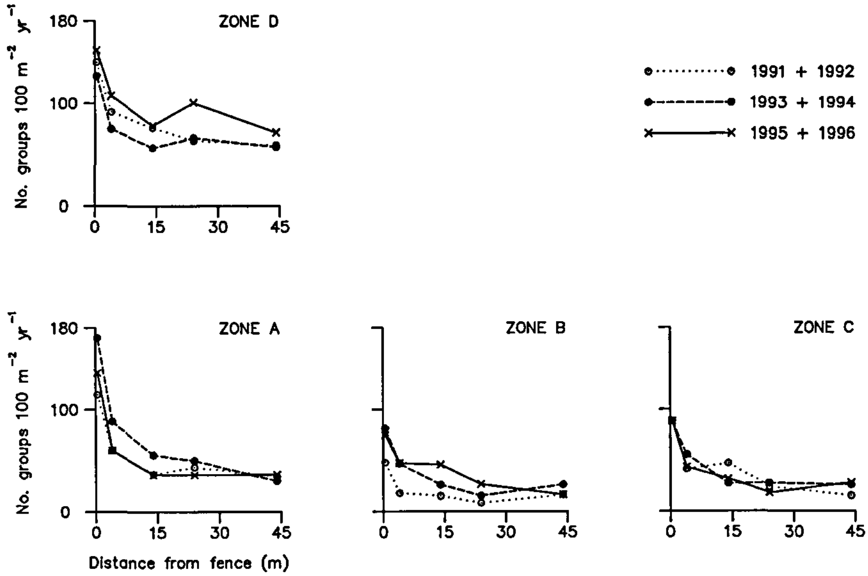

Fig. 4. Lateral patterns in the deposition of sheep pellet groups, as shown by means for two-year periods.

However, we observed sheep making new gaps the next day, breaking palings now ten years old with their heads and necks. So some occupance was recorded in the corridor in 1996, and although escarpment deposition increased and zone B deposition decreased compared to 1995, the difference in means was much less than in 1990 and 1991 (Table 4).

Lateral patterns in occupance with respect to the corridor were found in all years, and are shown for pairs of years in Fig. 4. The patterns were similar in all four zones, with greatest deposition 0-1 m from the fence, rather less deposition 3-5 m from the fence, and much less deposition at the remaining positions. Overall there was 10% less occupance at the 23-25 m position, and 22% less occupance at the 43-45 m position, than the 13-15 m position. But certain years contributed most of this decline, *e.g.* 1995-1996 for zone B, and deposition varied more between years in the 13-15 m plots than the 43-45 m plots. The outermost plots had low occupance in all years on the plateau but moderate occupance on the escarpment (Fig. 4).

Discussion

Our finding that red deer make negligible use of mountain-top vegetation that attracts substantial use by sheep is at variance with other observational studies involving both species in Scotland (Colquhoun, 1970; Osborne, 1984), and what is expected from general accounts of the Scottish Highlands, *e.g.* Darling & Boyd (1964) and Scottish Development Department (1967). Red deer were certainly present around Glas Maol and could easily climb to the summit; on most monitoring visits we saw a herd of *c.* 200 hinds at 700-800 m in Glas Choire about

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

1 km to the north (Fig. 1). They grazed *Agrosto-Festucetum*, *Nardetum* and flush communities there, as did the sheep which were also often present in this corrie basin.

On Osborne's study area, a block of *c*. 160 km^2 of moorland in the north-west Highlands, the sheep occupance was much less on ground >300 m than on ground <300 m, whereas for red deer the opposite pattern was observed particularly in summer. Colquhoun, however, found that the higher ground (790-910 m) of his 187-ha study hill near Ben Lawers, Perthshire, was somewhat more selected by sheep than deer, as measured by mean cgi (comparative grazing index) estimated from regular scans of the whole area. Colquhoun calculated means for each month of a six-month observation period from May to October, and only in July 1968 did deer cgi exceed sheep cgi on the higher ground. Also *Polytricheto-Caricetum bigelowii*, the most similar vegetation type at Ben Lawers to the Glas Maol *Carex bigelowii-Racomitrium* community, was strongly selected by the sheep, with an overall cgi of 160 compared to 26 for red deer. The 10-ha tract of this vegetation had an altitudinal range from 670 to 810 m, and lay on a ridge; *Nardetum, Juncetum squarrosi* and *Agrosto-Festucetum* were the chief communities on the surrounding slopes.

A possible reason for *Carex bigelowii* communities being more utilised by sheep than red deer is the shortness of their swards, sheep being more able than deer to secure satisfactory intake at low sward heights due to their smaller mouth size (Illius & Gordon, 1987; Illius *et al*., 1992). Unfortunately no measurements of sward condition were obtained by Colquhoun (1970), and at Glas Maol we measured height only in mid July in 1990-1992. As mean heights ranged from 5.4 to 6.6 cm in these three years, it is very likely that earlier and later in summer the sward height is less than 5 cm, at which level the use of grass (*Agrostis* L. and *Festuca* L.) patches by deer has been shown to be positively correlated with height (Clarke *et al.*, 1995).

The presence of a substantial biomass of green palatable forage would seem to be the main factor governing sheep occupance on the Glas Maol plateau. Mean temperatures were very similar in May-June and September (Table 2), yet dung deposition was on average much greater in September. In May the swards had a grey-brown appearance due to dead *Carex* leaves, relieved only by patches of dark-green *Polytrichum alpinum* and mid-green *Dicranum fuscescens*. New sedge growth did not become visible until late May, and until mid June it was masked by the dead tufts of the previous year. The greater occupance of sheep in June 1992 (Table 2, Fig. 3) followed a noticeably earlier start to sedge growth than in the other years of the study, and was associated with a higher May-June mean temperature (Table 2).

Seasonal patterns of sheep grazing have been studied in other British uplands (Hughes *et al.*, 1975; Rawes & Welch, 1969), but the sites monitored were at lower altitudes than the Glas Maol plateau, the highest in Snowdonia, North Wales, reaching only to 915 m. The duration of grazing appears to be related to altitude, as found by Rawes & Welch (1969) in the North Pennines: *Agrosto-Festucetum* sites at 480-540 m had substantial grazing for 5-6 months and at 730-760 m for 4 months, whilst a *Festucetum* at 820-840 m was grazed substantially for only 3 months. Similarly, an *Agrosto-Festucetum* at 460 m in

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

Snowdonia was grazed for 7 months from May to November (Hughes *et al.*, 1964). For the North Pennine *Agrosto-Festucetum* at 750 m, Welch & Rawes (1965) showed that the green graminoid biomass did not increase appreciably until June, and was still greater at the end of September than in early June. This fitted the observed pattern of grazing, and supports the view that sheep visit sites only when sufficient forage is available.

The inconsistency of sheep occupance of high-level sites in Britain even in the season of most use was brought to attention by Rawes & Welch (1969). In their North Pennine study area two high-level exposed sites had more nil counts than expected from the mean numbers of sheep recorded, expectancy being judged from a relationship between frequency of nil counts and mean sheep numbers based on 30 sites mostly rather lower in altitude (460-600 m). British mountains are particularly windy (Grace & Unsworth, 1988), and shelter-seeking by sheep in these cool environments is normal behaviour, minimising the heat losses caused by fleece insulation being reduced in wind (Blaxter *et al.*, 1963; Squires, 1975). The inference is that to avoid exposure to wind and at the same time maximise intake the sheep utilising high ground move on and off sites more often than do sheep at lower altitudes; returning when the weather permits to sites having good-quality forage is an integral part of this behaviour pattern. Another possible reason for herbivores moving to high ground is avoidance of insect pests.

At Glas Maol these movements of sheep were much affected by the 750-m long ski corridor and its associated 1000-m long tow (Fig. 1). When the paling fences were in good condition, sheep in a 40-ha block in Glas Choire could only reach the summit plateau by a long walk round the north end of the corridor, whilst sheep from the western section of Glas Choire had much plateau ground with dominant *Carex bigelowii* available when they reached the top of the tow. Hence they were unlikely to walk a further 300 m through zone A to reach zone B. So zone B occupance was artificially low, and zone D occupance artificially high until gaps in the fencing became numerous in 1994 and 1995 (Table 4).

The width of a zone of shelter given by a barrier is related to the height (h) of the barrier and many other factors including the porosity of the barrier, the roughness of the ground to its leeward, and the mean wind speed (Brenner *et al.*, 1995; Wang & Takle, 1997). Field studies have shown a zone of maximum shelter extending up to 4-6h from a barrier, a zone of intermediate shelter reaching about 8h distance and a 'wake' zone of slight shelter reaching up to 15-17h distance (Nord, 1991; Brenner *et al.*, 1995). As the Glas Maol plateau vegetation is relatively smooth and the mean wind speed is high, the extent of the shelter zone is likely to be minimised, though no studies of such fencing in these situations are known to the authors. With the fence being 1.3 m tall, this would mean the 13-15 m plots experience slight shelter, but not the 23-25 m plots, which is consistent with the lateral patterns observed (Fig. 4).

Sheep occupance on the main bulk of the Glas Maol plateau is probably similar to the levels observed on the outer plots of zones A and C at 23-25 and 43-45 m distance, which were neither influenced by the access problems affecting zones B and D, nor the increased shelter within 15 m of the fencing (Fig. 4). This is supported by the standing crops of pellet groups visible on *Carex bigelowii-Racomitrium* swards elsewhere on the plateau, and our own direct counts of all sheep on the plateau and other counts carried out by Scottish Natural Heritage (Whitfield, pers. comm.): often in July and August about 100 sheep were present on the 40 ha of the plateau. Dung deposition rates are affected by diet and other factors, but Scottish Blackface sheep were estimated to have a mean deposition rate of 17 groups per day from observations in NE Scotland (Welch, 1982). Using this rate, the 1991-1996 mean deposition on the zone A and C outer plots equates to a 6-month (May-October) stocking of 1.1 sheep ha^{-1}, or a stocking of approximately 2 sheep ha^{-1} during the three months of greatest occupance. If only the outermost plots at 43-45 m from the fence are used in the calculation, the estimated sheep stocking is 10% less (Fig. 4), equating to 1.0 sheep ha^{-1} May to October.

That so great a sheep density can occur without shepherding at an average altitude of 1000 m in northern Scotland, given the presence of nearby lower-altitude areas attractive to sheep because of the forage and shelter available, means that grazing pressures on many other Scottish mountains could potentially much increase if substantial numbers of sheep were grazed within a 2-5 km range; SNH sheep counts suggest that several Grampian mountains have similar occupance (Whitfield, pers comm.). The rapidity of the changes in botanical composition observed at Glas Maol in the zones of heaviest pressure (Welch, Scott & Thompson, in prep.) confirms the important influence grazing can have on high-altitude communities with low annual growth rates, and emphasises the need for a predictive understanding of where within the overall range of sheep flocks the concentrations in occupance occur.

Acknowledgements

We are grateful to the Glenshee Chairlift Company, the Invercauld Estate and the tenant farmers for help with access and information on management, to Mr Simon Blackett (factor of Invercauld Estate) for information on sheep numbers, to Drs David Bale, John Miles, Des Thompson and Adam Watson for discussions during the course of the study, to Dr Gordon Miller for his involvement in the planning of the study, and to Mr David Elston for statistical advice. Dr Fiona Stewart and Dr Philip Whitfield have kindly commented on drafts of the paper.

References

Abrahamson, M., O'Connor, K.F. & Harris, P.S. (1989). Changes in sheep grazing behaviour and herbage after partial area improvement of a high country summer range. *New Zealand Journal of Agricultural Research* **32**, 167-180.

Blaxter, K.L., Joyce, J.P. & Wainman, F.W. (1963). Effect of air velocity on the heat losses of sheep and cattle. *Nature (London)* **198**, 1115-1116.

Brenner, A.J., Jarvis, P.G. & van den Beldt, R.J. (1995). Windbreak – crop interactions in the Sahel. 1. Dependence of shelter on field conditions. *Agricultural & Forest Meteorology* **75**, 215-234.

Cadbury, C.J. (1992). *Grazing and other management of upland vegetation: a review with special reference to birds*. Royal Society for the Protection of Birds, Sandy.

Clarke, J.L., Welch, D. & Gordon, I.J. (1995). The influence of vegetation pattern

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014

on the grazing of heather moorland by red deer and sheep. I. The location of animals on grass/heather mosaics. *Journal of Applied Ecology* **32**, 166-176.

Colquhoun, I.R. (1970). The grazing ecology of red deer and blackface sheep in Perthshire, Scotland. PhD thesis, University of Edinburgh.

Darling, F.F. & Boyd, J.M. (1964). *The New Naturalist. The Highlands and Islands*. Collins, London.

Galbraith, H., Murray, S., Duncan, K., Smith, R., Whitfield, D.P. & Thompson, D.B.A. (1993a). Diet and habitat use of the dotterel *Charadrius morinellus* in Scotland. *Ibis* **135**, 148-155.

Galbraith, H., Murray, S., Rae, S., Whitfield, D.P. & Thompson, D.B.A. (1993b). Numbers and distribution of dotterel *Charadrius morinellus* breeding in Great Britain. *Bird Study* **40**, 161-169.

Grace, J. & Unsworth, M.H. (1988). Climate and microclimate of the uplands. In *Ecological Change in the Uplands*, ed. M.B. Usher & D.B.A. Thompson. Blackwell, Oxford, pp. 137-150.

Hughes, R.E., Dale, J., Mountford, M.D. & Williams, I.E. (1975). Studies in sheep population and environment in the mountains of north west Wales. II. Contemporary distribution of sheep population and environment. *Journal of Applied Ecology* **12**, 165-178.

Hughes, R.E., Milner, C. & Dale, J. (1964). Selectivity in grazing. In *Grazing in Terrestrial and Marine environments*, ed. D.J. Crisp. Blackwell, Oxford, pp. 189-202.

Hunter, R.F. (1962). Hill sheep and their pasture: a study of sheep grazing in South-east Scotland. *Journal of Ecology* **50**, 651-680.

Illius, A.W., Clark, D.A. & Hodgson, J. (1992). Discrimination and patch choice by sheep grazing grass-clover swards. *Journal of Animal Ecology* **61**, 183-194.

Illius, A.W. & Gordon, I.J. (1987). The allometry of food intake in grazing ruminants. *Journal of Animal Ecology* **56**, 989-999.

Jones, V.I., Flower, R.J., Appleby, P.G., Natkanski, J., Richardson, N., Rippey, B., Stevenson, A.C. & Battarbee, R.W. (1993). Palaeolimnological evidence for the acidification and atmospheric contamination of lochs in the Cairngorm and Lochnagar areas of Scotland. *Journal of Ecology* **81**, 3-24.

Nord, M. (1991). Shelter effects of vegetation belts - results of field experiments. *Boundary-Layer Meteorology* **54**, 363-385.

Osborne, B.C. (1984). Habitat use by red deer (*Cervus elaphus* L.) and hill sheep in the West Highlands. *Journal of Applied Ecology* **21**, 497-506.

Ratcliffe, D.A. & Thompson, D.B.A. (1988). The British uplands: their ecological character and international significance. In *Ecological Change in the Uplands*, ed. M.B. Usher & D.B.A. Thompson. Blackwell, Oxford, pp. 9-36.

Rawes, M. & Welch, D. (1969). Upland productivity of vegetation and sheep at Moor House National Nature Reserve, Westmorland, England. *Oikos Supplement* 11, 72 pp.

Rodwell, J. (ed.) (1992). *British Plant Communities. 3. Grasslands and Montane Communities*. Cambridge University Press, Cambridge.

Scottish Development Department (1967). *The Cairngorm Area*. HMSO, Edinburgh.

Squires, V.R. (1975). Ecology and behaviour of domestic sheep (*Ovis aries*): a review. *Mammal Review* **5**, 35-57.

Thompson, D.B.A., MacDonald, A.J., Marsden, J.H. & Galbraith, C.A. (1995). Upland heather moorland in Great Britain: a review of international importance, vegetation change and some objectives for nature conservation. *Biological Conservation* **71**, 163-178.

Thompson, D.B.A. & Whitfield, D.P. (1993). Research Progress Report. Research on mountain birds and their habitats. *Scottish Birds* **17**, 1-8.

Wang, H. & Takle, E.S. (1997). Momentum budget and shelter mechanism of boundary-layer flow near a shelterbelt. *Boundary-Layer Meteorology* **82**, 417-435.

Welch, D. & Rawes, M. (1965). The herbage production of some Pennine grasslands. *Oikos* **16**, 39-47.

Welch, D. (1982). Dung properties and defecation characteristics in some Scottish herbivores, with an evaluation of the dung-volume method of assessing occupance. *Acta Theriologica* **27**, 189-210.

Downloaded by [Istanbul Universitesi Kutuphane ve Dok] at 09:08 23 December 2014