CHAPTER 4

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4•1 INTRODUCTION

The approach taken to describing plant communities by British and continental European plant ecologists has developed along different lines. Since the early years of the twentieth century European ecologists have been attempting to devise systems of classification based solely upon the study of the vegetation itself (i.e. its floristic composition, structure, development and distribution) whereas British ecologists have placed more emphasis on the relationship of plants with their habitat. Phytosociology is strictly the name given to the European system but is often loosely used to refer to any system of vegetation classification.

The two major systems devised by European ecologists are the Zürich-Montpellier school of Braun-Blanquet, based on plants faithful to a given community (fidelity), and the Uppsala (or Nordic-Alpine) system, based on the constant and dominant species in a community. Theoretically, the former is to be preferred as plants with a high fidelity will probably have a narrow ecological amplitude and will be restricted to one or, at most, a few closely related communities whereas dominant or constant species are liable to be plants with a wide ecological amplitude and hence are likely to occur in a number of different, unrelated, communities. Poore (1954a) has suggested that species with a high fidelity to a community will evolve only in areas with a high ecological continuity and that this accounts for the lack of well-defined communities with faithful species in the north of the British Isles and middle and north Sweden compared with the species-rich areas of southern Europe. This explains the development in Scandinavia of a system of plant community classification based on constant and dominant species rather than faithful ones. Although this may be the case for vascular-plant communities it is less true for cryptogamic ones, both in montane areas and elsewhere (e.g. oceanic woodlands).

As the plant communities of montane Britain have a much closer affinity with those of Scandinavia than with the species-rich communities of the Alps, the Uppsala system appears better suited for describing them. However, for the reasons given above, the Zürich-Montpellier system is to be preferred and where faithful species are recognisable they should be used to characterize the vegetation.

4•1•1 Zürich-Montpellier System

4•1•1•1 Introduction

The Zürich-Montpellier system is based on the concept of fidelity. Species of narrow ecological amplitude (high fidelity) - which are consequently confined to a particular habitat (and hence community) - are used to characterise the community in which they occur. The various grades of fidelity are given in Table 4•1.

Table 4•1. Grades of Fidelity.

A. Characteristic (faithful) Species

Fid. 5 - Exclusive species; completely or almost completely confined to one community.

Fid. 4 - Selective species; found most frequently in a certain community but also, though rarely, in other communities.

Fid. 3 - Preferential species; present in several communities more or less abundantly but predominately, or with better vitality, in one certain community.

B. Companions

Fid. 2- Indifferent species, without pronounced affinity for any community.

C. Accidentals

Fid. 1 - Strange species, rare and accidental intruders from another plant community or relicts from a preceding community.

However, the assessment of fidelity has a number of practical difficulties which jeopardise the fundamental objectivity upon which the phytosociological system is based. The fidelity of a plant to a certain community can be assessed only when the vegetation of an area is completely known and this is very rarely the case. In practice, the system usually involves non-random sampling, relying on the experience and intuition of the investigating ecologist to select appropriate stands of vegetation - a process which is subject to various prejudices and pre-conceptions. Stands are usually selected on the grounds of dominance or constancy of a certain plant species, similarity of physiognomy or habitat, or the regular occurrence of species which are already suspected of having a narrow ecological amplitude. Used in this way the system appears to be little more than a method of adding pseudo-quantitative (i.e. statistically meaningless) data to a qualitative observation.

Degree of fidelity is also dependent on area. A species which has a narrow ecological amplitude in one area may have a wider amplitude in another or occupy a different ecological niche. Consequently, it is necessary to distinguish three types of fidelity - local, regional and general - depending on over how wide an area a characteristic species is confined to a particular fidelity grade. A plant may, for example, be 'exclusive' to a certain community over part of its range but only 'selective' or 'preferential' over another. This is illustrated by the distribution of *Stereocaulon saxatile*. Gilbert & Fox (1985) considered this species to be confined to areas of late snow-lie in the Cairngorms. Further west in Scotland, however, *S. saxatile* is a widespread species of montane heaths occurring in a number of different communities. A more extreme example is that of *Trapelia obtegens* which is a frequent species of siliceous rocks in upland and low-montane areas but in the mid- and high-montane sub-zones occurs only in the vicinity of areas of late snow-lie. Failure to appreciate that phytogeographic, historical and anthropogenic factors can have a significant influence on the plants which occur in an area may lead to the description of a new community for what is essentially the same grouping of plants but with the faithful species replaced by another locally faithful one.

Many of these problems stem from the desire to create a syn-taxonomic system of classification of plant communities equivalent to the aut-taxonomic one of plant species. However, this is unrealistic for a number of reasons, not least that there is no basic entity equivalent to the type specimen. 'A type relevé is in some respects equivalent to a type description but the actual vegetation unit which this refers to is a transient area of vegetation which cannot be referred back to in the future' (Nimis 1991). Vegetation also forms a continuum influenced by outside factors. James *et al.* (1977) consider that phytosociology should 'aim to determine those major noda in the continuum of plant communities which are related to clearly recognisable ecological and environmental parameters, rather than to fit all stands encountered into a rigid system of too strictly defined associations.' Creveld (1981) echoes this sentiment in her statement that ' the strict application of nomenclatural rules considers as 'type relevés' relevés that are not typical.' This is because any new stand of vegetation which does not fit into the existing system can, and indeed should, be described as new.

The desire of the phytosociologist to devise a system of vegetation classification which takes no account of ecology or other environmental factors is equivalent to an aut-taxonomist working solely on herbarium specimens with all the hazards that can bring (i.e. it takes no account of environmental modifications). This is to some extent responsible for the proliferation of community names which has overwhelmed phytosociology. If no account is taken of environmental conditions then every variation in plant grouping will be recognised as a distinct community rather than as an environmentally-induced modification of an existing one.

4•1•1•2 Constants and Dominants

Constants and dominants have been used by other phytosociological systems to classify vegetation but they are rejected by the Zürich-Montpellier school as they are often plants of wide ecological amplitude and, consequently, inhabit a wide range of habitats and occur in a number of different communities. They are, however, often recorded, in which case the scale given in Table 4•2 is used for recording degree of consistency:-

Table 4•2. Scale for recording degree of consistency of plants to a given community.

Percentage of stands in which plant is present	Class
81-100	5 (Constants)
61-80	4
41-60%	3
21-40%	2
0-20%	1

4•1•1•3 Estimation of Abundance

Braun-Blanquet used a five point system for assessing the abundance of a plant in a community along with a further five-point system to give an estimation of sociability. However British workers have routinely used the ten-point Domin scale (Dahl & Hadac 1941) which has the advantage of greater accuracy at the lower end where small differences in abundance are most significant. It can be directly converted to the Braun-Blanquet scale if required. The values given to percentage cover in the two systems is given in Table 4•3

Table 4•3. Values given by the Domin and Braun-Blanquet systems for various levels of percentage cover.

Percentage Cover	Domin	Braun-Blanquet
91-100	10	5
76-90	9	5
51-75	8	4
34-50	7	3
26-33	6	3
11-25	5	2
4-10	4	2
< 4, many individuals	3	1
< 4, several individuals	2	1
< 4, few individuals	1	1
< 4, single individual	x	x

4•1•2 National Vegetation Classification

4•1•2•1 Introduction

The recently published National Vegetation Classification (NVC, Rodwell 1991, 1992) has provided the definitive work on plant communities in the British Isles for the foreseeable future. The expressed aim of this project was 'to give priority to the definition of vegetation types rather than to the construction of a hierarchical classification' (Rodwell, op. cit.) and, in this, it follows the British tradition of delimiting plant communities in a pragmatic fashion as a tool for ecological research rather than following the purely academic approach typical of phytosociology.

Unfortunately, NVC specifically excludes communities dominated by non-vascular plants and is also very poor when dealing with lichens as part of vascular plant dominated communities; the majority of their field-workers were insufficiently trained in, for example, identifying *Cladonia* species. Most of the lichen information appears to have been taken from previously published accounts (e.g. McVean & Ratcliffe 1962) with little or no reference to subsequent lichenological work (e.g. James *et al.* 1977) and, consequently, is seriously out of date. Lichen nomenclature follows Dahl (1968) which, although admirable in its day, has been superseded by later, more comprehensive and more widely known works (e.g. Duncan 1970; Hawksworth *et al.* 1980; Dobson 1981; Cannon *et al.* 1985), as a result some of the names used have not been current for many years (e.g. *Cetraria glauca* has been known as *Platismatia glauca* since 1965). It also means that many species mentioned in NVC cannot be traced in the current lichenological literature; most notably The Lichen Flora of Great Britain and Ireland (Purvis *et al.* 1992) or The Checklist of Lichens of Great Britain and Ireland (Purvis *et al.* 1993).

4•1•2•2 Montane communities

The investigation of montane plant communities in Britain was given an excellent starting point with the comprehensive work of McVean & Ratcliffe (1962) and the data they collected forms a major part of those used in describing montane communities in the NVC. Due to the long gestation period of NVC an interim classification was supplied by Birks & Ratcliffe (1981) and this was used by Thompson & Brown (1992) who list in an appendix the corresponding NVC communities which occur in montane Britain. Only three NVC communities were not included (CG 10,11,13) although others were represented only by their sub-communities.

More recently Brown *et al.* (1993a) listed the NVC communities which are more or less confined to high altitude sites in Scotland. This list formed the basis for the selection of the communities considered in the present work although mires and some other communities which are of minimal lichen interest are excluded along with some others which do not reach a sufficient altitude (900m) to be considered.

4•1•2•3 Communities considered in this work

The main communities considered are:-

H13 *Calluna vulgaris-Cladonia arbuscula* heath.

H19 *Vaccinium myrtillus-Cladonia arbuscula* heath.

U7 *Nardus stricta-Carex bigelowii* grass heath

U8 *Carex bigelowii-Polytrichum alpinum* alpine sedge-heath.

U9 *Juncus trifidus-Racomitrium lanuginosum* rush heath.

U10 *Carex bigelowii-Racomitrium lanuginosum* moss heath.

U11 *Polytrichum sexangulare-Kiaeria starkei* snow-bed

U12 *Salix herbacea-Racomitrium heterostichum* snow-bed

Also of some interest, although more strictly sub-montane or of minimal lichen interest, are:-

CG11 *Festuca ovina-Agrostis capillaris-Alchemilla alpina* grass heath.

CG12 *Festuca ovina-Agrostis capillaris-Silene acaulis* dwarf herb community.

CG14 *Dryas octopetala-Silene acaulis* ledge community.

H17 *Calluna vulgaris-Arctostaphylos alpinus* heath.

U4 *Festuca ovina-Agrostis capillaris-Galium saxatile* grass heath.

4•1•2•4 Bryophyte-dominated snow-bed communities

Cryptogam-dominated communities in general were not considered by NVC and the bryophyte-dominated communities of areas of late snow lie, although mentioned, were recognised as in need of further attention (Rodwell, 1992). These are dealt with in the next chapter. Of the communities mentioned above U11 and U12 fall into this category

4•2 PHYTOSOCIOLOGY OF TERRICOLOUS MONTANE LICHENS

4•2•1 Introduction

This section deals with terricolous communities; those which occur on rock present a special case with a number of additional problems and will be considered in the next section.

The history, current status and many of the problems involved in lichen community studies have been excellently reviewed by Nimis (1991). The problems are both theoretical and practical in nature and combine to present a situation in which the method used is very much dependent on the problem to be solved. The theoretical problems mostly concern the decision which has to be made as to whether to treat the vegetation of an area as a whole (phytocoenosis) or whether to treat the various elements (including the lichen vegetation) separately (synusiae). Ideally the former is to be preferred but a number of practical problems intervene:-

a) the difficulty of identifying all the organisms at a site
b) the different minimum areas required for sampling different synusiae
c) the different micro-climate and soil conditions which pertain for different synusiae
d) the often independent behaviour of the synusiae in that the boundaries do not coincide.

If the object of the exercise is the description of the vegetation at a given site then there appears to be little alternative to the phytocoenosal approach but if the object is to classify the vegetation then the synusial approach appears to be preferable. Other practical problems concern the identification of homogeneous stands in lichen vegetation, where micro-habitat is such an important influence and lichens often occur in gaps in the vegetation or reach their best development in the boundaries between vascular-plant-dominated areas. A further difficulty involves identifying all the species present at a site. This has been investigated by Roux (1990) who compared the literature results of relevés taken by various investigators from the same lichen communities but with identifications made at three different levels, a) in the field, b) difficult specimens removed for laboratory identification and c) all specimens removed to the laboratory. His results are given in Table 4•4.

Table 4•4. Numbers of lichen species identified from various lichen communities a) in the field, b) partly removed to the laboratory, c) completely removed to the laboratory (from Roux 1990).

	Field	Part Laboratory	Full Laboratory
Corticolous	11-12	-	26
	8-10	13	23
	9	-	19
	7-9	14	22
Calcareous Saxicolous	11	23	-
	12	19	-
	7	14	23
	10-14	18-29	-
	8	16-27	
	7	18	-
	5	10	22
Terricolous	-	13	26
	-	12	25
	-	12	28
	11	-	18

These results have serious implications for comparing work by different investigators. Unfortunately, although Roux compiled his data from a number of different sources he did not take the next step and carry out original work to eliminate any errors which might have resulted from different levels of expertise of the various investigators or from the different relevés of the communities examined.

4•2•2 The Communities

4•2•2•1 Introduction

In the British Isles the only montane area with extensive terricolous lichen communities is the Cairngorm mountains in the Eastern Highlands of Scotland; elsewhere ground conditions are, in general, too wet to support a good lichen growth. Consequently, most of the relevés in the present study were collected in this area, although other areas were sampled mainly to provide a comparison. The only areas outside N-E Scotland where good terricolous lichen vegetation is to be found are those with a basic substratum, most importantly the mica-schist of the Breadalbanes, the fucoid-beds of Beinn Eighe in Toriddon, and the limestone of Coire Cheap on Aonach Beag in the Ben Alder range. All these areas were visited and relevés collected. Other areas where the lichen vegetation was sampled were Carn Eige/Mam Sodhail and Creag Meagaidh in the Central Highlands, Aonach Mòr in Lochaber, Beinn Dearg in West Ross and Bidian nan Bian in Glen Coe. Other sites were visited but suitable areas for sampling were not discovered either because they were insufficiently lichen-rich or these were of too small a size, e.g. Ben Lomond in the Southern Highlands, Ben Cruachan in the south-west Highlands, Liathach in Torridon and Inchnadamph in the north-west Highlands. A total of 141 relevés was collected and these were of two sizes, either 4x4m, for more continuous, homogeneous stands of vascular-plant vegetation, or 2x2m. All species of lichen were recorded, with difficult specimens being collected and later identified in the laboratory, along with all the vascular plants and the most numerous and/or most obvious bryophytes. A number of ecological factors were also recorded as were some of the physical characteristics of the site. Many of the relevés were collected from the vicinity of areas of late snow-lie; these will be analysed in the next chapter.

Only three of the NVC communities sampled supported a significant lichen vegetation. These were:-

H13 *Calluna vulgaris-Cladonia arbuscula*

H19 *Vaccinium myrtillus-Cladonia arbuscula*

U9 *Juncus trifidus-Racomitrium lanuginosum*

The results of the relevés collected from these communites are presented in Tables 4•5-4•7.

The data for saxicolous lichens in these tables are of little relevance as they are very much dependent upon the presence, frequency and size of a suitable substratum. They are included, however, as they do form a part of the vegetation in the area and it is possible to determine some patterns, although these have little in common with the terricolous vegetation.

Table 4•5. Relevés collected from NVC H13 *Calluna vulgaris-Cladonia arbuscula* heath

	LOCALITY													
	Beinn a'Bhuird	Cairn Gorm												
Relevé Number	**45**	**1**	**3**	**10**	**11**	**18**	**23**	**24**	**25**	**26**	**27**	**135**	**136**	**140**
Vegetation Cover (%)	90	90	90	95	90	90	70	85	60	65	60	95	45	80
Height of vegetation (cm)	2	2	2	5	2	4	7	3	3	3	2	2	2	1
Lichen Cover (%)	7	40	40	35	15	20	5	30	12	30	20	5	5	25
Gravel (%)	-	5	5	5	9	9	25	13	35	10	15	5	55	5
Rocks (%)	-	5	5	0	1	1	5	2	5	25	25	-	-	15
Slope (°)	0	10	5	25	7	15	6	15	8	12	2	5	5	0
Aspect (°)	-	270	275	270	330	280	0	0	90	315	90	340	340	-
Arctostaphylos uva-ursi	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Calluna vulgaris	10	7	8	9	9	8	8	9	8	7	8	6	5	7
Empetrum nigrum	1	4	4	5	4	5	4	3	2	4	2	5	4	7
Loiseleuria procumbens	.	3	1	2	1	4	3	4	3	1	1	6	5	.
Pinus sylvestris	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Vaccinium myrtillus	.	.	3	1	1	4	.	1	.	3	1	.	.	.
V. vitis-idaea	.	.	1	1	.	.	.	.	.	.	.	1	.	.
Carex bigelowii	2	3	3	1	1	3	2	3	2	2	3	4	3	.
C. piliferum	1	.	.	.	.	.	.	1	1	1	1	.	.	.
Deschampsia flexuosa	.	.	1	.	.	1	.	1	.	.	.	3	.	.
Juncus trifidus	.	.	1	.	.	1	.	1	1	2	1	1	.	.
Trichophorum cespitosum	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Diphasiastrum alpinum	.	.	1	.	.	1	4	1	.	.	.	.	.	.
Huperzia selago	2	2	1	1	1	1	1	2	.	2	1	1	1	.
Barbilophozia floerkei	.	.	.	.	.	1	.	.	1	1	.	.	.	.
Diplophyllum albicans	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Gymnomitrion concinnatum	.	.	.	.	.	1	.	.	.	.	.	.	.	.

Hypnum cupressiforme	.	.	.	.	1	.	.	3	2	1	.	.	.	.
Pohlia nutans	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Polytrichum piliferum	.	.	.	1	.	1	.	1	1	.	.	.	.	.
Racomitrium lanuginosum	2	.	1	1	.	1	1	2	.	3	1	.	.	.
Alectoria nigricans	2	1	2	2	1	2	1	.	1	.	.	1	.	.
A. ochroleuca	.	.	.	.	.	.	.	.	.	.	.	1	2	3
A. sarmentosa ssp. vex'fera	3	.	.	.	1	.	.	.	1	.	.	1	1	1
Arthrorhaphis grisea	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Baeomyces rufus	.	1	.	1	1	1	1	1	1	1	.	.	.	1
Cetraria aculeata	.	2	.	2	.	3	1	1	2	3	3	3	2	3
C. ericetorum	.	.	.	.	.	.	.	.	.	.	.	1	.	1
C. islandica	.	2	3	2	1	2	2	3	.	3	1	2	2	4
C. nivalis	.	1	1	2	2	1	1	1	2	1	.	2	3	2
Cladonia arbuscula	.	4	5	5	4	4	2	3	2	4	1	.	.	1
C. bellidiflora	.	1	2	.	1	1	.	1	.	.	1	.	.	.
C. chlorophaea	.	1	.	.	.	.	.	.	.	.	.	.	.	1
C. ciliata	.	.	1	.	.	.	.	.	.	.	1	.	.	.
C. coccifera aggr.	.	1	1	1	3	2	1	2	2	2	2	.	.	2
C. fimbriata	.	.	.	1	.	.	.	.	.	.	.	.	.	.
C. floerkeana	.	.	.	.	1	.	.	.	.	.	.	.	.	.
C. furcata	1	4	3	2	2	3	2	2	2	2	1	3	2	3
C. luteoalba	.	1	.	.	.	.	.	.	.	.	.	.	.	.
C. portentosa	1	2	.	.	1	1	.	.	1	1	.	1	1	.
C. rangiferina	.	.	1	1	.	.	.	2	.	1	.	.	.	.
C. uncialis	1	2	3	3	.	3	2	5	1	2	3	1	1	1
C. zopfii	.	.	.	.	.	1	.	.	.	1	.	.	.	.
Dibaeis baeomyces	.	1	1	.	.	1	1	1	1	2	1	.	.	1
Hypogymnia physodes	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Icmadophila ericetorum	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Lecanora symmicta	.	.	1	.	1	.	1	.	1	1	.	2	1	.
Lecidea limosa	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Micarea cinerea	.	.	.	.	.	.	.	.	.	1	1	.	.	.
M. leprosula	.	.	.	.	1	1	.	.	.	.	2	.	.	.

M. lignaria	.	3	1	1	1	2	2	2	2	2	2	1	.	1
M. turfosa	.	1	1	.	1	1	.	.	.	.	.	.	.	.
M. viridiatra	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Ochrolechia androgyna	.	1	.	.	.	.	.	.	.	.	.	.	.	.
O. frigida	1	5	5	5	3	2	2	2	4	4	2	4	3	1
O. tartarea	.	.	1	.	1	1	1	1	1	3	1	.	.	.
O. xanthostoma	1	1	1	1	1	.	1	.	.	.	.	1	.	1
Parmeliopsis ambigua	.	.	.	.	1	.	.	.	.	.	.	.	.	.
P. hyperopta	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Placynthiella icmalea	.	.	.	.	.	.	.	.	.	.	.	.		2
P. uliginosa	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Platismatia glauca	.	.	.	.	1	.	.	.	.	.	.	.	.	1
Pycnothelia papillosa	.	.	.	.	1	1	.	1	.	.	.	.	.	1
Thamnolia vermicularis	.	1	1	1	1	1	.	2	1	2	.	.	.	.
Trapeliopsis gelatinosa	.	.	.	.	1	.	.	.	.	1	.	.	.	.
T. granulosa	.	1	.	1	1	.	.	.	.	.	.	.	.	.
Saxicolous Lichens														
Allantoparmelia alpicola	.	x	.	.	.	.	.	.	.	.	x	.	.	x
Claurouxia chalybeioides	.	.	.	.	.	.	.	.	.	.	x	.	.	.
Cornicularia normoerica	.	x	x	.	.	.	.	x	.	.	x	.	.	x
Fuscidea cyathoides	.	x	.	.	.	.	.	.	.	.	.	.	.	.
F. intercincta	.	x	x	.	.	.	.	.	.	.	x	.	.	.
F. kochiana	.	x	x	.	.	x	.	.	.	x	x	.	.	.
F. gothoburgensis	.	.	.	.	.	.	.	.	.	.	x	.	.	.
Lecanora polytropa	.	.	.	x	.	x	.	.	.	.	.	.	.	x
Lecidea lithophila	.	.	x	.	x	x	.	x	.	.	x	.	.	.
L. ?lithophiloides	.	.	.	.	x	.	.	.	.	.	.	.	.	.
L. pycnocarpa	.	.	.	.	.	x	.	.	.	x	x	.	.	.
L. pycnocarpa f. sorediata	.	x	x	.	.	.	.	.	.	.	.	.	.	.
L. swartzioidea	.	.	.	.	.	x	.	.	.	.	x	.	.	x
Lecidella carpathica	.	x	.	.	.	.	.	.	.	.	.	.	.	.
Micarea leprosula	.	.	.	.	.	.	.	.	.	.	.	.	.	x
M. lignaria	.	.	.	.	.	.	.	.	.	.	.	.	.	x

Miriquidica liljenstroemii	.	.	.	.	.	.	.	.	.	.	x	.	.	.
M. lulensis	.	.	.	.	.	.	.	.	.	.	x	.	.	.
M. nigroleprosa	.	.	x	.	.	.	.	.	.	.	.	.	.	.
Ochrolechia tartarea	.	.	.	.	.	.	.	.	.	.	.	.	.	x
Parmelia incurva	.	.	.	.	.	.	.	.	.	.	.	.	.	x
Pertusaria corallina	.	x	.	.	x	.	.	.	.	.	.	.	.	.
Porpidia crustulata	.	x	.	x	x	x	.	x	x	x	.	.	.	.
P. 'striata'	.	.	.	x	.	x	.	.	.	.	.	.	.	.
P. tuberculosa	.	.	x	x	.	.	.	.	x	.	.	.	.	.
Pseudephebe pubescens	.	x	x	.	.	.	.	.	.	.	x	.	.	x
Rhizocarpon 'colludens'	.	.	.	.	.	.	.	.	.	x	.	.	.	.
R. aff. eupetraeoides	.	.	.	.	.	.	.	.	.	.	x	.	.	.
R. geographicum	.	x	x	.	x	x	.	.	x	x	x	.	.	x
R. jemtlandicum	.	.	.	.	.	.	.	.	.	.	x	.	.	.
Rimularia gyrizans	.	.	x	.	.	.	.	.	.	.	.	.	.	x
Schaereria cinereorufa	.	x	.	.	.	.	.	.	.	.	.	.	.	.
S. fuscocinerea	.	.	.	.	x	.	.	.	.	.	.	.	.	x
Sphaerophorus globosus	.	x	.	.	.	.	.	.	.	.	.	.	.	x
Tremolecia atrata	.	.	.	.	.	x	.	.	.	.	.	.	.	.
Umbilicaria cylindrica	.	x	x	.	x	.	.	x	.	x	x	.	.	x
U. proboscidea	.	.	.	.	x	x	.	.	.	x	.	.	.	x
U. torrefacta	.	.	.	.	.	.	.	.	.	.	x	.	.	.

Relevé	Grid Ref.	Alt. (m)	Date
45	37/0796	750	18/7/94
1	28/9906	890	15/6/94
3	28/9906	930	15/6/94
10	38/0107	920	16/6/94
11	38/0107	870	16/6/94
18	38/0005	910	18/6/94
23	38/0006	810	18/6/94
24	38/0006	790	18/6/94

25	38/0006	775	18/6/94
26	28/9904	880	19/6/94
27	28/9904	900	19/6/94
135	38/0107	850	22/8/94
136	38/0107	850	22/8/94
140	38/0006	750	16/9/94

Notes:

1) Low, wind-clipped dwarf shrubs, high on ridge. Patches of granite gravel and occasional low boulders. Large patch of *Ochrolechia frigida* overgrowing prostrate ericoid shrubs. Crustose lichens concentrated around edges of gravel, fruticose lichens among shrubs. Except for *O. frigida*, lichens in small, scattered thalli; *O. frigida* only lichen which over-grows shrubs to any extent. *Calluna vulgaris* stems only support *O. xanthostoma*.

3) Increase in *Cladonia arbuscula* due to slight bank on south side of quadrat where *C. vulgaris* reaches 5cm deep. This is also where most *Empetrum nigrum* and *Ochrolechia tartarea* occur.

10) Soil and gravel unstable due to steep slope so unsuitable for lichens. Very exposed site. *O. frigida* locally has 80% cover. *Alectoria ochroleuca* nearby.

11) *C. arbuscula* common beneath *C. vulgaris* canopy. One patch of bare peat which supports *Cladonia coccifera* aggr.

18) Other shrubs and fruticose lichens (*ie. Empetrum nigrum, Vaccinium myrtillus, Cetraria islandica, C. arbuscula*) strongly associated with deeper vegetation below low bank. Crustose lichens (especially *O. frigida*) associated with prostrate *C. vulgaris*, most others and bryophytes (eg. *Racomitrium lanuginosum*) with edge of gravelly areas.

23) Lichens poor. Wave prostrate *C. vulgaris* with large areas of bare gravel. Presumably too unstable and/or wind abraded to support good lichen growth. Best area is around boulders where *C. vulgaris/E. nigrum* can reach 12cm and better developed *Cetraria islandica, Cladonia arbuscula* and *C. uncialis* are present.

24) Loose gravel and associated peat too unstable to have many lichens but *Thamnolia vermicularis, Micarea lignaria, Baeomyces rufus* all centred there. Lichens rather patchy but well mixed in with *C. vulgaris*. *O. frigida* locally overgrowing *C. vulgaris* on exposed ridges.

25) *Alectoria sarmentosa* on very exposed crest. Unstable gravel/peat mixture.

26) A complex relevé due to the boulders, some of which are large and shelter patches of *C. vulgaris* and *E. nigrum* with luxurient *Cladonia arbuscula, C. furcata, C. rangiferina* and *C. uncialis*. Exposed wind-clipped, wind-burnt *C. vulgaris* overgrown with large patches of *O. frigida* and *O. tartarea*. Gravel unstable but peaty edges with fair cover of *Micarea lignaria* and *Dibaeis baeomyces*. *Micarea cinerea* on bases of *Juncus trifidus*.

27) Relevé on a level area of a steeper east-facing slope with less *C. vulgaris* (more bare rock and gravel). Lichens associated with edges of boulders and gravel patches. Soil thin (c. 1cm deep) but forming a rich loam. *Pertusaria oculata* present on *C. vulgaris* stem nearby.

Table 4·6. Relevés collected from NVC H19 *Vaccinium myrtillus-Cladonia arbuscula* heath

	LOCALITY											
	Lochnagar		Glas Maol	Beinn a'Bhuird		Cairn Gorm						Cairn Lochan
Relevé Number	**82**	**85**	**77**	**43**	**44**	**5**	**7**	**9**	**19**	**21**	**141**	**137**
Vegetation Cover (%)	90	100	95	95	100	90	95	95	95	95	95	100
Height of vegetation (cm)	5	5	1(5)	2	8	5	5	5	12	3	10	5
Lichen Cover (%)	20	25	10	50	80	45	30	45	30	60	15	40
Gravel (%)	8	-	-	-	-	0	3	1	0	0	-	-
Rock (%)	2	-	3	-	-	0	2	4	5	5	5	-
Peat (%)	-	-	2	.	.	.	.	.	.	.	-	-
Slope (°)	10	5	0	5	0	2	5	1	20	20	3	5
Aspect (°)	200	180	-	130	-	0	40	90	280	280	340	350
Calluna vulgaris	1	.	.	.	.	.	.	.	3	.	.	.
Empetrum nigrum	6	4	.	.	4	8	8	8	8	6	6	9
Loiseleuria procumbens	.	.	.	.	.	.	.	.	2	.	.	.
Melampyrum pratense	.	.	.	.	.	.	.	.	1	1	.	2
Vaccinium myrtillus	5	8	9	5	3	5	4	4	5	6	.	5
V. uliginosa	.	.	.	.	.	2	.	1	4	4	.	4
V. vitis-idaea	.	2	.	.	.	3	.	1	2	5	3	.
Carex bigelowii	1	4	7	1	3	4	3	4	2	4	.	2
C. piliferum	.	.	.	.	1	.	.	.	2	.	.	.
Deschampsia flexuosa	.	.	5	2	2	.	1	1	2	2	1	4
Festuca vivipara	4	3.	.	.	.	.	.	.	.	.	.	.
Juncus trifidus	5	1	.	5	3	.	1	1	.	.	7	.
Minuartia sedoides	.	.	.	.	.	.	1	.	.	.	.	.
Nardus stricta	.	.	.	.	.	.	.	.	1	.	.	.
Trichophorum cespitosum	.	.	.	.	.	.	.	.	1	.	.	.
Diphasiastrum alpinum	.	.	.	4	.	.	.	.	3	.	.	.
Huperzia selago	.	.	.	.	.	1	1	1	1	1	.	1

Anastrepta orcadensis	.	.	.	.	.	.	.	1	.	.	.	.
Barbilophozia floerkei	.	.	.	.	.	1	.	.	1	1	.	.
Calypoegia suecica	.	.	.	.	.	.	.	.	.	1	.	.
Dicranum scoparium	1	.	4	.	.	1	1	1	1	1	3	.
Diplophyllum albicans	.	.	.	.	.	.	.	.	1	.	.	.
Hylocomium splendens	.	.	.	.	.	.	.	1	1	1	.	.
Hypnum cupressiforme	.	.	.	.	.	.	.	.	3	2	.	.
Plagiothecium undulatum	.	.	.	.	.	.	.	.	1	.	.	.
Pleurozium schreberi	.	.	.	.	.	1	1	1	1	1	.	2
Pohlia nutans	.	.	.	.	.	.	1	.	.	.	.	.
Polytrichum commune	.	.	.	.	.	.	.	1	.	1	.	.
P. formosum	.	.	.	.	.	.	.	.	1	1	.	.
P. juniperinum	.	.	.	.	.	2	1	.	.	.	.	.
P. piliferum	.	1	.	.	.	.	.	1	.	??	.	.
Ptilidium ciliare	.	.	.	.	2	.	.	.	1	.	.	.
Racomitrium lanuginosum	2	4	3	5	2	3	5	.	1	3	5	3
Rhytidiadelphus loreus	.	.	.	.	.	.	1	1	2	2	.	.
R. squarrosus	.	.	.	.	.	1	.	.	.	.	.	.
Sphagnum quinquearium	.	.	.	.	.	.	.	.	.	1	.	.
Alectoria nigricans	.	.	3	.	.	1	1	1	.	.	2	.
Arthrorhaphis grisea	.	.	.	.	.	.	1	.	.	.	.	.
Baeomyces rufus	.	.	.	.	.	.	1	1	.	.	1	.
Cetraria aculeata	1	.	.	.	.	1	1	3	.	1	3	.
C. ericetorum	3	.	.	.	.	.	.	.	.	.	.	.
C. islandica	5	5	3	5	5	4	3	2	4	4	3	5
C. muricata	.	.	.	.	.	1	.	.	.	.	.	.
C. nivalis	.	.	.	2	1	.	1	1	.	1	1	.
Cetrariella delisei	.	.	.	.	.	.	1	.	.	.	.	.
Chromatochlamys 'geislerioides'	.	.	.	.	.	.	1	.	.	.	.	.
Cladonia arbuscula	2	3	3	4	6	5	4	5	5	5	2	6
C. bellidiflora	2	1	1	.	.	.	1	1	1	1	.	.
C. chlorophaea	.	.	.	.	.	.	1	.	1	1	.	.

C. coccifera aggr.	.	.	.	1	.	1	1	1	3	1	1	.
C. floerkeana	.	.	.	.	.	.	1	.	1	.	.	.
C. furcata	2	2	.	3	2	2	2	3	2	2	3	1
C. gracilis	.	.	.	.	.	.	.	.	1	1	.	.
C. macilenta	2	.	3	.	.	.	.	.	.	.	.	.
C. portentosa	.	.	.	.	.	.	.	.	.	1	.	.
C. rangiferina	1	3	3	.	3	1	3	3	2	4	.	.
C. squamosa	.	.	.	.	.	.	.	.	.	1	1	.
C. uncialis	3	5	4	4	4	3	5	5	2	4	3	2
C. zopfii	.	.	.	.	.	.	.	.	.	1	.	.
C. sp. (squamules)	.	.	2	.	.	.	.	.	.	.	.	.
Dibaeis baeomyces	.	.	.	.	.	.	1	.	.	.	.	.
Lecidea limosa	.	.	.	.	.	.	1	.	.	.	.	.
Lecidoma demissum	1	.	.	1	.	.	.	1	.	.	.	.
Micarea cinerea	.	.	1	.	.	.	.	.	.	.	2	.
M. leprosula	.	.	.	.	.	.	1	1	1	.	.	.
M. lignaria	2	.	.	.	.	1	.	1	1	1	2	.
M. peliocarpa	.	.	.	.	.	.	.	.	.	.	1	.
M. turfosa	.	.	.	.	.	.	1	.	.	.	.	.
Ochrolechia frigida	3	4	2	2	2	2	2	4	.	1	2	.
O. tartarea	1	.	.	1	.	1	1	1	.	.	1	.
Omphalina sp. (sterile)	.	.	.	.	.	.	1	.	.	.	.	.
Placynthiella uliginosa	.	.	.	.	.	.	.	.	1	.	.	.
Pseudephebe pubescens	.	.	.	.	.	.	.	.	.	.	1	.
Pycnothelia papillosa	1	.	1	1	.	.	1	.	.	.	.	.
Thamnolia vermicularis	.	.	.	.	.	.	1	.	.	1	3	.
Trapeliopsis gelatinosa	.	.	.	.	.	.	.	.	.	.	1	.
T. granulosa	.	.	.	.	.	.	.	1	.	1	.	.
Saxicolous Lichens												
Allantoparmelia alpicola	.	.	.	.	.	.	.	x	.	.	.	.
Cetraria hepatizon	.	.	.	.	.	.	.	x	.	.	.	.
Cornicularia normoerica	.	.	.	.	.	.	.	x	.	.	.	.
Fuscidea gothoburgensis	.	.	.	.	.	.	.	.	x	x	.	.

F. intercincta	.	.	.	.	.	.	.	x	.	.	.	.
F. kochiana	.	.	x	.	.	.	.	x	x	x	.	.
Lecanora polytropa	.	.	.	.	.	.	.	x	x	.	.	.
Lecidea lithophila	.	.	.	.	.	.	x	.	.	.	.	.
L. pycnocarpa	.	.	.	.	.	.	.	x	.	.	.	.
L. pycnocarpa f. sorediata	.	.	.	.	.	.	x	.	.	.	.	.
Ochrolechia tartarea	.	.	.	.	.	.	.	.	.	x	x	.
Pertusaria corallina	.	.	.	.	.	.	.	x	.	.	.	.
P. oculata	.	.	.	.	.	.	.	.	x	.	.	.
Porpidia cinereoatra	x	.	.	.	.	.	.	x	.	.	.	.
P. contraponenda	x	.	x	.	.	.	.	.	.	.	.	.
P. crustulata	x	.	x	.	.	.	x	x	.	.	.	.
P. tuberculosa	x	.	x	.	.	.	x	.	x	.	x	.
Protoparmelia badia	.	.	.	.	.	.	.	x	.	x	.	.
Pseudephebe pubescens	x	.	.	.	.	.	x	x	.	x	x	.
Rhizocarpon copelandii s. lat.	.	.	.	.	.	.	.	x	.	.	.	.
R. geographicum	x	.	x	.	.	.	x	x	x	x	x	.
R. lecanorinum	.	.	.	.	.	.	x	x	.	.	.	.
Schaereria fuscocinerea	.	.	.	.	.	.	.	x	.	.	.	.
Stereocaulon dactylopyllum	.	.	.	.	.	.	.	x	.	.	.	.
S. vesuvianum	.	.	.	.	.	.	.	x	x	.	x	.
Tremolecia atrata	.	.	.	.	.	.	.	.	.	.	x	.
Umbilicaria cylindrica	.	.	.	.	.	.	.	x	.	x	x	.
U. proboscidea	.	.	.	.	.	.	.	.	.	.	x	.
U. torrefacta	.	.	.	.	.	.	.	x	.	.	.	.

Relevé	**Grid Ref.**	**Alt. (m)**	**Date**
82	37/2585	1050	8/7/95
85	37/2485	1050	8/7/95
77	37/1577	920	7/7/95
43	37/0898	1020	18/7/94
44	37/0898	990	18/7/94

5	38/0005	990	16/6/94
7	38/0105	1040	16/6/94
9	38/0106	960	16/6/94
19	38/0005	930	18/6/94
21	38/0006	960	18/6/94
141	38/0005	950	16/9/95
137	28/9704	800	24/8/95

Notes:

85) Large, luxuriant patches of *Cetraria islandica* where vegetation is deepest.

43) Interesting mixture of *Juncus trifidus, Diaphasiastrum alpinum, Vaccinium myrtillus* and *Racomitrium lanuginosum* with lichens in mat. *Cetraria islandica* more widespread, *Cladonia* spp. in clumps.

44) Lichens are the main structural element.

5) Lichens scattered throughout, Occasional clumps of *Cladonia uncialis* and *Ochrolechia frigida*, less *Alectoria nigricans*. *V. myrtillus* and *V. uliginosum* probably under-recorded due to earliness in year. In slight hollow within U10.

7) Scattered lichens, disassociated with *Racomitrium lanuginosum*. *Lecidea limosa* appears to be stabilizing gravel (with *O. tartarea*). *Cladonia rangiferina* in more sheltered areas. *O. frigida* (with *C. uncialis*) associated with *V. myrtillus*.

9) On generally east-facing slope; vegetation and lichens uniformly distributed.

19)Sheltered upper section of valley. Squamulose *Cladonia* spp. only near to boulders on little faces of peat. Very few places suitable for crustose lichens. *Cladonia arbuscula* abundant and conspicuous in the ericaceous canopy where it locally exceeds 50% cover. *Cetraria islandica* also locally very abundant. Bryophytes mainly in deep hollows away from ericaceous shrubs where they are rather overshaded and form a lower field layer in pockets. *Pertusaria oculata* on side of boulder in deep shelter. *Placynthiella uliginosa, Micarea leprosula,* and *M. ligraria* all together on a peat face below a boulder.

21) On exposed brow of ridge alternating with patches of H13 but slightly more sheltered. Continuous, low, wind-clipped cover 3cm high. Canopy is densely packed with lichens including species of exposed sites *ie. Cetraria nivalis, O. frigida* and *Thamnolia vermicularis*. *Cladonia chlorophaea, C. gracilis, C. portentosa* and bryophytes are concentrated in sheltered hollows and depressions. Crustose lichens, including *Cladonia* spp. centred around low boulders which are lapped by the shrubs but the lichens occur in the exposed living edge. Soil; 10cm, reddish, well developed peat over granite, full of living rhizomes.

137)*Racomitrium lanuginosum* as one large patch; *Cladonia furcata* and *C. uncialis* associated with this. *Empetrum nigrum* not associated with other vascular plants, lichens projecting through.

Table 4•7. Relevés collected from NVC U9 *Juncus trifidus-Racomitrium lanuginosum* rush heath.

	LOCALITY																
	Lochnagar	Beinn a'Bhuird		Cairn Lochan						Beinn MacDuibh			Braigh Riabhaich		Creag Meagaidh	Carn Eige	
Relevé	**84**	**41**	**42**	**12**	**13**	**30**	**31**	**32**	**33**	**14**	**15**	**16**	**17**	**48**	**122**	**50**	**51**
Vegetation Cover (%)	90	80	30	40	55	45	50	80	80	50	60	40	50	60	90	50	85
Height of vegetation (cm)	5	15	12	2	2	3	3	5	7	5	7	5	5	5	5	2	0•5
Lichen Cover (%)	3	5	3	7	10	10	5	20	15	10	30	5	15	5	5	15	15
Gravel (%)	-	nd	nd	50	25	45	35	20	2	25	25	50	25	35	-	-	-
Rocks (%)	-	nd	nd	10	20	10	15	-	-	15	15	10	20	-	10	40	15
Peat (%)	2	nd	nd	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Slope (°)	0	3	5	3	4	15	3	0	0	0	0	0	4	3	10	0	5
Aspect (°)	-	90	90	210	225	100	110	-	-	-	-	-	280	60	0	-	280
Empetrum nigrum ssp. hermaphroditum	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium saxatile	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.
Salix herbacea	.	2	.	4	2	4	3	4	4	.	.	2	1	.	.	2	3
Silene acaulis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Vaccinium myrtillus	7	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Carex bigelowii	6	3	1	2	2	1	.	2	4	2	1	.	.	.	4	2	2
C. piliferum	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.
Deschampsia cespitosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.
D. flexuosa	.	5	3	2	3	4	2	4	4	2	4	4	4	3	2	.	.
Festuca ovina	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	3	.
Juncus trifidus	9	10	6	7	7	5	7	6	8	7	8	7	7	7	7	5	.
Luzula spicata	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	3	3
Nardus stricta	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.
Huperzia selago	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	.	.

Bryum ?alpinum	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
?Campylopus sp.	.	.		.	.	.	..	.	2	.	.	.	.	.	.	.	.
Dicranum fuscescens	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.
D. scoparium	1	1	.	.	.	.	.	.	1	.	.	2	.	.	3	.	.
Kiaeria starkei	.	.	.	1		1	.	1	1	.	1	.	.	.	.	.	.
Polytrichum alpinum	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
P. commune	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.
P. piliferum	.	3	3	.	.	1	3	2	1	2	1	1	1	1	2	3	1
P sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.
Racomitrium fasciculare	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.
R. heterostichum	.	.	.	.	.	2	1	5	4	.	.	.	.	.	.	.	4
R. lanuginosum	2	4	4	1	2	4	5	4	4	4	4	4	2	6	3	5	4
Rhytidiadelphus squarrosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.
Barbilophozia floerkei	.	1	.	.	1	.	.	3	2	1	.	.	.	.	.	.	.
Gymnomitrion spp.	.	.	.	.	1	4	3	4	5	1	1	.	.	.	1	4	6
Marsupella spp.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.
Ptilidium ciliare	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Terricolous																	
Alectoria nigricans	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arthrorhaphis grisea	.	.	.	.	1	1	.	.	.	1	.	.	.	.	.	.	.
Baeomyces placophyllus	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
B. rufus	.	1	.	1	2	.	1	.	.	1	.	.	1	.	.	1	.
Catillaria contristans	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Cetraria aculeata	.	.	1	1	1	.	.	.	1	3	1	1	.	.	.	.	1
C. ericetorum	3	3	.	.	.	.	.	2	2	.	1	.	.	1	.	.	.
C. islandica	4	1	.	.	1	2	1	.	2	4	4	.	1	3	2	.	1
C. nivalis	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cetrariella delisei	.	1	.	.	.	.	.	2	1	1	1	1	.	.	.	.	.
Cladonia arbuscula	1	2	.	1	.	2	.	1	1	.	1	1	.	.	.	.	.
C. bellidiflora	2	.	.	1	1	2	1	.	2	1	3	1	2	2	1	1	.
C. chlorophaea	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.

C. chlorophaea	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
C. ciliata v. tenuis	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. coccifera aggr.	3	1	1	3	2	2	2	2	4	3	3	3	4	1	.	2	2
C. furcata	.	2	.	3	3	2	3	.	3	3	2	.	4	.	.	1	.
C. gracilis	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
C. pyxidata	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.
C. rangiferina	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. uncialis	5	4	2	1	1	3	2	4	4	2	2	1	1	2	1	1	.
C. sp (squamules)	3	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.
Dibaeis baeomyces	.	.	2	1	2	3	.	.	.	1	1	1	1	1	.	.	1
Epigloea soleiformis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Epilichen scabrosus	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Frutidella caesioatra	.	.	.	.	.	.	.	3	2	1	1	.	.	.	.	.	.
Lecidea hypnorum	.	.	.	1	1	.	.	1	.	.	.	.	.	.	.	.	.
L. limosa	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	.
Lecidoma demissum	2	.	.	1	2	2	2	1	3	.	1	1	.	.	.	.	.
Lepraria neglecta	.	.	.	.	1	.	.	1	1	.	.	.	.	.	.	.	.
Micarea cinerea	.	.	.	2	2	.	1	.	.	2	1	.	1	.	.	.	.
M. incrassata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
M. lignaria	1	.	.	1	1	1	.	.	.	.	1	1	1	.	.	.	.
M. turfosa	.	.	2	1	2	2	.	1	3	2	3	1	2	.	1	.	.
Ochrolechia frigida	2	1	.	1	.	.	.	2	3	1	2	1	1	.	.	1	.
O. tartarea	1	2	3	1	2	3	1	3	3	1	2	1	1	2	.	5	1
Pertusaria oculata	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Pseudephebe pubescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Pycnothelia papillosa	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Solorina crocea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Sphaerophorus globosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.
Stereocaulon condensatum	.	.	1	1	.	1	2	.	.	1	1	1	1	.	.	1	1
S. saxatile	.	.	.	.	.	1	.	.	1	.	.	.	.	.	2	.	1
S. vesuvianum	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
S. sp	.	.	1	.	1	.	.	.	.	.	.	.	.				
Thamnolia vermicularis	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2

Toninia squalescens	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Verrucaria bryoctona	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Saxicolous																	
Amygdelaria pelobotryon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x
Immersaria athroocarpa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.
Lecanora leptacina	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.
L. polytropa	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.
Lecidea limosa	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.
L. lithophila	x	.	.	x	x	.	x	.	.	x	x	x	.	.	x	x	.
L. pycnocarpa	.	.	.	x	.	.	x	.	.	x	x	x	x	.	.	.	.
f. sorediata	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.
L. swartzioidea	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.
Lepraria neglecta	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.
Miriquidica lulensis	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.
Ochrolechia tartarea	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Placopsis gelida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x
Porpidia contraponenda	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.
P. crustulata	x	.	.	x	x	.	x	.	.	.x	x	x	.	.	x	x	.
P. tuberculosa	x	.	.	.	x	.	.	.	.	x	.	x	.	.	.	.	.
'v. grisea' ad int	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x
Protoparmelia badia	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudephebe pubescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.
Rhizocarpon copelandii s. lat.	.	.	.	.	x	.	.	.	.	.	x	.	.	.	.	.	.
R. 'colludens'	.	.	.	.	.	.	.	.	.	.	x	.	.	.	x	.	.
R. geographicum	x	.	.	x	x	.	.	.	.	x	x	.	x	.	.	x	.
Rimularia gyrizans	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.
Stereocaulon evolutum	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.
S. tornense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	x	.
S. vesuvianum	.	.	.	.	.	.	x	.	.	x	x	.	.	.	.	.	.
Tephromela atra	.	.	.	.	.	.	x	.	.	x	x	x	.	.	.	.	.
Umbilicaria cylindrica	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.

Relevé	Grid Ref.	Alt.	Date	Location
84	37/2485	1150	8/7/95	Lochnagar
41	37/0998	1170	18/7/94	Beinn a'Bhuird
42	37/0998	1150	18/7/94	Beinn a'Bhuird
12	28/9903	1120	17/6/94	Cairn Lochan
13	28/9902	1140	17/6/94	Cairn Lochan
30	28/9802	1170	19/6/94	Cairn Lochan
31	28/9802	1180	19/6/94	Cairn Lochan
32	28/9802	1200	19/6/94	Cairn Lochan
33	28/9802	1200	19/6/94	Cairn Lochan
14	28/9800	1170	17/6/94	Beinn MacDuibh
15	28/9800	1170	17/6/94	Beinn MacDuibh
16	28/9800	1170	17/6/94	Beinn MacDuibh
17	28/9800	1170	17/6/94	Beinn MacDuibh
48	27/9498	1240	20/7/94	Braigh Riabhaich
122	27/4082	1000	12/8/95	Creag Meagaidh
50	28/1226	1110	22/7/94	Carn Eighe
51	28/1125	850	22/7/94	Mam Sodhail

Notes:

41) Lichen cover decreases with increasing higher plant cover. *Cetraria nivalis* present nearby in shelter of shaded edge of *Juncus trifidus* tussock.

42) Vegetation very sparse. Lichen mostly associate with edge of *J. trifidus* tussocks or encrusting moribund bryophytes. Few patches of *Cetraria nivalis*; largest c. 20x15cm

12) Lichens all very abraded and porly developed; *Cladonia* spp. rarely with podetia. Lichens completely associated with *J. trifidus* (especially moribund bases which are very persistent). Rocks only colonised on sides and in crevices due to wind abrasion. Lichens better developed in lee of large boulders.

13) Increased rock content helps stabilize gravel giving better lichen cover. Vegetation forms 'waves' (migrating east) with lichens colonising rear edge.

30) Vegetation on faces of terracettes, steps are gravelly ledges with peaty soil showing through; often gravel 60%, peat 40%. Peat well covered with *Anthelia/Gymnomitrium* spp., *Dibaeis baeomyces* and *Micarea turfosa*. Fruticose lichens associated with *J. trifidus* as is *Stereocaulon saxatile*.

31) Areas and patches of *J. trifidus* with associated *Racomitrium lanuginosum*. Large patches of *Lecidoma demissum* on gravel and

decaying ridges of *J. trifidus* - which is where most lichen interest is usually centred.
32) Large tussocks of *J. trifidus, Deschampsis flexuosa, R. lanuginosum, R. heterostichum, Cladonia uncialis* raised approximately 5-10 cm above level of gravel.
33) Soil deep dunes of gravel. Gravel/peat lining deep pockets in the *J. trifidus* turf so fairly stable and with much *Lecidoma demissum, Frutidella caesioatra, Micarea turfosa. Cladonia* and *Ochrolechia* spp. tend to be on exposed turf edges facing west. Bryophytes in with the dense higher plants except for *Anthelia/Gymnomitrion* and cushion-forming species.
14) Ungrazed so highly vegetated giving protection; also gravel intermixed with small rocks (c.10cm). Clumps of *Cetraria islandica, Cladonia uncialis, C. furcata* up to 10cm hidden in *J. trifidus* clumps.
15) *J. trifidus* fairly thick tussocks full of *R. lanuginosum. Cetraria islandica* and *Cladonia* spp. all well developed. Much *Micarea turfosa* in among gravel. *Ochrolechia* spp. in edge of tussocks.
17) Lichens concentrated on the down-wind side of the tussocks and in the middle of taller ones.
50) Characterised by large patches of *Ochrolechia tartarea.* Apparently 'bare soil' is a *AntheliaGymnomitrion* carpet.
51) 'Bare soil' and small rocks with *J. trifidus* and *R. lanuginosum* clumps. *O. tartarea* in relevé 50 replaced by *Soloria crocea* (the lichenicolous lichen *Rhagadostoma lichenicola* usually present). *Micarea incrassata* also frequent.

4•2•2•2 H13 *Calluna vulgaris-Cladonia arbuscula* heath (Figs 4•1 & 4•2)

The lichen-rich facies of this community is that known as prostrate *C. vulgaris* heath. It is almost confined to the Cairngorm Mountains of north-east Scotland where it covers large areas of low-montane heath. It is most typical of wind-swept, exposed sites but occasionally occurs in less-exposed areas. All except one of the relevés collected were from the northern Cairngorms where this community reaches its maximum development, the other relevé (from Beinn a' Bhuird) had a significantly lower lichen diversity than any other relevé with a similarly high vegetation cover (90%). This pattern is confirmed by the relevés of H19 which were collected from a more representative range of sites.

The community is characterized by macro-lichens (*Cetraria* spp. and *Cladonia* subgen. *Cladina* spp - mostly confined to deeper area of vegetation in the lee of banks) but also with a high percentage cover of *Ochrolechia frigida* (overgrowing the prostrate *C. vulgaris*). Many of these species qualify as 'constants', being present in more than 80% of stands, e.g. *Cetraria aculeata, C. islandica, Cladonia arbuscula, C. coccifera* aggr., *C. furcata* and *C. uncialis,* but as they are equally 'constant' in other communities they are of little value in characterizing the community. There are, however, three character lichen species at fidelity 5:- *Alectoria ochroleuca,* (Fig. 4•3) *A. sarmentosa* subsp. *vexillifera* (Fig. 4•4) and *Ochrolechia xanthostoma* (on *C. vulgaris* stems), and two at fidelity 3:- *Cetraria nivalis* (Fig. 4•5) and *Ochrolechia frigida* (Fig. 4•6). Purvis *et al.* (1992) give the habitat of *A. ochroleuca* as 'In *Rhacomitrium-Empetrum* communities above *c.* 800m.' but in this study it was found to be restricted to the lower facies of the prostrate *C. vulgaris* heath, often on the upper edge of the cline between this community and that in which *Arctostaphylos uva-ursi* becomes frequent (H16 *C. vulgaris-Arctostaphylos uva-ursi*). *Cetraria nivalis* was also found to be most frequent in this community, in spite of the somewhat wider ecological amplitude given to it by Purvis *et al.* (1992).

Figure 4•1. NVC H13 *Calluna vulgaris-Cladonia arbuscula* heath. Creagan Dubh, Northern Cairngorms (Relevé 140).

Figure 4•2. NVC H13 *Calluna vulgaris-Cladonia arbuscula* heath (close-up). Sròn a' Cha-no, Northern Cairngorms (Relevé 135).

Figure 4·3. *Alectoria ochroleuca* - an exclusive species (Fidelity 5) of NVC H13 *Calluna vulgaris-Cladonia arbuscula* heath. (Magnification x1).

Figure 4·4. *Alectoria sarmentosa* subsp. *vexillifera* - an exclusive species (Fidelity 5) of NVC H13 *Calluna vulgaris-Cladonia arbuscula* heath. (Magnification x2).

Figure 4•5. *Cetraria nivalis*- a selective species (Fidelity 3) of NVC H13 *Calluna vulgaris-Cladonia* arbuscula heath. (Magnification x1)

Figure 4•6. *Ochrolechia frigida* - a selective species (Fidelity 3) of NVC H13 *Calluna vulgaris-Cladonia arbuscula* heath. (Magnification x2).

4•2•2•3 H19 *Vaccinium myrtillus-Cladonia arbuscula* heath. (Figs 4•7 & 4•8)

This community has a similar distribution to H13, replacing it at higher altitudes. The ericaceous shrubs which form the main structural element of the community do not generally become as prostrate as the *C. vulgaris* in H13 and as a consequence crustose lichens are not as numerous. Conversely, as the vegetation tends to be deeper the abundance of macro-lichens is often greater. It follows the same trend as H13 with lichen diversity being greatest in those stands from the northern Cairngorms and lower further east and west.

The lichen vegetation of this community is very similar to that of H13. It differs from it mainly in the absence, or lower incidence, of the character species. The two fidelity category 3 species, *Cetraria nivalis* and *Ochrolechia frigida*, are frequent but less so than in H13. Another major difference is the crustose species which occur in soil in gaps in the vegetation as, due to the generally higher altitude of this community, these are species having more affinity with mid-montane communities (e.g. H9 *Juncus trifidus-Racomitrium lanuginosum*) rather than the low-montane conditions of H13. These include *Chromatochlamys 'geislerioides'* ad int. and *Lecidoma demissum*. This is an indication that the greatest change in the macro-lichen vegetation occurs between H19 and U9 whereas for micro-lichens it is between H13 and H19. However, many other micro-lichens occur in both H13 and H19 and more work is required to clarify this proposition.

4•2•2•4 U9 *Juncus trifidus-Racomitrium lanuginosum*. (Figs 4•9–4•11)

This is the dominant community on exposed summits in the Scottish Highlands. Like H13 and H19 this community also reaches is maximum lichen diversity on the northern Cairngorms (Cairn Lochan) as further west *Racomitrium lanuginosum* forms a much greater component of the vegetation and largely replaces lichens. Further east (Lochnagar) the increasingly continental climate allows vascular-plants to attain a higher altitude with the result that stands are not only smaller but vascular-plants fill those gaps in the community which are occupied by lichens on Cairn Lochan.

Figure 4•7. NVC U19 *Vaccinium myrtillus-Cladonia arbuscula* heath. Maidan Creag an Leth-choin, Northern Cairngorms (Relevé 137).

Figure 4•8. NVC U19 *Vaccinium myrtillus-Cladonia arbuscula* heath. Lichen-rich facies, southern slope of Beinn a' Bhuird (Relevé 44).

Figure 4•9. NVC U9 *Juncus trifidus- Racomitrium lanuginosum* rush heath. Carn Lochan, Northern Cairngorms; looking towards Braigh Riabhaich (Relevé 31).

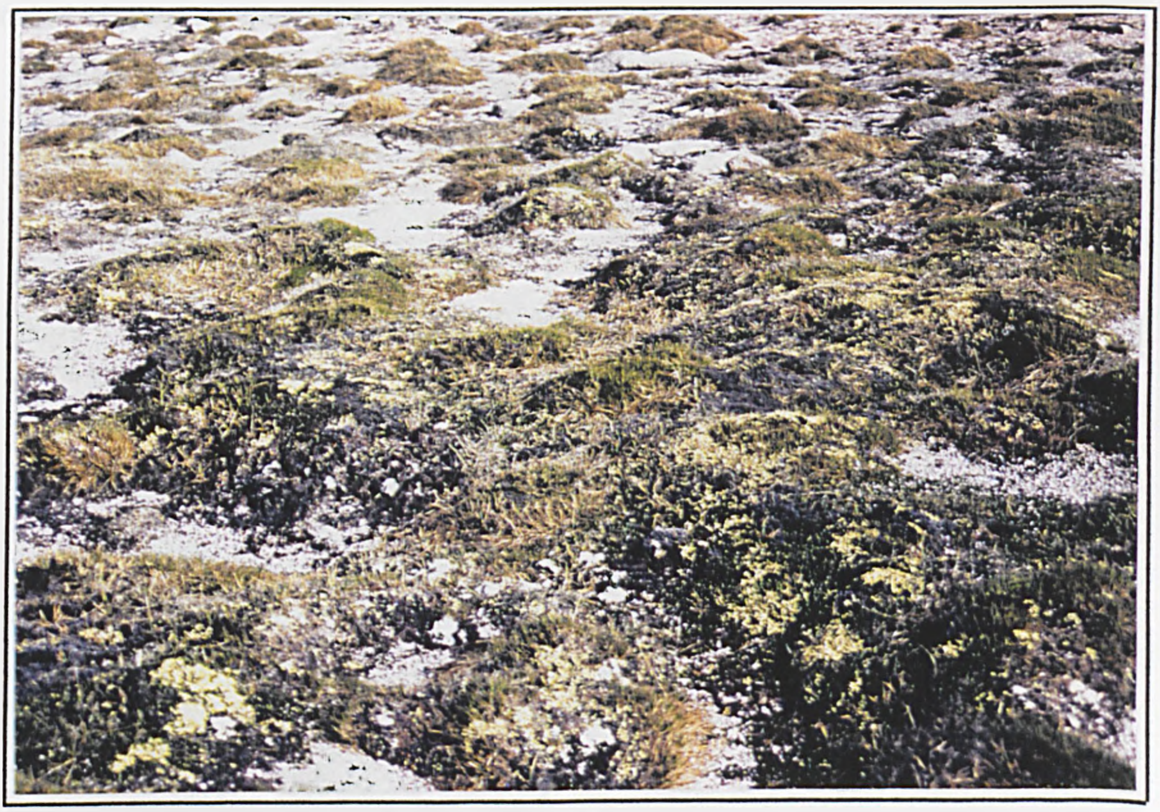


Figure 4•10. NVC U9 *Juncus trifidus- Racomitrium lanuginosum* rush heath. Carn Lochan, Northern Cairngorms. Increased lichen growth on raised peat associated with *J. trifidus* tussocks (Relevé 33).

Figure 4•11. NVC U9 *Juncus trifidus- Racomitrium lanuginosum* rush heath. Mam Sodhail, Central Highlands. The gravel of the Cairngorms is replaced by peat covered with an hepatic mat which supports numerous micro-lichens (Relevé 51).

Figure 4•12. *Lecidea limosa* - a preferential species (Fidelity 4) of NVC U9 *Juncus trifidus-Racomitrium lanuginosum* rush heath. (Magnification x2).

The changes in the cover of *R. lanuginosum* and vascular plants is not obvious from the data but this is largely a consequence of choosing relevés with a high lichen (and consequently low *R. lanuginosum* or vascular-plant) cover and also by the bias of the Domin scale towards lower cover values so the difference between 4 (4-10% cover) and 6 (26-33 % cover) is much larger than it would appear at first sight. It will be necessary to sample randomly and record actual percentage cover, rather than Domin values to show this shift in the vegetation.

There is a shift away from macro-lichens towards micro-lichens in this community with the former being confined to clumps of vegetation and the latter mainly occupying the 'bare soil' in-between. The decline in cover and occurrence of *Cetraria islandica* (largely replaced by *C. ericetorum*) and *Cladonia arbuscula* is particularly apparent. Two macro-lichens are, however, more frequent in this community than either of H13 or H19. These are *Cladonia bellidiflora* and *Stereocaulon saxatile*, both species considered by Gilbert & Fox to be character species of late snow-lie vegetation. Among the micro-lichens which do not occur in H13 or H19 are *Catillaria contristans, Frutidella caesioatra, Lecidea hypnorum, Lepraria neglecta, Micarea incrassata* and *Stereocaulon condensatum* while others are much more frequent here, e.g. *Lecidea limosa, Lecidoma demissum, Micarea cinerea* and *Ochrolechia tartarea*. Many of the former group also occur in other mid- to high-montane communities, e.g. U8 and late snow-lie vegetation, but the latter group, in general reach their best development here, at least in the Cairngorms, and many can be considered as character species. These are *Catillaria contristans, Lecidea limosa* (Fig. 4•12) and *Lecidoma demissum* which are best assigned to fidelity 4 and the anamorph of *Micarea cinerea* which is recognised at fidelity 3. It is probable that this lichen-dominated vegetation should be recognised as a separate community (see Chapter 5)

4•2•2•5 Other Communities

The two other most important NVC montane communities, U7 *Nardus stricta-Carex bigelowii* (Fig. 4•13) and U10 *Carex bigelowii-Racomitrium lanuginosum* were also sampled but were of only minor lichenological interest.

Figure 4•13. NVC U7 *Nardus stricta- Carex bigelowii* grass heath. Ciste Mhearad, Cairngorm (Relevé 2).

Figure 4•14. *Cladonia maxima* - an exclusive species (Fidelity 5) of NVC U7 *Nardus stricta - Carex bigelowii* grass heath. (Magnification x2).

Lichens mostly occurred in gaps in the vegetation and so were not strictly part of the community. U7 does, however, have one character species at fidelity 5, *Cladonia maxima* (Fig. 4.14; Table 4•7). Rodwell (1991) also includes *Cetrariella delisei* (as *Cetraria delisei*) as a rare species occurring in this community but the actual situation is somewhat more complex, the lichen occurring on the boundary between this and other communities, usually U8 or U9, and is more a part of those communities than it is of U7 (see below).

Also of interest were U8 *Carex bigelowii-Polytrichum alpinum*, U11 *Polytrichum sexangulare-Kiaeria starkei* and U12 *Salix herbacea-Racomitrium heterostichum*. The latter two (U11 and U12) are confined to areas of late snow-lie so are dealt with in the next chapter whereas U8 was usually represented by very small stands in mosaics with other communities and was hard to sample adequately as the micro-climate effects associated with the boundaries of the community rendered it almost impossible to recognise a homogeneous stand. Only on Beinn a' Bhuird were stands of any size encountered and a relevé from one of these is given in Table 4•8. The lichen vegetation of this stand differs little from that of U9.

The general relative arrangement of these communities in the Cairngorm mountains, along with their character lichen species, is given in Fig. 4•15.

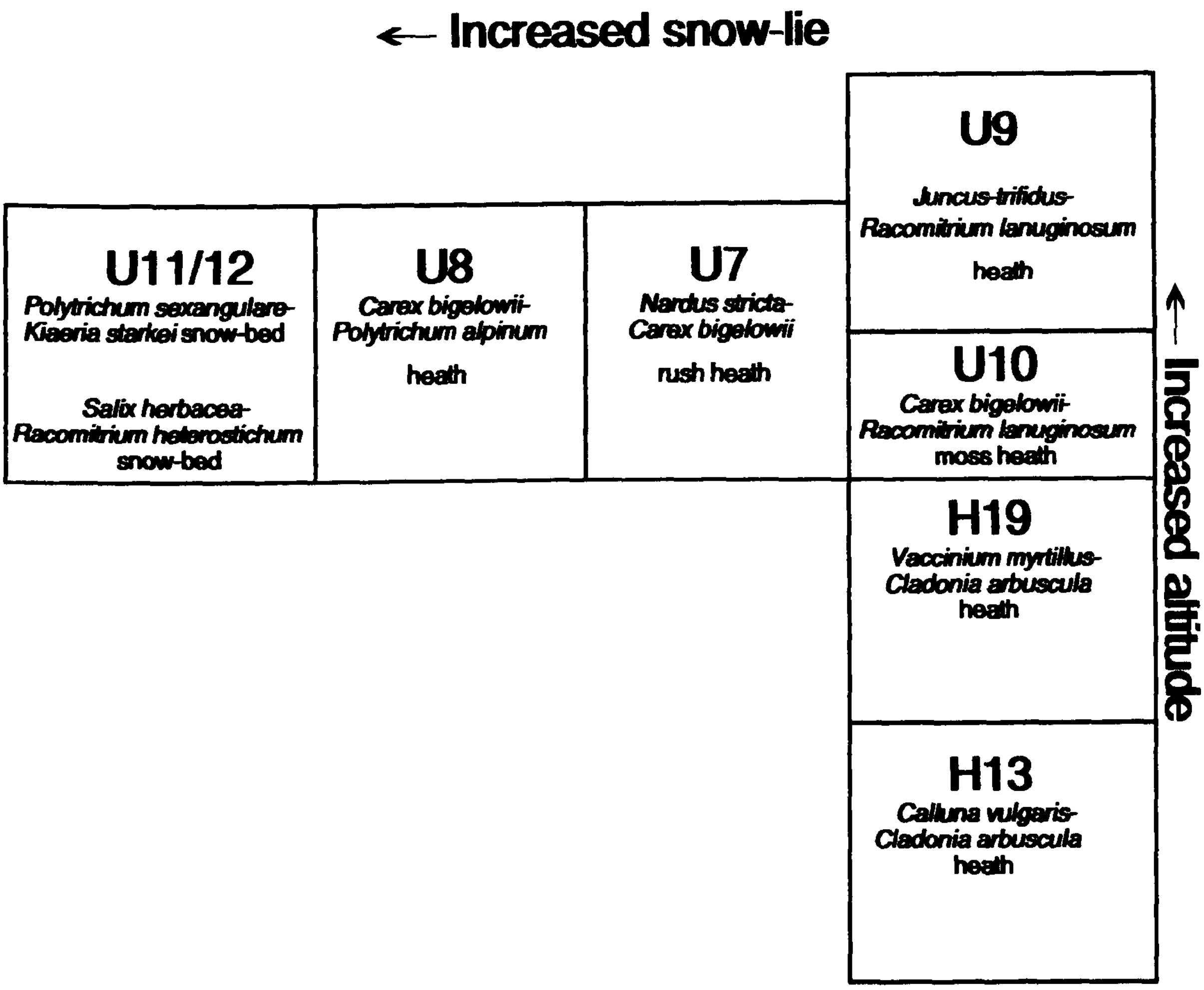
Table 4•8. Relevé 39 from Beinn a' Bhuird: NVC U8 *Carex bigelowii-Polytrichum alpinum* sedge heath.

Vegetation Cover (%)	100
Height of vegetation (cm)	1(5)
Lichen Cover (%)	25
Slope (°)	0
Aspect (°)	-
Carex bigelowii	10
Deschampsia flexuosa	4
Dicranum scoparium	1
Polytrichum alpinum	4
Ptilidium ciliare	2
Catillaria contristans	1
Cetrariella delisei	3
Cladonia coccifera aggr.	1
Micarea turfosa	1
Ochrolechia frigida	2
O. tartarea	1
Omphalina sp. (sterile)	1
Cecidonia xenophana	x

Relevé	**Grid Ref.**	**Alt. (m)**	**Date**
39	37/0899	1150	18/7/94

Notes:

39) Lichens strongly associated with deeper vegetation (*Nardus stricta*). Soil gravelly, very deep.



Character Species

H13

Fidelity 5
Alectoria ochroleuca
A. sarmentosa subsp. *vexillifera*
Ochrolechia xanthostoma

Fidelity 3
Cetraria nivalis
Ochrolechia frigida

H19

Fidelity 4
Cetraria nivalis
Ochrolechia frigida

U9

Fidelity 4
Catillaria contristans
Lecidea limosa
Lecidoma demissum

Fidelity 3
Micarea cinerea (anamorph)

U7

Fidelity 5
Cladonia maxima

Figure 4·15. Schematic diagram of main NVC communities in the Cairngorm mountains of north-east Scotland with character lichen species.

4•2•3 Discussion

Initially it was planned to analyse the data collected from the relevés by TWINSPAN. However, during the collection process it became clear that this would probably be a poor utilization of time and resources as the macro-lichen data appeared to fit very well with NVC communities whereas the micro-lichen data showed little correlation with NVC and the relevé size used to sample NVC communities was far too large to provide the required 'homogeneous stand' of micro-lichen dominated vegetation. This was confirmed by the TWINSPAN analyses of data collected from the vicinity of areas of prolonged snow-lie (see chapter 5) where the vegetation was largely dominated by cryptogams and, consequently, the 2x2 relevé size was less inappropriate for sampling the micro-lichen vegetation. Although not completely without value, this analysis added little to what was apparent from hand-sorting and visual inspection of the data and so this was the method used for the phytosociology data.

A number of conclusions can be drawn from the present study most of which are related to the sensitivity of lichens to small environmental changes:-

a) **small-scale mosaics cannot be treated as homogeneous stands when investigating the lichen vegetation as each micro-environment has its own characteristic lichen vegetation.**

The NVC treated mosaics 'as a single vegetation type where they were repeatedly encountered in the same form or where the scale made it quite impossible to sample the elements separately' (Rodwell 1990). This approach will obscure the basic pattern of lichen syn-ecology as it is characterised by small-scale mosaics determined by changes in the micro-ecology of the substratum. This is well illustrated by a relevé from Ben Lawers (Table 4•10, relevé 55). This is a mosaic of *Salix herbacea-Carex bigelowii* (U12) and *Anthelia/Gymnomitrion* sp.-*Polytrichum sexangulare* (U11) dominated areas with *Cladonia bellidiflora* and *Stereocaulon saxatile* strongly associaed with the former and crustose lichens with the latter. It is also shown by *Cetrariella delisei* which, as pointed out below, occurs in the clines or transition zones between NVC communities (Fig 4•17, p. 304). If small scale mosaics are treated as homogeneous stands this will fail to be recognised. This is illustrated by the relevés of *C. delisei* (Table 4•9) which show it occurring in a wide range of NVC communities.

Table 4-9. Relevés containing *Cetrariella delisei*

	LOCALITY												
	Loch-nagar	Glas Maol	Beinn a'Bhuird			Cairn Gorm		Cairn Lochan			Beinn MacDuibh		
Relevé Number	**83**	**81**	**38**	**39**	**41**	**2**	**7**	**32**	**33**	**47**	**14**	**15**	**16**
NVC Community	U8	U12	U7	U8	U9	U7	H19	U9	U9	U7	U9	U9	U9
Vegetation Cover (%)	95	70	85	100	80	95	95	80	80	95	50	60	40
Height of vegetation (cm)	1(-5)	1(-5)	10	5	15	10	5	5	7	5	5	7	5
Lichen Cover (%)	25	20	15	3	5	15	30	20	15	20	10	30	5
Peat (%)	.	25	.	.	.	.	.	-	-	5	.	.	.
Gravel (%)	-	-	.	.	.	.	3	20	20	0	25	25	50
Rocks (%)	5	5	.	.	.	5	2	-	-	-	15	15	10
Slope (°)	5	15	0	0	3	8	5	0	0	0	0	0	0
Aspect (°)	230	350	-	-	90	90	40	-	-	-	-	-	-
Empetrum nigrum ssp. hermaphroditum	.	.	.	.	.	2	8	.	.	.	.	.	.
Salix herbacea	.	5	.	.	2	.	.	4	4	.	.	.	2
Vaccinium myrtillus	.	8	.	.	.	5	4	.	.	3	.	1	.
Carex bigelowii	9	5	4	10	3	4	3	2	4	.	2	1	.
C. nigra	.	.	.	.	.	.	.	.	.	4	.	.	.
C. piliferum	.	.	.	.	.	.	.	1	1	.	.	.	.
Deschampsia flexuosa	.	6	3	4	5	.	1	4	4	3	2	4	4
Festuca ovina	.	.	.	.	.	.	.	.	1	.	.	.	.
F. vivipara	3	.	.	.	.	.	.	.	.	.	.	.	.
Juncus trifidus	5	.	.	2	10	1	1	6	8	5	7	8	7
Minuartia sedoides	.	.	.	.	.	.	1	.	.	.	.	.	.
Molinia caerulea	.	.	.	.	.	.	.	.	.	1	.	.	.
Nardus stricta	.	.	8	.	.	9	.	.	.	9	.	.	.
Trichophorum cespitosum	.	.	1	.	.	.	.	.	.	2	.	.	.

Diphasiastrum alpinum	.	.	.	.	.	1	.	.	.	.	.	.	.
Huperzia selago	.	.	.	.	.	1	1	.	.	.	.	.	1
Anastrepta orcadensis	.	.	.	.	.	.	1	.	.	.	.	.	.
Barbilophozia floerkei	.	.	.	.	1	.	.	3	2	2	1	.	.
Bryum ?alpinum	.	.	.	.	.	.	.	1	.	.	.	.	.
Campylopus sp.	.	.	.	.	.	.	.	.	2	2	.	.	.
Dicranum fuscescens	.	.	.	.	.	2	.	.	3	.	.	.	.
D. scoparium	.	4	.	1	1	.	1	.	1	4	.	.	2
Diplophyllum albicans	.	.	.	.	.	.	.	.	.	.	.	1	.
Gymnomitrion/Anthelia sp.	.	.	.	.	.	.	.	4	5	.	1	1	.
Kiaeria starkei	.	.	.	.	.	.	.	2	1	.	.	1	.
Marsupella sp.	.	.	.	.	.	.	.	1	.	.	.	1	.
Moerckia blyttii	.	.	.	.	.	1	.	.	.	.	.	.	.
Pleurozium schreberi	.	.	.	.	.	1	1	.	.	.	.	.	.
Pohlia nutans	.	.	.	.	.	.	1	.	.	.	.	.	.
Polytrichum alpinum	6	4	1	4	.	.	.	.	1	.	.	.	.
P. juniperinum	.	.	.	.	.	.	1 .	.	.	.	.	.	.
P. piliferum	.	.	.	.	3	.	.	2	1	.	2	1	1
Ptilidium ciliare	.	.	.	2	.	1	.	.	.	.	.	.	.
Racomitrium fasciculare	.	.	.	.	.	.	.	.	.	.	.	.	1
R. heterostichum	.	.	.	.	.	.	.	5	4	.	.	.	.
R. lanuginosum	.	3	.	.	4	1	5	.	4	3	4	4	4
Rhytidiadelphus loreus	.	.	.	.	.	.	1	.	.	.	.	.	.
Alectoria nigricans	.	.	.	.	.	.	1	.	.	.	.	.	.
Arthrorhaphis grisea	.	.	.	.	.	.	1	.	.	.	1	.	.
Baeomyces rufus	.	.	.	.	1	.	1	.	.	.	1	.	.
Catillaria contristans	.	.	1	1	.	.	.	.	1	.	.	.	.
Cetraria aculeata	.	.	.	.	.	.	1	.	1	.	3	1	1
C. ericetorum	.	.	.	.	3	.	.	2	2	1	.	1	.
C. islandica	.	2	1	.	1	4	4	.	2	4	4	4	.
C. nivalis	.	.	.	.	.	.	1	.	.	.	.	.	.
Cetrariella delisei	7	2	4	3	1	1	1	2	1	1	1	1	1

Chromatochlamys 'geislerioides' ad int.	.	1	.	.	.	.	1	.	.	.	.	.	.
Cladonia arbuscula	.	1	.	.	2	2	4	1	1	1	.	1	1
C. bellidiflora	2	3	.	.	.	2	1	.	2	1	1	3	1
C. ciliata v. tenuis	.	.	.	.	.	1	.	.	.	2	.	.	.
C. chlorophaea	.	.	.	.	.	2	1	.	.	.	.	.	.
C. coccifera aggr.	1	.	1	1	1	1	1	2	4	1	3	3	3
C. floerkeana	1	.	.	.	.	2	1	.	.	.	.	.	.
C. furcata	.	1	.	1	2	2	2	.	3	2	3	2	.
C. gracilis	.	.	.	.	.	.	.	1	.	.	.	.	.
C. maxima	.	.	.	.	.	3	.	.	.	.	.	.	.
C. pyxidata	.	.	.	.	.	.	.	.	1	.	1	.	.
C. rangiferina	.	1	.	.	.	.	3	.	.	.	.	.	.
C. uncialis	.	2	.	.	4	2	5	4	4	3	2	2	1
C. sp (squamules)	3	2	.	.	.	.	.	.	.	.	1	.	.
Dibaeis baeomyces	.	.	.	.	.	.	1	.	.	1	1	1	1
Epilichen scabrosus	.	.	.	.	.	.	.	.	.	.	.	1	.
Frutidella caesioatra	.	.	.	.	.	.	.	3	2	.	1	1	.
Lecidea hypnorum	.	.	.	.	.	.	.	1	.	.	.	.	.
L. limosa	.	.	1	.	.	.	1	.	.	.	1	.	1
Lecidoma demissum	.	.	.	.	.	.	.	1	3	.	.	1	1
Lepraria neglecta	.	.	.	.	.	.	.	1	1	.	.	.	.
Micarea cinerea	.	3	.	.	.	.	.	.	.	1	2	1	.
M. leprosula	.	.	.	.	.	.	1	.	.	.	.	.	.
M. lignaria	.	.	.	.	.	.	.	.	.	.	.	1	1
M. peliocarpa	.	3	1	.	.	.	.	.	.	.	.	.	.
M. turfosa	1		3	1	.	1	1	1	3	.	2	3	1
Mniacea jungermanniae	.	1	.	.	.	.	.	.	.	.	.	.	.
Ochrolechia frigida	4	1	3	2	1	.	2	2	3	1	1	2	1
O. tartarea	1	1	2	1	2	,	1	3	3	1	1	2	1
Omphalina sp. (sterile)	.	.	.	1	.	.	1	.	.	.	.	.	.
Pertusaria oculata	.	.	.	.	.	.	.	1	.	.			
Pycnothelia papillaria	.	1	.	.	.	.	1	.	.	.	.	.	.
Stereocaulon condensatum	.	.	.	.	.	.	.	.	.	.	1	1	1

S. saxatile	.	1	.	.	.	.	.	.	1	3	.	.	.
Thamnolia vermicularis	.	.	.	.	.	.	1	.	.	.	.	.	.
Toninia squalescens	.	.	.	.	.	.	.	.	.	.	.	1	.
Saxicolous													
'Amelia andreaeaicola' ad int.			.	.	.	x	.	.	.	.	.	.	.
Cecidonia xenophana			.	x	.	.	.	.	.	.	.	.	.
Frutidella caesioatra			.	.	.	x	.	.	.	.	.	.	.
Lecanora leptacina	.	.	.	.	.	.	.	.	.	.	.	x	.
Lecidea limosa	.	.	.	.	.	.	.	.	.	.	.	x	.
L. lithophila		x	.	.	.	.	x	.	.	.	x	x	x
L. pycnocarpa			.	.	.	x	.	.	.	.	x	x	x
f. sorediata			.	.	.	.	x	.	.	.	.	.	.
L. swartioidea	.	.	.	.	.	.	.	.	.	.	.	x	.
Lecidella bullata			.	x	.	.	.	.	.	.	.	.	.
Lepraria caesioalba			.	.	.	x	.	.	.	.	.	.	.
Miriquidica lulensis	.	.	.	.	.	.	.	.	.	.	x	.	.
Ochrolechia tartarea			.	.	.	x	.	.	.	.	.	.	.
Porpidia cinereoatra	.	x	.	.	.	.	.	.	.	.	.	.	.
P. contraponenda			x	.	.	.	.	.	.	.	.	.	.
P. crustulata		x	.	.	.	x	x	.	.	.	x	x	x
P. platycarpoides	.	x	.	.	.	.	.	.	.	.	.	.	.
P. tuberculosa		x	.	.	.	.	x	.	.	.	x	.	x
Pseudephebe pubescens			.	.	.	.	x	.	.	.	.	.	.
Rhizocarpon 'colludens' ad int.		x	.	.	.	x	.	.	.	.	.	.	x
R. copelandii s lat.			.	.	.	x	.	.	.	.	.	x	.
R. geographicum			.	.	.	x	x	.	.	.	x	x	.
R. lecanorinum			.	.	.	.	x	.	.	.	.	.	.
R. obscuratum	.	x	.	.	.	.	.	.	.	.	.	.	.
Stereocaulon vesuvianum	.	.	.	.	.	.	.	.	.	.	x	x	.
Trapelia coarctata	.	x	.	.	.	.	.	.	.	.	.	.	.
Tremolecia atrata	.	.	.	.	.	.	.	.	.	.	x	x	x
Umbilicaria cylindrica	.	.	.	.	.	.	.	.	.	.	.	x	.

Relevé	Grid Ref.	Alt. (m)	Date
83	37/2485	1150	8/7/95
80	37/1676	1050	7/7/95
38	37/0899	1150	18/7/94
39	37/0899	1150	18/7/94
41	37/0998	1170	18/7/94
2	38/0104	1120	15/6/94
7	38/0105	1040	16/6/94
32	28/9802	1200	19/6/94
33	28/9802	1200	19/6/94
47	28/9702	1100	19/7/94
14	28/8900	1170	17/6/94
15	28/8900	1170	17/6/94
16	28/8900	1170	17/6/94

Notes:

83) Mosaic of *Juncus trifidus* and *Carex bigelowii/Polytrichum alpinum* dominated vegetation with former on hummocks and latter in depressions (cf. Glas Maol). *Cetreriella delisei* strongly associaied with *Carex/Polytrichum* although it does also occur in with the *Juncus*. In general *J. trifidus* has quite a bit of *Vaccinium myrtillus* (plus *E. nigrum* and *R. lanuginosum*) which gives body to the vegetation and allows the development of *Cladonia uncialis* and *Cetraria islandica*. Where *J. trifidus* is thinner these disappear and *C. delisei* reoccurs.

80) On lip of norther coire. Low solifluction terracettes. Best lichen vegetation on the 'Bare soil' of the 'steps'.

39) Lichens strongly associated with deeper vegetation (*Nardus stricta*). Soil gravelly, very deep.

41) Lichen cover decreases with increasing higher-plant cover. *Cetraria nivalis* present nearby in centre of sheltered edge of *J. trifidus* tussock.

2) Cryptogams more associated with *Vaccinium myrtillus* than *Nardus stricta*. *Cladonia maxima* present as scattered tufts to 10 cm diam.

7) Scattered lichens, disassociated with *Racomitrium lanuginosum*. *Lecidea limosa* appears to be stabilizing gravel (with *Ochrolechia tartarea*). *Cladonia rangiferina* in more sheltered areas. *Ochrolechia frigida* (with *Cladonia uncialis*) associated with *Vaccinium myrtillus*.

32) Large tussocks of *J. trifidus, Deschampsia flexuosa, Racomitrium lanuginosum, R. heterostichum* and *Cladonia uncialis* raised approximately 5-10 cm above level of gravel.

33) Soil deep dunes of gravel. Gravel/peat lining deep pockets in the *J. trifidus* turf so fairly stable and with much *Lecidoma demissum, Frutidella caesioatra, Micarea turfosa*. *Cladonia* and *Ochrolechia* spp. tend to be on exposed turf edges facing west. Bryophytes in with the dense higher plants except for *Anthelia/Gymnomitrion* and cushion forming species.

47) One large patch of *C. delisei.*
14) Ungrazed so highly vegetated giving protection; also gravel intermixed with small rocks (c.10cm). Clumps of *Cetraria islandica, Cladonia uncialis, C. furcata* up to 10cm hidden in *J. trifidus* clumps.
15) *J. trifidus* fairly thick tussocks full of *R. lanuginosum*. *Cetraria islandica* and *Cladonia* spp. all well developed. Much *Micarea turfosa* in among gravel. *Ochrolechia* spp. in edge of tussocks.

b) lichens, especially micro-lichens, are largely absent from homogeneous stands of vascular plant vegetation, lichen-rich areas often occur in the clines between vascular-plant communities where conditions are sub-optimal for both communities.

Where the vascular-plant vegetation forms a continuous stand only macro-lichens are able to compete (e.g. *Cetraria islandica, Cladonia* subgen. *Cladina* spp.). Micro-lichens occur only where the vegetation is so sparse as to allow gaps to appear (e.g. U9 *Juncus trifidus-Racomitrium lanuginosum* heath) or where they can over-grow it (e.g. H13 *Calluna vulgaris-Cladonia arbuscula* heath). Even macro-lichens often reach their optimum development where vascular-plant growth is suppressed which occurs at the clines between communities.

The distribution of *Cetrariella delisei* in the Cairngorms illustrates this problem (Fig. 4•16 & 4•17). NVC assigns this species to U7 *Nardus stricta-Carex bigelowii* but closer examination reveals that it does not form part of this community as do some other macro-lichens, e.g. *Cladonia maxima, Cetraria islandica* and *C. ericetorum*, which grow within the *N. stricta* sward. *C. delisei* is very rare in this situation but reaches its optimal development on the edge of the grassland where it gives way to other communities, most frequently U8 *Carex bigelowii-Polytrichum alpinum* or U9 *Juncus trifidus-Carex bigelowii* where it is often associated with *Stereocaulon saxatile.* It is possible that a separate community will be required to accommodate this assemblage.

c) lichen species do not have the same habitat boundaries as vascular-plants. The same lichen can often be found in a number of different communities if the appropriate micro-habitat is available

This is illustrated by the distribution of *Stereocaulon saxatile* which occurs in a wide range of NVC communities, U7, U8, U9, U10, U11 and CG12 (Table 4•10). In two of these (i.e. U7 and U10) it is associated with gaps in, or the edges of, the vegetation referable to other communities but in the others it forms an integral part of the vegetation.

Table 4•10. Relevés containing *Stereocaulon saxatile*.

	LOCALITY															
	Glas Maol	**Cairn Lochan**			**Ben Lawers**			**Beinn Heasgarnich**		**Creag Meagaidh**		**Aonach Mor**			**Carn Eige**	
Relevé Number	**81**	**30**	**33**	**47**	**55**	**58**	**102**	**86**	**90**	**121**	**122**	**112**	**113**	**114**	**49**	**50**
NVC Community	U12	U9	U9	U7	U12	CG	U12	CG	CG	U7	U9	U11	U8	U8	U10	U9
Vegetation Cover (%)	70	45	80	95	80	80	60	50	85	98	90	90	100	95	80	85
Height of vegetation (cm)	1(-5)	3	7	5	1	1	1-3	1(-3)	1-5	2-5	3-5	5-9	7-9	5	3	0•5
Lichen Cover (%)	20	10	15	20	3	15	10	15	10	<1	<1	<1	20	15	10	15
Gravel (%)	-	45	20	0	-	-	-	-	-	-	-	-	-	-	-	-
Rocks (%)	5	10	-	-	0	10	5	10	5	2	10	10	-	-	10	15
Peat (%)	25	-	-	5	0	10	35	40	10	-	-	-	-	5	-	-
Slope (°)	15	15	0	0	3	5	30	2	10	10	10	7	3	2	30	5
Aspect (°)	350	100	-	-	80	310	70	310	300	0	0	280	210	70	250	280
Alchemilla alpina	.	.	.	.	.	4	.	5	4	.	.	.	.	.	.	.
Arenaria maritima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.
Galium saxatile	.	.	.	.	2	1	2	.	1	3	3	.	.	.	.	.
Gnaphalium supinum	.	.	.	.	.	.	.	2	3	.	.	1	.	.	.	.
Minuartia sedoides	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.
Polygonum viviparum	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.
Salix herbacea	5	4	4	.	7	.	7	3	.	.	.	.	.	.	.	3
Sibbaldia procumbens	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Silene acaulis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2
Vaccinium myrtillus	8	.	.	3	.	2	2	.	.	.	.	.	.	.	.	.
Agrostis capillaris	.	.	.	.	.	6	.	.	.	.	.	.	.	.	.	.
Carex bigelowii	5	1	4	.	7	1	4	3	3	3	4	4	9	8	4	2
C. nigra	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.
C. piliferum	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.
Deschampsia cespitosa	.	.	.	.	.	.	.	.	3	5	4	2	.	.	.	.
D. flexuosa	6	4	4	3	4	2	.	.		4	2	8	.	.	.	.
Festuca ovina	.	.	1	.	4	.	.	.	.	.	.	.	.	.	3	3

F. vivipara	.	.	.	.	.	6	5	4	4	.	.	.	.	.	.	.
Juncus trifidus	.	5	8	5	.	.	.	.	1	.	7	.	.	.	2	5
Luzula spicata	.	.	.	.	1	.	.	.	1	.	.	.	2	3	3	3
Molinia caerulea	.	.	.	1	.	.	.	.	.	2	.	.	.	.	.	.
Nardus stricta	.	.	.	9	1	1	1	.	.	9	2	.	1	4	.	.
Trichophorum cespitosum	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
Huperzia selago	.	.	.	.	.	.	.	.	.	3	2	.	.	.	.	.
Selaginella selaginoides		.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Campylopus sp.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Dicranum fuscescens	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
D. scoparium	4	.	1	4	.	.	3	.	.	4	3	3	3	.	.	.
Kiaeria starkei	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Polytrichum alpinum	4	.	1	.	2	.	.	.	.	2	3	3	2	2	.	.
P. piliferum	.	1	1	.	1	4	.	.	1	.	.	.	.	.	2	1
P. sexangulare	.	.	.	.	3	2	.	.	.	1	.	4	.	.	.	.
Racomitrium heterostichum	.	2	4	.	.	.	.	.	.	.	.	.	.	.	2	4
R. lanuginosum	3	4	4	3	.	.	1	3	.	.	3	.	5	5	9	4
Rhytidiadelphus loreus	.	.	.	.	.	.	.	.	.	3	2	.	.	.	.	.
Anthelia/ Gymnomitrion sp.	.	4	5	.	5	4	1	4	6	2	1	4	.	1	.	6
Barbilophozia floerkei	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.
Marsupella sp.	.	.	.	.	.	.	3	.	.	.	.	3	.	.	.	.
'Amelia grisea' ad int.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Arthrorhaphis grisea		1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
A. muddii	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Baeomyces placophyllus		1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
B. rufus		.	.	.	.	2	2	.	1	1	.	1	.	.	.	.
Belonia incarnata	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Catillaria contristans		.	1	.	1	1	.	.	.	.	.	1	.	.	.	.

Cetraria aculeata		.	1	.	.	.	.	.	.	.	.	.	.	.	1	1
C. ericetorum		.	2	1	.	.	.	.	.	.	.	.	.	.	.	.
C. islandica	2	2	2	4	.	.	1	.	.	1	2	.	5	4	.	1
Cetrariella delisei	2	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Chromatochlamys																
'geislerioides' ad int.	1	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.
Cladonia arbuscula	1	2	1	1	.	.	1	.	.	.	.	.	.	1	.	.
C. bellidiflora	3	2	2	1	3	.	2	.	.	.	1	.	1	1	.	.
C. cervicornis		.	.	.	.	.	3	.	.	.	.	.	.	.	.	.
C. ciliata		.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
C. coccifera aggr.		2	4	1	.	.	1	.	.	.	.	.	.	.	2	2
C. furcata	1	2	3	2	.	.	2	.	.	.	.	.	1	.	2	.
C. pyxidata	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
C. rangiferina	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. subcervicornis	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
C. uncialis	2	3	4	3	.	1	3	.	4	.	1	.	1	1	3	.
C. sp (squamules)	1	.	.	.	.	3	.	2	2	1	.	.	.	.	.	.
Dibaeis baeomyces		3	.	1	.	2	2	2	3	.	.	.	.	.	.	1
Frutidella caesioatra		.	2	.	2	.	.	.	.	.	.	.	.	.	.	.
Lecidea hypnorum		.	.	.	.	.	.	1	1	.	.	.	.	.	.	.
L. limosa	.	.	.	.	3	.	.	2	2	1	.	.	.	.	1	.
Lecidoma demissum	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.
Lepraria neglecta		.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Micarea cinerea	3	.	.	1	1	.	2	.	1	.	.	.	.	.	.	.
M. incrassata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
M. lignaria		1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M. leprosula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.
M. peliocarpa	3	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.
M. turfosa		2	3	.	2	.	.	1	1	1	1	3	.	1	.	.
M. viridiatra	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	.
Mniacea jungermanniae	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
?Moriola sp.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.
Ochrolechia androgyna	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.
O. frigida	1	.	3	1	.	.	.	.	.	.	.	.	.	.	3	.

O. inaequatula	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
O. tartarea	1	3	3	1	.	.	.	.	3	.	.	.	.	.	4	1
Polyblastia gothica	.	.	.	.	.	.	.	2	.	.	.	1	.	.	.	.
P. helvetica	.	.	.	.	.	.	.	3	.	.	.	1	.	.	.	.
Pseudephebe pubescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Pycnothelia papillaria	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solorina crocea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
Sphaerophorous globosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Stereocaulon condensatum		1	.	.	.	.	.	.	1	.	.	.	.	2	1	1
S. saxatile	1	1	1	3	2	4	2	1	4	1	2	1	4	4	1	1
Steinia geophana	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Thamnolia vermicularis		1	.	.	.	.	.	.	.	.	.	.	.	.	2	2
Trapeliopsis granulosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Verrucaria bryoctona	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Saxicolous Lichens																
'Amelia andreaeaicola'	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Amygdalaria pelobotryon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x
Cecidonia xenophana	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.
Lecanora polytropa	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.
Lecidea lapicida	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.
L. lithophila	x.	.	.	.	.	.	x	x	.	.	x	x	.	.	.	.
L. swartzioidea	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.
Micarea paratropa	.	.	.	.	.	.	.	x	.	.	.	x	.	.	.	.
Placopsis gelida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x
Porpidia cinereoatra	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. contraponenda	.	.	.	.	.	.	.	x	x	x	x	x	.	.	.	.
P. crustulata	x	.	.	.	.	.	x	x	x	x	x	x	.	.	.	.
P. macrocarpa aggr.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.
P. melinoides	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.
P. platycarpoides	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. 'striata' ad int.	.	.	.	.	.	.	.	x	x	.	.	.	.	.	.	.
P. tuberculosa	x	.	.	.	.	.	x	x	x	.	.	.	.	.	.	.
'v. grisea'	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x

Rhizocarpon 'colludens'	x	.	.	.	.	.	.	.	.	x	x	x	.	.	.	.
R. lavatum	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.
R. lecanorinum	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.
R. obscuratum s. lat.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scoliciosporum umbrinum	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.
Stereocaulon tornense	.	.	.	.	.	.	.	.	.	.	x	x	.	.	.	.
Trapelia coarctata	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Relevé	**Grid Ref.**	**Alt.**	**Date**
81	37/1677	1000m	7/7/95
30	28/9802	1170	19/6/94
33	28/9802	1200	19/6/94
47	28/9702	1100	19/7/94
55	27/6441	1050	17/7/94
58	27/6644	900	18/7/94
102	27/6141	1000	12/7/95
86	27/4238	925	10/7/95
90	27/4138	1000	10/7/95
121	27/4087	1000	12/8/95
122	27/4087	1000	12/8/95
112	27/1972	1100	10/8/95
113	27/1972	1200	10/8/95
114	27/1973	1200	10/8/95
49	28/1226	1150	22/7/94
51	28/1225	1090	22/7/94

Notes:

81) Low solifluction terracettes. Best lichens are on 'bare soil' of 'steps'

30) Vegetation on faces of terracettes, steps are gravelly ledges with peaty soil showing through; often gravel 60%, peat 40%. Peat well covered with hepatic carpet, *Dibaeis baeomyces* and *Micarea turfosa*. Fruticose lichens associated with *Juncus trifidus* as is *S. saxatile*.

33) Soil deep dunes of gravel. Gravel/peat lining deep pockets in the *J. trifidus* turf so fairly stable and with much *Lecidoma demissum, Frutidella caesioatra* and *Micarea turfosa*. *Cladonia* and *Ochrolechia* spp. tend to be on exposed turf edges facing west. Bryophytes in with the dense higher plants except for *Anthelia/Gymnomitrion* and cushion forming species.

47) One large patch of *Cetrariella delisei.*
55) Mosaic of *Salix herbacea/Carex bigelowii* and *Gymnomitrion/Polytrichum sexangulare* dominated communities. Crustose lichens strongly associated with the latter, *Cladonia* and *Stereocaulon* sp. with the former. ?*Moriola* sp. has a thallus composed of brown algocysts and spores 15-18x5•5-6μm.
58) *Stereocaulon saxatile* most strongly associated with *Polytrichum piliferum.*
102) *Solorina crocea* nearby.
86) On north ridge. 'Bare soil' is actually a hepatic mat (*Anthelia/Gymnomitrion* spp.) with numerous micro-lichens (mostly pyrenocarps) all with very thin thallus and scattered perithecia most of which do not contain spores.
90) On slope opposite snow-bed, ie. affected by snow-lie but well-drained.
121) Terricolous lichens associated with bryophytes, mostly in slight depressions on the edge of solifluction terracettes (c. 2cm high).
122)This relevé is adjacent to the last (121) but is in the *Juncus trifidus* community whereas 121 was in the *Nardus stricta* community. In spite of this the associated vegetation is very similar.
113) In slight depression in summit heath dominated by *R. lanuginosum/Carex bigelowii.* This allows lichens to develop.
49) Lichens associated with gaps in *R. lanuginosum* carpet (as 113 &114).
51) 'Bare soil' (actually hepatic carpet) and small stones in *Juncus trifidus* heath with clumps of *Racomitrium lanuginosum.*

Figure 4•16. *Cetrariella delisei.* (Magnification x2).

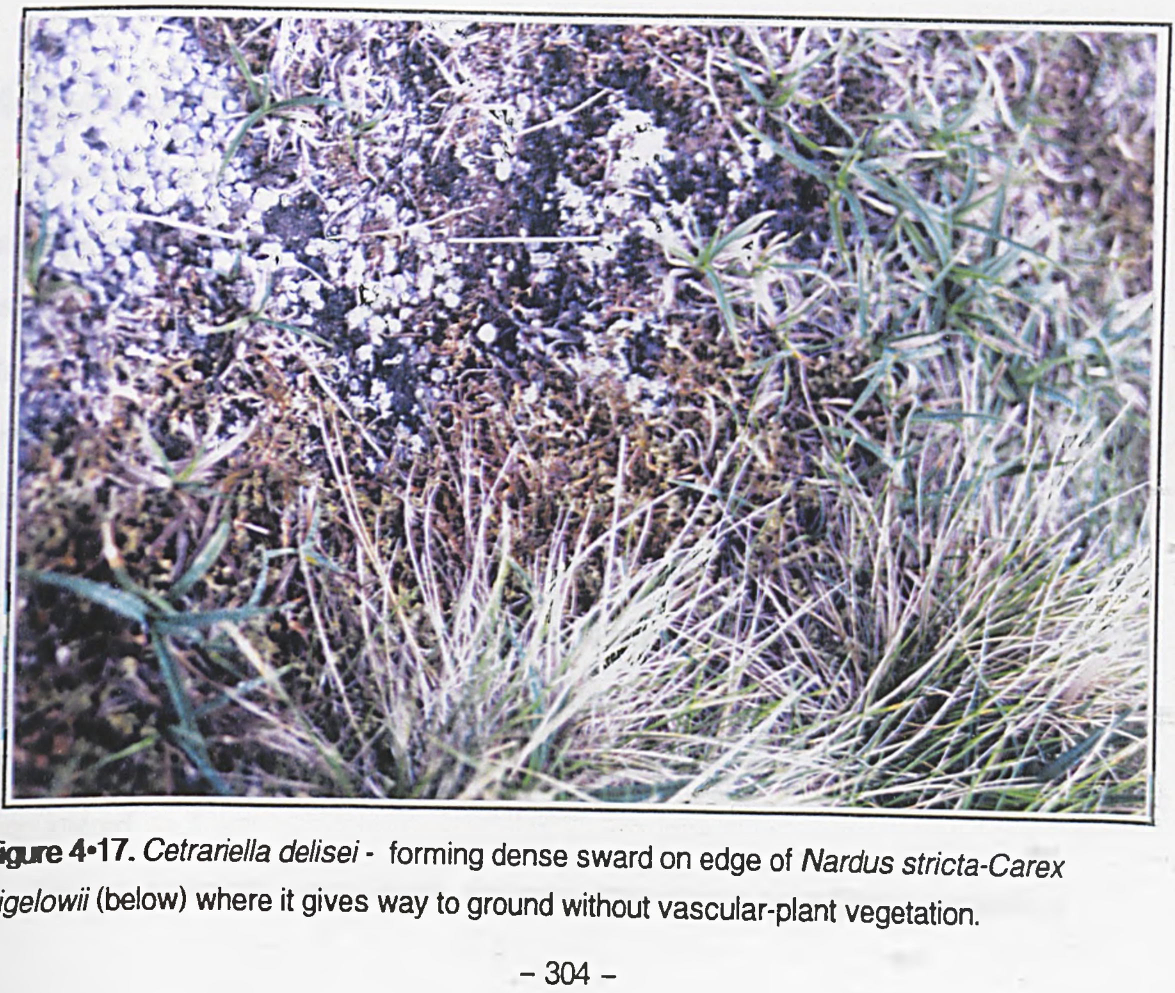


Figure 4•17. *Cetrariella delisei* - forming dense sward on edge of *Nardus stricta-Carex bigelowii* (below) where it gives way to ground without vascular-plant vegetation.

d) homogeneous stands of vascular-plant vegetation often contain a number of distinct lichen habitats supporting distinct lichen communities.

An example of this is U9 *Juncus trifidus-Racomitrium lanuginosum* in the Cairngorms where *R. lanuginosum* is often scattered and *Juncus trifidus* occurs as isolated clumps separated by areas of gravel (Fig. 4•10). In these cases the relative shelter afforded by the *J. trifidus* clumps allows the development of macro-lichens (e.g. *Cladonia* subgen. *Cladina* spp., *Cetraria* spp., *Stereocaulon* spp.) while the decaying bases are colonized by the larger crustose lichens (e.g. *Cladonia* subgen. *Cladonia* spp., *Lecidoma demissum, Ochrolechia* spp.) and the gravel between the clumps is, when stabilized, the habitat of smaller micro-lichens, e.g. *Catillaria contristans, Dibaeis baeomyces, Lecidia limosa* and *Micarea* spp., especially *M. turfosa* (Fig. 4•10). There is considerable overlap between the lichen vegetation of these last two habitats and there is a case for recognising this as a distinct community.

Here and in other communities, rocks, low boulders or banks can create micro-habitats with their own distinctive lichen vegetation and even the relative luxuriance of the dominant vascular-plants can produce a similar effect.

4•2•4 Conclusions

The present work has been most successful when sampling large areas of homogeneous, lichen-rich vascular-plant vegetation which occupy an ecologically uniform habitat, especially where the lichen vegetation is dominated by macro-lichens, e.g. prostrate *Calluna vulgaris* heath. Elsewhere, what appear to be homogeneous stands of vascular-plant vegetation very rarely are with regard to their lichen vegetation. Due to the sensitivity of micro-lichens to micro-environmental variations, minor variations in the relief of the ground or small changes in the vascular-plant vegetation often result in significant changes in the lichen vegetation. Conversely, the same assemblage of micro-lichens will occur in a specific habitat regardless of the vascular-plant community in which it occurs. Consequently, character micro-lichens with a high degree of fidelity to a vascular-plant community are rarely encountered.

Lichens, especially micro-lichens, are largely absent from homogeneous stands of vascular-plant vegetation and, consequently do not fit well into the NVC classification. However, some macro-lichens (e.g. *Cetraria islandica, Cladonia* subgen. *Cladina* spp.) do play a structural role in the terricolous vegetation and these are covered by NVC. Inclusion of comprehensive lichen data serves only to complicate the delimination of NVC communities as micro-lichens operate on a very different size scale than vascular plants and much smaller relevés will be required to sample accurately the vegetation if their syn-ecology is to be revealed.

It is possible that if the vegetation of an area were to be studied on a much smaller scale then character micro-lichens would emerge as this may reveal that they are associated with small vascular-plant stands which can be assigned to a relevant NVC community. It is more probable, however, that it will be necessary to investigate the micro-lichen vegetation separately from the vascular-plants if a true picture of the syn-ecology of the lichen vegetation is to be attained.

4•3 PHYTOSOCIOLOGY OF SAXICOLOUS MONTANE LICHENS

4•3•1 Introduction

The lichen communities which make such a major contribution to botanical bio-diversity in montane areas are not those dominated by terricolous macro-lichens but are those growing on rocks composed, to a large extent, of crustose species . There are many problems concerned with the sampling of saxicolous lichen communities, mostly a consequence of the topography of the substratum and the multitude of micro-habitats this produces. The influence of micro-habitat on small-scale lichen distribution is so great that the sampling of an homogeneous stand of any size is virtually impossible as where one does exist it can usually be regarded as atypical.

Saxicolous lichen communities have been investigated by, among others, Creveld (1981) and John (1989). John lists the micro-habitats which occur on a rock surface whereas Creveld considers the numerous ecological parameters which have to be taken into account to adequately describe a lichen's habitat. These include the general position of the surface (valley, plateau, ridge, slope etc.), whether it is isolated or close to other boulders, its size and shape, the part of the rock on which the lichen occurs and its relief. She also lists the many environmental factors which may effect lichen distribution, i.e. light, wind, snow, moisture, precipitation, maximum temperature, nutrient enrichment, trophic level, calcium content and metal content. An example of the differences in operating conditions in micro-habitats is given by Fashelt *et al.* (1988) who measured the surface temperature of rocks in the vicinity of a glacier in the Canadian Arctic. They found that in overcast conditions the rock surface was 2C higher than the air temperature whereas in sunny conditions the difference was 7C, this in spite of high winds. The operating temperature of the lichens on this surface will be even higher (Kershaw 1985). They also recorded higher temperatures on large boulders (0•4C in overcast conditions and 2•0C in sunny ones) than on smaller ones and significantly higher temperatures in fissures (which will be protected from the cooling effects of wind) except on N-W faces in overcast conditions.

Saxicolous communities were not a major part of the present work as it was considered that the scale of the problem was outside the scope of a three year study and that there were numerous taxonomic problems that needed to be resolved before serious ecological work could commence. It was also appreciated that the problems involved in the sampling of saxicolous substrata were immense as the range of micro-habitats present on a single boulder required a different approach than that used in sampling vascular-plant terricolous vegetation. However, some data from saxicolous habitats were collected, notably from Ben Lawers and the area of late snow-lie in Ciste Mhearad on Cairn Gorm. The latter is dealt with in the next chapter but that from Ben Lawers will be considered here.

4•3•2 Development of saxicolous communities

There is good evidence that competitive exclusion is far less important in lichen communities than in vascular-plant ones; lichen communities, consequently, develop by a process of species addition rather than species replacement (Lawrey 1991; Woolhouse *et al.* 1985). This effect becomes increasingly more pronounced the more stable the substratum and appears to be, at least in part, due to the slow development of lichen communities, as pioneer species are then able to maintain their presence by a process of continued recolonization. Also of importance on very stable substrata is the development of the substratum along with the community as, with time, new micro-habitats become available due to weathering allowing new species to enter the assemblage. Saxicolous substrata are also invariably a small-scale mosaic of variously aged surfaces and this helps to maintain pioneer, and other, species in the assemblage, and assists in a process of constant recolonization and reverse succession (Armstrong 1974).

Another factor may be that newly exposed rock is an extremely inhospitable environment and species that colonise saxicolous habitats tend to be those adapted for stress tolerance rather than for colonisation. Rodgers (1990), using the triangular ordination model of Grime (1977), showed that saxicolous species were scattered between the stress-tolerant and competitive poles and furthest away from the ruderal pole with *Rhizocarpon obscuratum* (i.e. *R. reductum*), a primary colonizing species of saxicolous habitats, occurring the closest to the stress- tolerant pole of any of the 34 species studied. It is possible that saxicolous lichen communities develop rather differently from vascular-plant communities, as well as from cryptogamic communities on less stressful substrata, with species adapted for colonisation appearing after the surface has been colonised by stress-tolerant species and that a mature community has species with all three ecological strategies present. As montane lichen communities mainly occur on stable substrata (i.e. rocks) the number of species recorded is, in all probability, a good indication of the ecological continuity of that community and the use of indicator species is unnecessary.

4•3•3 Data collected from Ben Lawers

Due to the generally heterogeneous nature of saxicolous substrata, and the plant communities which develop upon them, all saxicolous relevés collected had a maximum dimension of 1x1m. The data collected from Ben Lawers are presented in Table 4•11. Relevé 72 was collected from a boulder in the northern coire of Ben Glas but the other four were from Creag Loisgte (the S-W cliffs of Ben Lawers), the first three (73, 74 and 75) from the south-facing rock-face and the other (76) from the north-facing side. These relevés were chosen as the surfaces were relatively uniform and, consequently, the variations in micro-habitat less pronounced although they are mostly still far from homogeneous.

The major variation in micro-environment is indicated for relevés 72 and 76 whereas in relevés 73 and 75 the main cause of heterogeneity is the presence or absence of vascular-plants, lichens tending to occur on otherwise bare rock surfaces whereas the vascular-plants and bryophytes were restricted to shallow ledges. Only relevé 74 could be considered, in any sense, homogeneous. Bryophyte data are inadequate for comparative purposes as only the most obvious and/or easily recognised species were included.

Table 4•11. Saxicolous relevés from Ben Lawers NNR

Relevé No.	**72**	**73**	**74**	**75**	**76**
Lichen Cover (%)	70	55	75	40	45
Bryophytes (%)	30	25	5	60	5
Vascular-plants (%)	0	20	0	5	0
Bare Rock (%)	0	0	20	5	50
Slope (°)	80	80	90	90	80
Aspect (°)	155	170	150	150	270
Alchemilla alpina	.	.	.	1	.
Carex bigelowii	.	.	.	1	.
Cerastium alpinum	.	.	.	1	.
Luzula spicata	.	1	.	.	.
Nardus stricta	.	2	.	2	.
Saxifraga oppositifolia	.	4	.	1	.
Sedum rosea	.	1	.	2	.
Silene acaulis	.	1	.	1	.
Viola lutea	.	.	.	1	.
TOTAL 9	**0**	**5**	**0**	**8**	**0**
Bryum sp.	.	.	.	5	.
Grimmia sp.	.	.	.	4	.
Racomitrium heterostichum	.	.	.	.	1
R. lanuginosum	1	1	.	.	1
leafy liverwort	.	.	.	3	.
TOTAL 5	**1**	**1**	**0**	**3**	**2**
Acarospora rhizobola	.	.	.	1	.
A. sinopica	.	.	.	1	.
Agonimia tristicula	.	2	.	.	.
Aspicilia grisea	2	.	.	.	.
Catapyrenium cinereum	.	.	.	.	1(+)
C. lachneum	.	.	.	1	4(+)
Catillaria scotinodes	.	.	6	.	.
Cladonia bellidiflora	3	.	.	.	.
C. furcata	2	.	.	.	.
C. squamosa	.	.	.	1	.
Collema auriforme	.	.	.	.	1(+)

C. ceraniscum	.	.	.	3	.
C. crispum	.	4	.	.	.
Frutidella caesioatra	1	.	.	.	.
Koerberiella wimmeriana	.	1	.	1	5(*)
Lecanora albescens	.	2	1	1	.
L. atromarginata	.	.	.	1	.
L. polytropa	1(t)	.	.	.	.
Lecidea lithophila	1	.	.	.	.
L. phaeops	1	.	.	.	.
L. swartzioidea	1	.	.	.	.
Lempholemma radiatum	.	.	.	.	1(+)
Lepraria caesioalba	5	.	.	.	.
Lopadium pezizoideum	1	.	.	.	.
Leptogium gelatinosum	.	1	.	1	.
L. subtile	.	3	.	.	.
Melanelia commixta	2	.	.	.	.
M. hepatizon	1	.	.	.	.
Miriquidica griseoatra	2(b)	.	.	.	.
Parmelia saxatilis	1(t)	.	.	.	.
Pertusaria albescens	.	.	.	2	.
P. oculata	1	.	.	.	.
Placynthium asperellum	.	.	.	.	3(*)
P. pleuriseptatum	.	3	.	.	.
Polyblastia efflorescens	.	.	.	.	2(+)
P. melaspora	.	4	1	1	1(+)
P. theleodes	.	1	.	.	.
Porpidia 'confluenta' ad int.	4	.	.	.	.
Porpidia superba	.	5	.	1	4(*)
P. zeoroides	.	.	.	1	2(*)
Protoblastenia siebenhaariana	.	.	.	.	1(+)
Protoparmelia badia	1	.	.	.	.
Pseudephebe pubescens	1	.	.	.	.
Psora decipiens	.	.	.	1	.
P. rubiformis	.	.	.	4	.
Rhizocarpon 'colludens'	1	.	.	.	.
R. geographicum	1	.	.	.	.
R. lavatum	.	1	5	1	.
R. obscuratum aggr.	.	.	.	.	1(*)
R. petraeum	.	1	3	.	.

R. umbilicatum	.	1	4	2	.
Schaereria cinereorufa	2	.	.	.	.
Sphaerophorous globosus	2	.	.	.	.
Stereocaulon vesuvianum	2	.	.	.	.
Tephromela atra	1	.	.	1	.
TOTAL 55	**24**	**14**	**6**	**18**	**12**

72: t - near the top of the relevé, b - near the bottom.

76: + - in folds, * - on flat surfaces

Relevé	**NVC**	**Grid Ref.**	**Alt.**	**Date**
72	-	27/6240	950	14/6/95
73	CG14	27/6341	1050	14/6/95
74	-	27/6341	1050	14/6/95
75	CG14	27/6341	1050	14/6/95
76	-	27/6341	1050	14/6/95

Notes:

72: On side of large boulder (c. 130m) in the sheltered northern coire of Ben Glas. Extensive stand of *R. subgeminatum* on sub-top.

73: Creag Loistge, a site rich in montane calcicole vascular plants.

74: Relatively recently exposed mica-scist rock face. Very smooth.

75: As 73

76: Folded mica-schist boulder opposite Creag Loisgte.

4•3•4 Discussion

Although the number of relevés is small it is possible to make some tentative observations, although more work is required to test these hypotheses.

The most noticeable feature of the relevés is the high proportion of lichens compared with vascular plants. Only two relevés (73 and 75) supported any vascular plants and in these the ratio of lichens to vascular plants was 2•8:1 and 2•25:1 respectively, whereas the total ratio for all five relevés was 6•11:1.

The two relevés with vascular plants can be assigned to NVC: CG14 *Dryas octopetala-Silene acaulis* ledge community, although whether the lichen vegetation belongs in that community is less straight forward. The stand is physically and botanical heterogeneous and is best considered as a mosaic of CG14, which occupies small ledges, and the lichen vegetation occupying the near vertical faces. However, as the lichen vegetation associated with CG14 appears to be confined to rock faces with that NVC community on associated ledges there is a good case for considering the two as different facies of the same community.

Relevé 74 was from a very smooth vertical rock face near relevés 73 and 75 and had the appearance of having been more recently exposed by the flaking off of surface layers of schist. The lower species diversity and lack of vascular plants and bryophytes support this and, assuming this to be the case, then those lichens present are in all probability early colonizers of the lichen-rich facies of CG14. This applies in particular to *Catillaria scotinodes, Rhizocarpon lavatum, R. petraeum* and *R. umbilicatum* which occur at a higher cover than in any other relevé. *R. lavatum* is usually considered a species of siliceous rocks and its presence here as a co-dominant on a basic substratum is unexpected.

The lichen vegetation of relevé 76 has some similarities with that associated with CG14, e.g. *Koerberiella wimmeriana, Polyblastia melaspora* and *Porpidia superba*; the differences can probably be explained by its northern, rather than southern, aspect which produces more humid conditions.

Relevé 72 represents a different community. The only lichen in common with the other stands is *Tephromela atra* which is a widespread species of mildly basic rocks. The calcicole lichens from the other stands are absent and the vegetation is distinctly calcifuge, although the presence of *Lopadium pezizoideum* - a rare montane calcicole of damp rocks - indicates that some base enrichment is present. There is some evidence of late snow-lie with the occurrence of *Miriquidica griseoatra* (a species restricted to this habitat) low down on the rock face.

4•3•5 Conclusion

Although only a few stands were sampled, and these from a small area, they have shown that it is possible to identify trends in saxicolous lichen vegetation. It is also possible to relate certain saxicolous lichen assemblages to NVC communities if the latter are correlated to a strong ecological factor, in this case montane calcicole rocks. However, it is probable that, where environmental factors influencing the latter are less clear-cut lichen assemblages will not be restricted to a single NVC community. It can be seen from the data for saxicolous substrata included in Tables 4•5-4•10, that the lichen vegetation shows little variation and cannot be related to the appropriate NVC community as the habitat (low granite boulders) is uniform throughout. Variations are due more to aspect of the boulder face than any other factor.

It is interesting that, on Ben Lawers, a similar lichen vegetation occurred on rocks with different aspects. Again this is a consequence of the over-riding importance of base-status in determining plant distribution; if the substratum had been more siliceous then differences due to aspect would have been more pronounced.

The Ben Lawers stands were specially chosen for their low relief and consequent lack of micro-habitat variation. Less selective sampling would undoubtedly have yielded less satisfactory results. However, this is a valuable exercise as once the lichen vegetation of a flat surface in a particular environment has been characterized then it is possible to begin to identify variation brought about by micro-environmental factors.

Nimis (1991) considers that phytosociology should show an interest in ecology and phytogeography and be based on many relevés taken over a large area. The hyper-oceanic mountains of western Scotland with their distinctive lichen vegetation would appear to form a suitably distinct ecological area for such a study.

CHAPTER 5

LICHEN VEGETATION ASSOCIATED WITH AREAS OF PROLONGED SNOW-LIE

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5•1 INTRODUCTION

The most severe alpine and Arctic environments have been divided by Billings & Mooney (1968) into two general types:-

a) late lying snow-banks where the growing season is extremely short

b) windswept, dry ridges

At the limits of plant growth the vegetation of both habitats is dominated by cryptogams. When considering only terricolous vegetation snow-beds are, for the most part, dominated by bryophytes and the ridges by lichens. Flock (1978), working in Colorado, recorded a 62% bryophyte and 0% lichen cover in areas with high soil moisture and late-laying snow cover compared with a 64% lichen and 0•6% bryophyte cover in a dry, windswept rocky area. This reflects the very damp conditions that prevail in the immediate vicinity of snow beds which are unsuitable for lichen growth, although in less extreme situations, especially where more free draining conditions are available, lichen growth can be considerable. This is especially true when the vegetation occurring on rocks, boulders and other saxicolous habitats is taken into account. These are mostly free-draining and, as the substratum is not water-logged, lichens are the dominant plant form.

It is a character of the British mountains that their southern faces are usually smooth while the northern slopes are eaten into by huge coires formed during past periods of glaciation. This topography provides two types of site where late-lying snow-beds may form. The edges of the cliffs overlooking these coires are often sufficiently sheltered from the prevailing winds to support areas of late-snow lie and, consequently, receive protection from the harshest winter conditions. These sites are free-draining and much drier than the areas around the snow beds which form in coires (Gjærevoll 1956).

It is anticipated that the most characteristic 'snow-bed lichens' will be associated with the snow-beds that form on the edges of ridges ('cornice snow-beds') and the lichens which occur around those which form lower down ('coire snow-beds') will be species which have a preference for damper habitats and are only circumstantially associated with the snow-beds.

Late snow-beds are formed by the interaction of a number of climatic factors which combine with the relief of the mountain to cause snow to be deposited in the same place every year. The climatic factors involve the interaction of precipitation, temperature and wind in a unique manner and the slightest change in any of these will result in a change in the re-deposition of the snow and a consequent alteration to the snow-bed vegetation. The effects of global warming are likely to be varied but will almost certainly effect the distribution of snow-beds and their associated plant communities.

It has also been suggested that global warming will result in a shift towards a more continental climate which will result in increased snow-fall at intermediate altitudes (Harrison, 1973). The consequent re-deposition of this snow will form new snow-beds at these lower altitudes.

5•1•1 Aspects of the snow-bed environment

Snow beds are formed by the re-deposition of winter snow by winds. These winds are often ferocious, sweeping ridges and windward slopes almost completely clear of snow which is then concentrated in sheltered hollows and coires on the leeward side of the mountains where it may accumulate to a depth of 30m. As wind direction is relatively constant from year to year the re-deposition of the snow is also constant resulting in snow-beds always forming in the same places. This creates a stable environment supporting a characteristic vegetation.

5•1•1•1 Insulating effects of snow cover

Freshly fallen snow is an effective barrier to heat exchange as thermal conductivity is directly related to the square of the density of the medium. Consequently, a cover of 10mm of fresh snow is sufficient to offer some protection, 50mm affords effective protection, and maximum protection is obtained from 200mm (Bührer 1902). However, as the snow ages its density becomes greater and its insulating properties are significantly reduced.

Light transmission is greatest at visible wavelengths but some near-infrared also penetrates. The energy which does reach the base of the snow bed is effectively trapped as snow is opaque to the long-wave radiation emitted by the ground or plant cover. The resultant heat, combined with stored or geothermal heat, means that the temperature at the base of a snow-bed is unlikely to fall more than a few degrees below zero. There is also, commonly, a decreasing temperature gradient upwards from the base of the snow-bed and a consequent moisture gradient in the air between the snow particles as warm air is able to hold more water vapour than cold air. This results in a net movement of water molecules away from the base of the snow bed resulting in this area obtaining a relatively translucent, lattice-like structure comprising conical air spaces surrounded by a network of ice (Pruitt 1978). Older snow, therefore, has fewer, larger and less elaborately shaped crystals than fresh snow and, consequently, light penetration and thermal conductivity is greater in old, spring/summer snow. It will also be greater at lower depths than at the surface. The effects of this thawing/re-freezing of old snow has a similar effect on the surface of the snow bed thus considerably reducing its albedo and insulating properties (Curl, Hardy & Ellermeier 1972). It is, perhaps, of interest to note that the daytime maximum and night-time minimum temperatures do not occur at the surface of the snow-bed but 1-2 cm below it.

There is, however, some danger to plants buried beneath snow and not all species of lichen benefit by being covered. *Umbilicaria deusta* showed no change in photosynthetic rate when transplanted from a snow-covered to a snow-free site whereas *U. vellea* was adversely affected by reciprocal treatment (Scott & Larson 1985) and species of *Rhizocarpon* (subgenus *Rhizocarpon*) were killed by transplantation to an area affected by prolonged snow-lie (Benedict 1990). It is possible that plants beneath a snow bed may suffer from lack of air circulation if the surface ices over but the main danger is in periodic or partial exposure when metabolism may be started, due to excessive heating, only be to quickly halted at night.

5•1•1•2 Snow Melt

The pattern of snow-melt is closely related to topography; that is, although the time at which a snow-bed melts may vary from year to year the actual pattern remains constant (Friedel 1952; Benedict 1990). However, Billings & Bliss (1959) have pointed out that winter weather conditions influence the re-deposition of snow and, consequently, these will also effect the pattern of melting to a limited extent. The variation in the time at which a snow-bed melts will be less in those situated in nivation hollows than those in coires as the total depth of snow reached (and hence the time taken for it to melt) will be much more constant in the former. Cornice snow beds will have similar characteristics to those of nivation hollows as the depth of snow which can accumulate is restricted by the difference in altitude between the ridge and the edge of the cliff on which it forms. The plant communities around them are, therefore, likely to be better structured and more stable.

Snow melts more rapidly in humid conditions than in dry ones as every gram of water vapour which condenses from the atmosphere releases 600 calories (*c.* 2550 joules) of heat which is able to melt 7-8 grams of snow (Müller 1953). At an air temperature of 2•5C melting will not occur at 60% relative humidity while with 100% relative humidity 7mm a day can be melted. For fresh snow, with a density of 0•1 $g.cm^{-3}$, this represents a decrease in snow level of 70mm in 24 hours (Geiger 1966). This has great significance in the oceanic areas of Britain, where the Relative Humidity is in excess of 80% for 80% of the time (Meteorological Office 1975b), as snow will melt at lower temperatures than in more continental regions and expose the vegetation to harsher conditions. Ahlmann (1953) estimated that in the cloudy, wet climate of south-east Iceland 90% of snow melt is due to convection and condensation and less than 10% to radiation. In the sunless gullies of the Scottish mountains this figure is probably even higher.

It has been calculated that snow-beds in the Cairngorms melt at a rate of between 10-12 $mm.day^{-1}$ for every degree centigrade above freezing (Chapman 1950; McVean 1963). However, as these measurements were made in a nivation hollow, which would be far less humid than the deep coires and gullies in which many snow-beds are situated, it is to be expected that ablation rates in other areas will be higher than this, especially in the more oceanic regions of north-west Scotland.

The edge of a melting snow bed is an area of rapidly changing temperature; conditions of winter cold still prevail under a snow patch a few metres in diameter while 20mm away from its edge soil temperatures may reach 15C (Geiger 1966). Once large open patches form in snow-cover, melting continues rapidly because of intense heating of the exposed earth which has a lower albedo and higher thermal conductivity than the snow (Geiger 1966). These sharp climatic gradients are paralleled by similarly sharp, biological ones which makes them particularly suitable for environmental monitoring.

5•1•1•3 Light Penetration through Snow Cover

With freshly fallen snow, attenuation of radiation through the snow decreases exponentially with snow depth according to Beer's law;

$$S=S_0e^{-cx}$$

where S = irradiance after passage through snow bed

S_0 = irradiance at surface of snow bed

c = extinction coefficient of snow bed

x = distance travelled through snow bed

This was demonstrated by Weller & Holmgren (1974) who reported 37% transmission of radiation at 10cm, 13% at 20cm and 1% at 45cm (the base of the snow pack) giving a value of $c = 0{\cdot}1cm^{-1}$. This, presumably, takes no account of the albedo of the snow surface which is considerable (0•95% of short wavelength radiation for freshly fallen snow but less for older snow).

Kightley (reported in Walton 1984) measured the percentage of photosynthetically active radiation (PAR) penetrating through a snow bed in the Antarctic. It fell to nearly zero where the snow bed reached its maximum depth (80cm), but increased as a layer of ice formed below the snow later in the winter and was almost 100% through the last few centimetres before melting. Longton (1988) states that 'there is little evidence of lichen growth under winter snow' although Larson & Kershaw (1975) suggest that carbon assimilation commences earlier than would otherwise be the case in *Bryoria nitidula* when it grows in melt-pockets formed in the thin snow cover caused by its dark thallus absorbing radiation and consequently raising the temperature of its immediate environment.

5•1•2 Suitability of lichens as snow- bed species

Lichens are particularly suited for survival in this environment for a number of reasons:-

a) they are low growing and hence are completely covered by even a thin layer of snow.

b) they are long-lived perennials and therefore do not need to produce new bio-mass or reproduce each year.

c) it has been estimated (Gannutz 1970) that the freezing point of lichen protoplasts is likely to be as low as -10C due to the high concentration of lichen acids and other substances and will be depressed even further due to removal of water by extra-cellular freezing.

d) they appear to have more resistance to repeated wetting/drying and freezing/thawing than vascular plants. As water expands by about 9% of its volume on freezing the number of times this threshold is crossed in a given time is likely to be more critical to plant survival than the minimum temperature reached.

e) they respond rapidly to changes in operating conditions.

f) they have a broad response of net photosynthesis to temperature, with relatively low optima and continuation of both photosynthesis and respiration below 0C.

g) the low irradiance required for compensation and saturation.

h) interactions between irradiance and temperature that result in positive net assimilation, albeit at low rates, under cold, low-light conditions.

5•1•3 Cornice and coire snow-beds

Snow-beds are usually divided into two general types:-

a) **coire snow-beds** - these form in north or north-east facing coires which are protected from both wind and sun, the former leading to a large deposition of snow during the winter and the latter retarding its melting in the summer (Fig. 5•1)

b) **nivation hollow snow-beds** - these form in hollows in more exposed conditions where some protection from the wind allows snow to collect. Although they are more exposed to the sun during the summer months they persist due to the relatively low humidity in these situations compared to those in the coires (Fig. 5•2).

In this work a third type is recognised:-

c) **cornice snow-beds** - these are, in essence, a special form of the nivation hollow type in which the 'hollow' is extended laterally along the rim of the coire - the cornice (Figs 5•3 & 5•4). In Scotland they are also known as 'necklace snow-beds' as they can appear to circle the 'head' of a mountain.

Figure 5•1. Coire snow-bed - Garbh Coire, Braigh Riabhach.

Figure 5•2 Nivation-hollow snow-bed - Ciste Mhearad, Cairn Gorm.

Figure 5•3. Cornice snow-bed - Braigh Riabhach.

Figure 5•4. Cornice snow-bed - Beinn Dearg.

In the montane areas of the British Isles cornice snow-beds are much the more frequent and long-lived. Conditions provided by coire and cornice snow-beds have a number of important differences.

5•1•3•1 Temperature

Berg (1957) reported the temperature of the surface of a snow bed to be as much as 6C lower than the air 1mm above it while Nyberg (1938), working at night to avoid the effects of reflection from the snow surface, found that the increase in temperature with height decreased logarithmically. He found an increase of around 2C between 1mm and 25mm (-17•6C to -15•7C) and a predicted 5•5C increase (to -12•1C) at 1•4m. Consequently the surface of a snow bed may be 13•5C lower than the standard screen temperature. Although snow beds are, almost by definition, more or less windless places even a slight breeze will drastically modify these values. A breeze of <2m.sec^{-1} will raise the temperature at 1mm above the snow-bed to -4•1C (from -17•6C), at 25mm to -3•3 (from -15•7C) and there is a predicted temperature at 1•4m of -2•7C (Nyberg 1938). The air above a snow bed is therefore extremely cold and the phenomenon of temperature drainage down a slope means that temperature below a snow-bed will be markedly lower than that above it. Billings & Bliss (1959) working on the Niwot ridge, Colorado measured an average temperature difference of 3°F (1•67 C) at a height of 50 mm above the ground over a distance of 35 m. between the upper and lower edges of a snow bed; although this difference was still maintained after much of the snow had melted. They concluded that temperature was not an important factor in determining plant distribution around a snow-bed. However, as can be seen from the above figures, the temperature 1 mm above the snow can be 2 C or more lower than at 50 mm and as this is the region in which crustose lichens operate, temperature is liable to affect lichen distribution more than it does that of vascular plants.

The difference in temperature between an exposed cornice snow-bed and a shaded coire one will be even greater. The temperature of the rocks and soil around and below a coire snow-bed are unlikely to rise much above freezing point whereas rocks and soil above cornice snow-beds will have a similar temperature to those of the rest of the ridge where boundary-layer effects can elevate temperatures to as much as 80C (Turner 1958). How much these temperature differences directly effect lichen distribution is unclear. It is probable that their influence on other factors, e.g. soil moisture and relative humidity, will be of more consequence.

5•1•3•2 Soil Moisture

This is closely related to temperature and boundary-layer effects. Conditions immediately adjacent to the melting snow will be similar in coire and cornice areas but the latter will dry out much more quickly (Gjærevoll 1956) and as, unlike bryophytes, lichens are generally unaffected by prolonged dryness but soon damaged by prolonged damp these will provide a far more suitable habitat for lichen growth. The general high humidity and frequent rainfall of the British climate means that these areas seldom, if ever, dry out completely, so drought is not the same problem that it is in more continental areas where snow-beds provide a major source of moisture (Billings & Mooney 1968; Flock 1978).

5•1•3•3 Relative Humidity

As snow melt is enhanced by high relative humidity the less humid conditions which exist on ridges retards the melting of cornice snow-beds so that although, in general, they still melt sooner than coire ones, they do persist well into the summer in spite of being exposed to higher temperatures.

5•1•3•4 Exposure

As snow-beds are formed by snow being blown from exposed slopes (gathering grounds) into hollows that are sheltered from the wind the protection a cover of snow provides from desiccating and abrading winds is usually minimal. However, this protection is much more significant in cornice areas than in coires.

5•1•3•5 Stability of Habitat

Lichens are notoriously slow growing and so require ecological continuity in order to survive. The repeated night-time freezing and day-time thawing which occurs in coires will result in disruption of soil and rock surfaces and is likely to have an adverse effect on lichen growth.

5•1•4 Effects of acidic deposition

The effects of acidification on upland terrestrial habitats are far less well documented than on aquatic ones. However, they are likely to be considerable because :-

a) Most are already very acidic and consequently have a low buffering capacity.

b) Cloud droplets can have 10 times the concentration of sulphate or nitrate ions than rain and, consequently, occult precipitation (i.e. clouds and hill fog) will have a much greater effect than rain. This is particularly important as many surfaces are more or less vertical and, consequently, largely sheltered from rainfall (Hough 1986).

c) Lichens possess a remarkable ability to absorb water vapour from both saturated or partially saturated air (Blum 1973). The higher the relative humidity the higher the equilibrium point between thallus water content and atmospheric moisture and this will also be higher at the lower temperatures which generally prevail at higher altitudes, although boundary effects can greatly modify this effect.

These effects will be accentuated in areas of prolonged snow lie as the pollutants will be concentrated by the accumulation of snow. Although the relative merits of snow and rain as scavengers of atmospheric pollutants is in question, the subsequent redistribution of snow by wind and relief into long-lying snow beds concentrates the pollutants so that these are often very acidic. Subsequent thawing and re-freezing within these snow-beds and the effects of downward moving melt-water further concentrates the pollutants near the base of the snow bed so that when they first melt sulphate, nitrate and other ions are released all at once to produce an 'acid shock' (Davies *et al.* 1982). This is likely to have a considerable effect on lichens both beneath the snow bed and those influenced by run-off as there is evidence that some lichens can photosynthesise at very low temperatures, in some cases as low as -10C (Lange1965), and are, consequently, likely to be biologically active at this time. However, as lichens tend to be absent from the damper habitats which prevail below snow-beds these effects will be of less consequence to lichens than they are to bryophytes.

5•1•5 Classification of chionophilic vegetation

There have been few studies focused specifically on snow-bed vegetation in the British Isles but works attempting to classify montane vegetation in general invariablycontain information about the habitat. In Scandinavia the situation is somewhat different with a number of works devoted entirely to the habitat. The earliest of these was by Tycho Vestergren (1902) who attempted to classify the various plant communities and relate them to snow-cover and time of exposure although no analyses are given. Several works then followed, mostly concentrating on various areas of Scandinavia (e.g. Fries 1913, Samuelsson 1917a & b) but it was Nordhagen (1928, 1936) who first introduced a quantitative element to the study of snow-bed vegetation. Scandinavian snow-bed vegetation was specifically studied by Gjærevoll (1950, 1956), the latter work being a comprehensive treatise on the subject. Vestergren considered that snow-bed vegetation began at the inner edge of the grass heath which succeeds the ericaceous shrub-dominated communities in the altitudinal succession but Nordhagen and Gjærevoll considered that the grasslands should be included within the snow-bed vegetation.

In Britain McVean & Ratcliffe (1962) identified 22 'chionophilic noda' whereas the National Vegetation Classification (Rodwell 1992) identifies 6 communities with chionophilic tendencies which are subdivided into 13 sub-communities. Rodwell acknowledged that the bryophyte-dominated areas in the vicinity of late snow-lie were in need of further study. Rothero (1991) investigated these areas and devised a more accurate classification than that used by NVC. He recognises three main communities;-

a) *Polytrichum sexangulare - Kiaeria starkei* snow-bed

b) *Marsupella brevissima - Anthelia juratzkana* snow-bed

c) *Pohlia ludwigii* snow-bed

He also relates these communities to those mentioned in NVC:-

a) The *Polytrichum sexangulare - Kiaeria starkei* and *Pohlia ludwigii* snow-beds are both included in **U11 *Polytrichum sexangulare - Kiaeria starkei* snow-bed** which also includes the *Rhacomitreo-Dicranetum starkei* community of McVean and Ratcliffe placed in **U12 *Salix herbacea-Racomitrium heterostichum* snow-bed** by NVC.

b) The *Marsupella brevissima-Anthelia juratzkana* community includes the *Gymnomitrion concinnatum* and *Marsupella brevissima* sub-communities of **U12 *Salix herbacea-Racomitrium heterostichum* snow-bed**.

c) The *Silene acaulis-Luzula spicata* sub-community of **U12 is** considered to be better placed at the extreme chionophilic end of **U8 *Carex bigelowii - Polytrichum alpinum* snow bed**.

5•1•6 Previous work on chionophilic lichen vegetation

Previous work on the lichen vegetation associated with areas of prolonged snow-lie is extremely scarce. Some work has been carried out on the Niwot Ridge in the Front Range of Colorado, U.S.A. (Benedict 1990 & 1991; Flock 1978) but climatic conditions in this highly continental area are so different from those of the British Isles as to render comparisons almost meaningless. The only work attempting a treatment of the lichen vegetation of late-lying snow-beds in Europe appears to be Creveld (1981), whose most strongly chionophilic communities are chionophobic by British standards (see below), and two papers by Gilbert and co-workers (Gilbert & Fox 1985; Gilbert *et al.* 1992) in which a preliminary attempt was made to describe and classify the lichen vegetation occurring around snow-beds in the Scottish Highlands (Table 5•1).

Gilbert & Fox (1985) restricted their work to the areas of prolonged snow-lie in the Cairngorm Mountains of the Eastern Highlands; in particular to Ciste Mhearad, a nivation hollow north-east of Cairn Gorm. While they appreciated that their observations applied only to the Cairngorms they identified many of the characteristic lichens of the habitat in the Cairngorms and emphasized the importance of the 'niche structure of the higher plant vegetation' as a determining factor in lichen distribution.

Gilbert *et al.* (1992) had data from snow-beds in two other regions of Scotland (Ben Lawers and Ben Nevis/Aonach Mór) from which to identify snow-bed specialists. Their lists were, consequently, more detailed and they were able to produce separate lists for 'character', 'selective' and 'preferential' species. Many of the species which were identified as snow-bed specialists by Gilbert & Fox but were not restricted to snow-beds elsewhere were now considered to be 'selective species'. They emphasized that, although there were regional differences, there was a general similarity of the snow- bed vegetation across Scotland. They recognised that the most characteristic snow-bed lichens were those which occurred on rocks and attributed this to the higher stability of this habitat, although better drainage would appear to be of, at least, equal importance. They also considered those factors which contribute towards a rich snow-bed flora. They identified habitat diversity as the most important factor (e.g. clean rock, mossy rock, flushes, hepatic mats, bare soil, pebbles, *Salix herbacea* heath) with a gentle slope, leading to high stability, and good light and low humidity as also important.

Table 5·1. Lichens identified as being associated with areas of prolonged snow-lie in the Scottish Highlands.

Gilbert & Fox (1985)	
*'Amelia andreaeaiicola'**	*Protothelenella sphinctrinoidella*
Bellemerea alpina	*P. sphinctrinoides*
Cladonia maxima	*Rhizocarpon badioatrum*
C. stricta	*Schaereria* sp. (undescribed)
Lecanora leptacina	*Sporastatia polyspora*
Frutidella caesioatra (syn. *Lecidea caesioatra*)	*Stauothele areolata* (syn. *S. clopima*)
Lecidella bullata	*Stereocaulon saxatile*
Miriquidica griseoatra	*Toninia squalescens*
Micarea viridiatra	

Gilbert *et al.* (1992)

Character Species	**Selective Species**
'Amelia andreaeaiicola'	*Arthrorhaphis citrinella*
Bellemerea alpina (syn. *Aspicilia alpina*)	*Cetrariella delisei* (syn. *Cetraria delisei*)
Catillaria contristans	*Cladonia phyllophora*
Cladonia maxima	*Frutidella caesioatra* (syn. *Lecidea caesioatra*)
C. stricta	*Ionaspis odora*
Lecanora leptacina	*I. suaveolans*
Lecidella bullata	*Pertusaria geminipara*
Micarea paratropa (syn. *M. subviolascens*)	*Protothelenella corrosa*
Miriquidica griseoatra	*P. sphinctrinoidella*
Rhizocarpon badioatrum	*P. sphinctrinoides*
Schaeraria sp.	*Rhizocarpon expallescens*
Staurothele arctica	*Solorina crocea*
S. areolata (syn. *S. clopima*) - melt water	*Stereocaulon tornense*
Stereocaulon spathuliferum	*Trapelia mooreana*
Toninia squalescens	

* Mis-identified by Gilbert & Fox as *Caloplaca nivalis* and referred to as *'Lecidea'* sp. A by Gilbert *et al.*

5•2 METHODS

Four sites were chosen for investigation; Ciste Mhearad in the Cairngorm Mountains of the Eastern Highlands (GR 38/01,04), Creag Meagaidh in the Central Highlands (GR 27/40,87), Aonach Mór in the Western Highlands (GR 27/19,72) and Beinn Dearg in the North-Western Highlands (GR 28/25,81). The first three sites form a transect across Scotland from the relatively continental climatic conditions of Ciste Mhearad to the more oceanic conditions of Aonach Mór whereas Beinn Dearg was chosen as it occupies a unique position as an outlier far to the north of the main area of snow-bed occurrence (Fig. 5•5). The criteria used for selecting the actual sites to be surveyed within the broad geographical areas was the presence of a relatively gentle, soil slope above the snow-bed, as opposed to crags or a boulder field, as this was considered essential for the formation of a well-developed chionophilic lichen vegetation. An additional reason for selecting Ciste Mhearad and Aonach Mór was that these were the sites upon which Gilbert & Fox (1985) and Gilbert *et al.* (1992) based their classification of snow-bed lichens, although different areas of the sites were chosen for this investigation.

At each site a transect was laid down, starting from the upper edge of the snow-bed and extending upwards through the various snow-bed communities into the surrounding vegetation of the adjacent ridge (Fig. 5•6). At Creag Meagaidh the transect extended into the *Juncus trifidus- Racomitrium lanuginosum* sedge-heath (NVC U9) but at the other three sites this zone was not reached. At Ciste Mhearad the preceding *Nardus stricta- Carex bigelowii* grass heath (NVC U7) was so extensive (*c.* 100m) that the transect did not extend beyond this zone whereas on Aonach Mór the site was so exposed, on a narrow bealach, that *Deschampsia cespitosa-Galium saxatile* grassland (NVC U13) was the surrounding vegetation and on Beinn Dearg the vegetation changes were interrupted by a wall running parallel to the snow-bed (Fig. 5•4). Adjacent 2x2m quadrats were then surveyed along the line of the transect although these were selected either side of the line in an attempt to maintain as uniform a habitat as possible. To this end, large rocks and boulders were avoided as far as possible as were any other small-scale changes in habitat, e.g. hollows and small gullies.

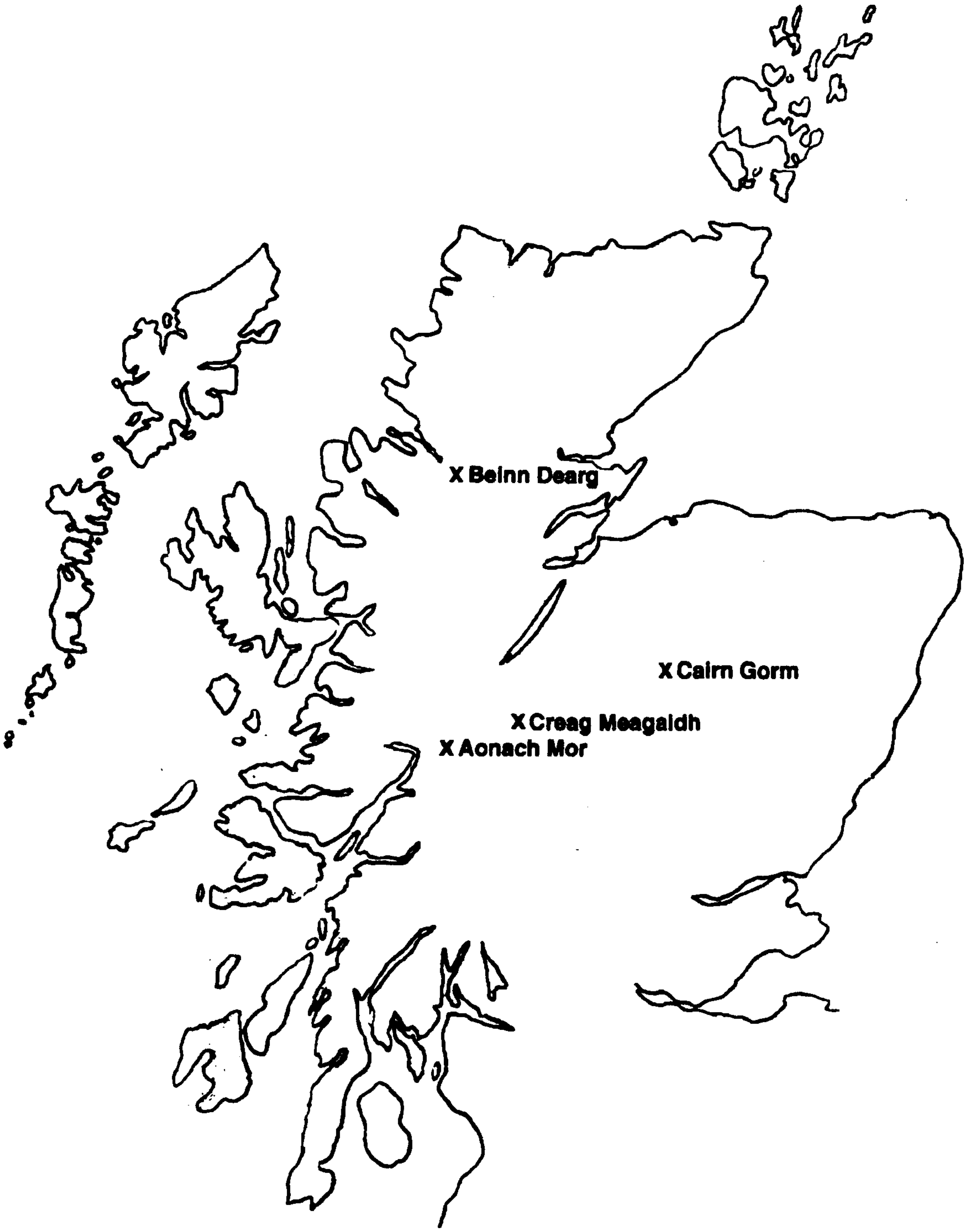


Figure 5•5. Map of Scotland showing sites of areas of prolonged snow-lie surveyed.

Figure 5·6. Transect above area of prolonged snow-lie - Beinn Dearg

This 2x2 quadrat size was chosen as the 4x4m used as standard by NVC was considered too large to reflect the rapid environmental changes which occur in the vicinity of snow-beds and any smaller would have tended to pick out micro-habitats within the general trend of NVC community succession. Although this may have been preferable for isolating the individual lichen assemblages it would not have related them to NVC communities or the effect of decreasing duration of snow-lie.

In each quadrat all vascular plants and lichens, along with the most prominent bryophytes, were recorded and assigned a score on the Domin scale. Also recorded for each quadrat were percentage cover of vascular plants, bryophytes, lichens, rocks and peat/gravel as well as the slope of the ground and aspect. At the two larger sites, Creag Meagaidh and Ciste Mhearad, relevés were also collected from boulders in a separate exercise. At Creag Meagaidh these were from a boulder field adjacent to the main area of the snow-bed and were, as far as possible, collected from horizontal surfaces approximately 1m square. This area would have been snow covered for much of the year and these relevés represent various degrees of prolonged snow-cover, although the duration of this for each relevé could not be determined. All lichens were recorded and assigned a score on the Domin scale. One relevé was also collected from an area outside the snow-bed. At Ciste Mhearad the relevés formed an irregular transect alongside the terricolous one, the positions of the relevés being determined by the position of suitable boulders. For each boulder the lichens present on the upper surface and the sides were recorded separately but no attempt was made to assign them a Domin value as these would have been largely arbitrary.

The data collected from the transects were processed using TWINSPAN in two ways:-

a) all plant groups

b) lichens only

The data from Creag Meagaidh and Ciste Mhearad were each processed separately but those from Aonach Mór and Beinn Dearg were not as the transects were too short to provide a sufficient number of samples to make any analysis meaningful. The data from all four transects was also combined and processed in the same way.

Unfortunately it was not possible to input much of the data directly into TWINSPAN as the programme only accepts vascular plants, bryophytes and macro-lichens. Consequently, all the micro-lichen data had to be entered in a coded form under other plant names and for this the micro-species of *Rubus* were used. This resulted in the TWINSPAN outputs having to be de-coded and redrawn before the information was readily understandable.

5•3 RESULTS

5•3•1 Terricolous lichen vegetation

The data collected from each of the four terricolous transects surveyed are presented in Tables 5•2 – 5•5 and the TWINSPAN analysis in Figs 5•7 – 5•12.

Table 5-2. Species recorded from transect above snow bed on Creag Meagaidh.

Relevé No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Slope (°)	30	30	30	30	27	27	27	27	25	25	25	25	20	10	10	10
Aspect (°)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lichen Cover (%)	20	35	30	20	10	12	15	25	20	5	5	<1	<1	<1	<1	5*
Bryophyte Cover (%)	60	50	60	55	50	45	45	50	40	30	15	25	15	10	5	5
Vascular Plant Cover (%)	3	3	6	20	40	60	60	60	70	75	75	75	85	90	95	90
Rocks (%)	40	60	40	25	15	15	20	30	20	5	5	3	10	3	2	10
Average size of rocks (cm)	10-20	40	30-40	20-40	20	20-60	40	20-40	20	10	10-15	5-10	5-10	2-10	2-5	3-5
Vascular Plants																
Deschampsia cespitosa	3	3	4	5	7	7	8	8	8	8	8	8	6	8	5	4
Saxifraga stellaris	1	1	1	2	1	2	2	1	2	1	1	1	.	1	.	.
Montia fontana	.	1	.	.	1	2	1	3	2	.	.	.	.	.	.	.
Rumex acetosa	.	1	.	.	1	2	1	3	2	.	.	.	.	.	.	.
Carex bigelowii	.	.	.	.	2	4	4	2	5	4	4	2	3	2	3	4
Deschampsia flexuosa		.	.	.	.	1	3	3	5	4	4	2	4	2	4	2
Huperzia selago	.	.	.	.	.	1	1	1	1	1	2	2	1	3	3	2
Nardus stricta	.	.	.	.	.	1	.	.	1	.	.	3	7	6	9	2
Cerastium cerastoides	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.
Viola palustris	.	.	.	.	.	.	1	.	.	.	2	3	3	3	.	.
Galium saxatile	.	.	.	.	.	.	.	1	1	2	2	2	4	3	4	3
Agrostis capillaris		.	.	.	.	.	.	1	2	4	.	.	.	.	.	.
Gnaphalium supinum	.	.	.	.	.	.	.	1	.	.	3	2	1	1	.	.
Blechnum spicant	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Vaccinium myrtillus	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Athyrium distentifolium	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.
Juncus trifidus	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	7
Molinia caerulea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.
Total 18	**2**	**4**	**2**	**2**	**4**	**7**	**8**	**11**	**9**	**9**	**8**	**10**	**9**	**11**	**7**	**7**

Bryophytes**																
Polytrichum sexangulare	5	5	5	5	5	5	4	2	3	2	2	2	1	1	1	.
Moerckia blyttii	3	3	3	3	3	2	2	1	1	2	.	1	1	1	.	.
Kiaeria starkei	4	4	4	4	4	5	4	4	2	1	.	.	.	.	.	.
Marsupella sp.	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.
Anthelia sp.	1	.	.	.	1	.	.	.	.	.	.	.	1	2	2	1
Racomitrium heterostichum	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Rhytidiadelphus loreus	.	.	.	.	.	1	1	1	1	2	.	2	1	2	3	2
Racomitrium lanuginosum	.	.	.	.	.	1	1	1	2	3	2	1	.	3	.	3
Polytrichum alpinum	.	.	.	.	.	.	.	2	2	3	.	4	4	2	2	2
Dicranum sp.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	4	3
Total 10	**6**	**4**	**4**	**4**	**6**	**5**	**5**	**6**	**6**	**6**	**2**	**5**	**6**	**7**	**5**	**5**
Lichens																
Stereocaulon tornense	4	4	4	4	3	3	2	2	2	1	2	1	1	2	.	1
Rhizocarpon 'colludens' s. lat.	4	4	3	4	2	3	2	2	2	1	1	1	.	1	1	1
Porpidia crustulata	4	3	3	4	3	3	3	3	3	3	1	.	.	.	1	1
Micarea turfosa	2	2	1	1	2	.	2	.	1	1	.	.	.	1	1	1
Trapelia obtegens	1	1	1	1	1	.	1	.	1	1	.	1	.	.	.	.
Ionaspis odora	1	2	1	.	.	.	.	.	.	.	.	.	1	.	.	.
Micarea paratropa	2	1	.	1	.	1	.	.	1	.	.	.	.	.	.	.
Porpidia contraponenda (sessile)***	1	1	.	.	.	.	.	1	.	2	1	1	2	1	1	1
Porpidia tuberculosa	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladonia bellidiflora	1	.	1	1	1	1	1	1	2	1	.	.	.	.	.	1
Verrucaria margacea	1	.	2	2	.	1	.	.	.	.	.	.	.	.	.	.
Stigmidium sp (on I. odora)	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Frutidella caesioatra	.	2	1	1	.	1	2	1	.	.	.	.	.	.	.	.
'Amelia andreaeaicola'	.	2	1	1	.	.	1	.	.	.	.	.	.	.	.	.
Rhizocarpon sp. (?subpostumum)	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Miriquidica griseoatra	.	1	.	1	1	1	.	1	.	.	.	.	.	.	.	.
Rhizocarpon lavatum	.	1	.	.	.	1	1	.	.	.	.	.	.	.	.	.
Stereocaulon vesuvianum	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Cecidonia xenophana	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lecidea pycnocarpa	.	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.

Lepraria neglecta	.	.	.	1	1	1	2	2	1	.	.	.	.	.	.	.
Micarea marginata	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.
Polyblastia gothica	.	.	.	1	.	.	1	.	.	.	.	.	.	1	.	.
Catillaria contristans	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.
Lecidella bullata	.	.	.	.	.	1	2	1	.	.	.	.	.	.	.	.
Lecanora leptacina	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.
Stereocaulon plicatile	.	.	.	.	.	1	.	.	2	.	.	.	1	.	.	.
Cladonia chlorophaea	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Micarea lignaria	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.
Omphalina ericetorum	.	.	.	.	.	.	1	2	1	.	.	.	.	.	.	.
Cladonia sp (squamules)	.	.	.	.	.	.	1	1	.	1	.	.	.	.	1	.
Cladonia furcata	.	.	.	.	.	.	1	1	.	1	.	.	.	.	.	.
Protothelenella corrosa	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.
Trapelia mooreana	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.
Trapelia coarctata	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.
Pertusaria oculata	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.
Porpidia contraponenda (innate)***	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.
Trapeliopsis gelatinosa	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.
Cladonia uncialis	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	1
Cladonia floerkiana	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Cetraria islandica	.	.	.	.	.	.	.	.	1	.	1	.	2	1	1	2
Micarea leprosula	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Cladonia pyxidata	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Baeomyces rufus	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1
Lecidea lithophila	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Polyblastia helvetica	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Stereocaulon saxatile	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2
Lecidea limosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Total 48	**12**	**16**	**12**	**14**	**11**	**16**	**19**	**20**	**17**	**11**	**7**	**4**	**6**	**8**	**9**	**10**
Ratio lichens/vascular plants 2·67	**6·0**	**4·0**	**6·0**	**7·0**	**2·75**	**2.28**	**2·37**	**1·82**	**1·89**	**1·22**	**0·87**	**0·4**	**0·67**	**0·73**	**1·29**	**1·43**

* on rocks

** Rothero (1991a) recorded a total of 19 vascular plants and 63 bryophytes (37 mosses, 27 hepatics) from the whole snow-bed. There is no doubt that the list of bryophytes here represents only a fraction of the species present but unfortunately their identification was beyond the scope of this project.

*** sessile = sessile apothecia; innate = innate apothecia

Notes:

1) Small rocks deeply embedded in stable bryophyte mat.
2) Larger boulders towards upper edge of relevé c. 70-80 cm.
3) Rock size is very important. Lower lichen cover and diversity due to smaller rocks which are less stable than larger ones. All but the largest rocks have partial cover of bryophytes which controls lichen colonization - where bryophytes die and fall off lichens can colonize. Bare rock due to recent exposure as moribund bryophytes fall of.
4) Smaller rocks have *Porpidia crustulata* and *Verrucaria margacea* (i.e. the best colonizers).
6) *Lecanora leptacina* and *Lecidella bullata* on large boulder - but not as large as those nearer the snow-bed. No topographic reason for increase in vascular plant diversity - must be due to effects of snow-lie.
11) Path through middle of relevé. The vegetation associated with this was atypical and so was ignored.
15) Terricolous lichens associated with bryophytes, mostly in slight depressions or on the edges of gelifluction terracettes (c. 2cm high).
16) *Juncus trifidus* heath. One large flat slab at top of relevé but almost bare and adds nothing to the saxicolous flora.

The area below the snow-bed was too wet to support a good lichen vegetation. Larger boulders, which are drier, support the typical snow-bed community i.e. *Euopsis pulvinata, Frutidella caesioatra, Lecanora leptacina, Lecidella bullata, Lepraria neglecta, Micarea paratropa, Miriquidica griseoatra, Rhizocarpon 'colludens* subsp. *rufoatra'* and *Toninia squamulosa*. *Stereocaulon tornense* appeared to be much less frequent below the snow-bed than above it. This is possibly because it usually inhabits small stones and these are much too wet to support this species.

Table 5-3. Species recorded from transect above snow-bed at Ciste Mhearad on Cairn Gorm.

Relevé No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20-
Maximum distance from snow-bed (m.)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	38	42	50
Vascular Plant Cover (%)	0	0	0	0	0	1	5	10	30	50	80	85	95	90	50	95	98	98	98	100
Bryophyte Cover (%)	70	95	90	70	90	90	90	80	60	45	15	10	2	3	2	<1	<1	2	<1	<1
Lichen Cover (%)	<1	<1	<1	<1	<1	<1	<1	2	2	1	2	2	3	5	5	3	3	3	5	3
Rock Cover (%)	20	5	5	10	5	5	5	10	10	5	5	5	0	0	0	0	0	0	0	0
Peat/Gravel	10	0	0	20	5	5	0	0	0	0	0	0	0	5	50	5	2	0	0	0
Slope (°)	25	25	25	25	25	25	25	25	25	25	25	22	20	15	10	5	3	3	2	2
Aspect (°)	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Vascular Plants																				
Deschampsia flexuosa	.	.	.	.	.	1	4	4	5	7	8	8	8	4	2	1	2	.	.	.
Saxifraga stellaris	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Carex bigelowii	.	.	.	.	.	.	.	.	4	1	1	1	2	3	3	2	3	3	2	2
Agrostis capillaris	.	.	.	.	.	.	.	.	.	1	4	4	1	3	.	.	.	.	.	.
Salix herbacea	.	.	.	.	.	.	.	.	.	5	1	.	.	3	2	.	.	.	.	.
Juncus trifidus	.	.	.	.	.	.	.	.	.	1	.	2	5	4	4	3	2	5	3	2
Nardus stricta	.	.	.	.	.	.	.	.	.	1	1	.	2	8	7	9	9	9	9	10
Gnaphalium supinum	.	.	.	.	.	.	.	.	.	.	1	3	.	1	.	.	.	.	.	.
Huperzia selago	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	1	3	2	1	2
Trichophorum cespitosum	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	1	1
Carex pilulifera	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Vaccinium myrtillus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	1	.	2	3
Empetrum nigrum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1
Diphasiastrum alpinum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3
Bryophytes																				
Kiaeria starkei	4	8	7	2	2	5	3	4	5	4	4	2	.	.	1	.	.	.	.	.
Marsupella sp.	8	6	6	7	8	6	7	6	4	4	3	2	1	.	.	.	.	.	.	.
Polytrichum sexangulare	2	4	5	3	3	6	5	7	7	4	3	3	1	1	1	.	.	.	.	.

Anthelia sp.	.	.	3	1	.	.	.	3	.	2	.	1	.	1	.	.	.	.	.	.
Moerckia blyttii	.	.	.	.	1	3	3	2	3	.	3	2	.	.	1	.	.	.	.	.
Racomitrium heterostichum	.	.	.	.	.	.	1	.	.	3	.	.	2	.	.	1	.	.	.	.
Polytrichum alpinum	.	.	.	.	.	.	.	.	.	2	3	.	3	3	.	.	1	3	.	.
Dicranum scoparium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2	2	3
Diplophyllum albicans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
Racomitrium lanuginosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1
Lichens																				
Ionaspis odora	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Micarea turfosa	.	1	.	.	.	1	.	1	.	.	.	1	3	2	.	1	.	.	.	.
Lecidea pycnocarpa	.	1	.	.	.	1	.	1	.	1	.	.	1	.	.	.	.	.	.	.
Stereocaulon tornense	.	.	1	1	.	.	.	1	.	1	1	.	1	.	.	.	.	.	.	.
Porpidia contraponenda*	.	.	1	1	1	.	1	1	1	2	2	1	1	.	1	.	.	.	.	.
Cecidonia xenophana	.	.	.	1	.	1	.	.	1	2	.	.	.	.	1	.	.	.	.	.
Rhizocarpon jemtlandicum	.	.	.	1	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.
'Amelia grisea'	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Rhizocarpon cinereonigrum	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhizocarpon 'colludens subsp. rufoatrum'	.	.	.	.	1	1	.	.	1	.	1	.	.	.	.	.	.	.	.	.
Lepraria borealis	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lecidella bullata	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Miriquidica griseoatra	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Micarea marginata	.	.	.	.	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.
'Amelia andeaeaicola'	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Micarea sp.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Porpidia crustulata	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.
Rhizocarpon lavatum	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Trapelia obtegens	.	.	.	.	.	.	.	.	1	1	2	1	2	.	.	.	.	.	.	.
Rhizocarpon 'colludens'	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.
Lecidella carpathica	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Frutidella caesioatra	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Polyblastia gothica	.	.	.	.	.	.	.	.	.	.	.	1	.	2	.	.	.	.	.	.
Polyblastia helvetica	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.
Belonia incarnata	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.	.

Belonia incarnata	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.	.
Micarea cinerea (anamorph)	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.
Porpidia macrocarpa	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Cladonia squamosa	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	1
Cladonia subcervicornis	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.
Protothelenella sphinctrinoidella	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.
Cetraria islandica	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	3	3	3	2	3
Cladonia furcata	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Cladonia cervicornis	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Cladonia macilenta	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Lecanora symmicta	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Cladonia bellidiflora	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	2	.	1	.
Catillaria contristans	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.
Lecidea limosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	1	.	.	.	.
Baeomyces rufus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Cladonia uncialis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Cladonia pyxidata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
Cladonia maxima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Cladonia arbuscula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Cladonia coccifera aggr.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1

* form with sessile apothecia. The form with innate apothecia was not recorded from the Cairngorms and would appear to be an oceanic entity.

Notes:

10) All rocks small and low-laying. *Miriquidica griseoatra* and *Lecidella bullata* on larger rocks adjacent to relevé.

12) Ledges starting to form which provide habitat for first terricolous lichens

13) Well-worn path runs across this relevé, the edges of which are the main location for terricolous lichens; although these also occur on flat 'ledges'.

14) Two distinct communities: *Nardus stricta* with *Cetraria islandica* and most *Cladonia* spp. and *Deschampsia flexuosa-Salix herbacea* with crustose lichens. Top 1cm of soil grey; red-brown beneath.

15) Many pale, indeterminate crusts on soil. Crusts with a dark thallus are more easily overlooked (especially in the wet) and probably

16) *Nardus stricta* heath with 'bare' patches.
17) *Nardus stricta* heath.
18) Closed *Nardus stricta* heath.
19) *Cladonia maxima* in deep *Nardus stricta*.
20) Gentle terracettes, *Nardus stricta* deeper (c. 10cm) in risers of terracettes.

Nardus stricta heath continues for a further 80m when it gives way to *Juncus trifidus* heath at a slight break in the slope.

Table 5-4. Species recorded from transect above snow-bed on Beinn Dearg

Vascular Plant Cover (%)	3	5	20	30	60	70	75
Bryophyte Cover (%)	90	85	65	45	15	5	5
Lichen Cover (%)	1	5	<1	10	15	20	15
Rock Cover (%)	10	10	15	25	25	25	20
Average size of rocks (cm)	5	30	25	20	20	10-25	20-50
Slope (°)	30	30	30	30	30	25	15
Aspect (°)	60	60	60	60	60	60	60
Vascular Plants							
Deschampsia cespitosa	2	4	5	5	7	3	2
Montia fontana	1	.	.	.	.	.	.
Saxifraga stellaris	.	1	3	3	3	2	1
Carex bigelowii	.	.	.	4	4	8	8
Huperzia selago	.	.	.	.	1	.	.
Gnaphalium supinum	.	.	.	.	1	.	.
Sibbaldia procumbens	.	.	.	.	1	.	.
Nardus stricta	.	.	.	.	1	.	3
Rumex acetosa	.	.	.	.	.	1	.
Deschampsia flexuosa	.	.	.	.	.	2	.
Bryophytes							
Anthelia sp.	1	2	4	4	1	.	.
Kiaeria starkei	7	7	6	6	4	.	.
Polytricum sexangulare	6	4	4	4	3	4	3
Moerckia blyttii	2	3	2	3	3	.	.
Racomitrium heterostichum	4	.	.	.	.	.	2
Marsupella sp.	.	2	3	2	.	.	.
Racomitrium lanuginosum	.	.	.	.	1	2	2
Rhytidiadelphus loreus	.	.	.	.	.	1	.
Polytrichum alpinum	.	.	.	.	.	1	1
'leafy liverwort'	.	.	.	.	.	1	2
Lichens							
Porpidia macrocarpa	2	2	2	3	2	2	.
Stereocaulon tornense	1	1	1	.	.	.	.
Verrucaria margacea	1	1	1	.	.	.	.
Porpidia contraponenda	1	1	.	1	1	2	3
Trapelia obtegens	1	1	.	1	2	.	2
Rhizocarpon 'colludens'	.	2	2	2	2	3	1
Porpidia crustulata	.	1	2	2	3	3	2
Micarea marginata	.	1	1	.	1	1	.
Lecidella bullata	.	.	1	.	1	.	.
Polyblastia gothica	.	.	1	.	.	.	.
Porpidia 'striata'	.	.	1	.	.	.	.
Lecidea pycnocarpa	.	.	.	1	2	.	.
Micarea turfosa	.	.	.	1	.	1	.
Frutidella caesioatra	.	.	.	.	1	1	1
Miriquidica griseoatra	.	.	.	.	1	1	1
Micarea paratropa	.	.	.	.	1	1	.
Stereocaulon vesuvianum	.	.	.	.	1	.	1
Lecidella carpathica	.	.	.	.	1	.	1
Cladonia sp. (squamules)	.	.	.	.	1	.	.
Lepraria neglecta	.	.	.	.	.	1	1
Cladonia bellidiflora	.	.	.	.	.	1	.

Ochrolechia tartarea	.	.	.	.	.	1	.
'Amelia andeaeaicola'	.	.	.	.	.	1	.
Rhizocarpon 'colludens ssp. rufoatrum'	.	.	.	.	.	1	.

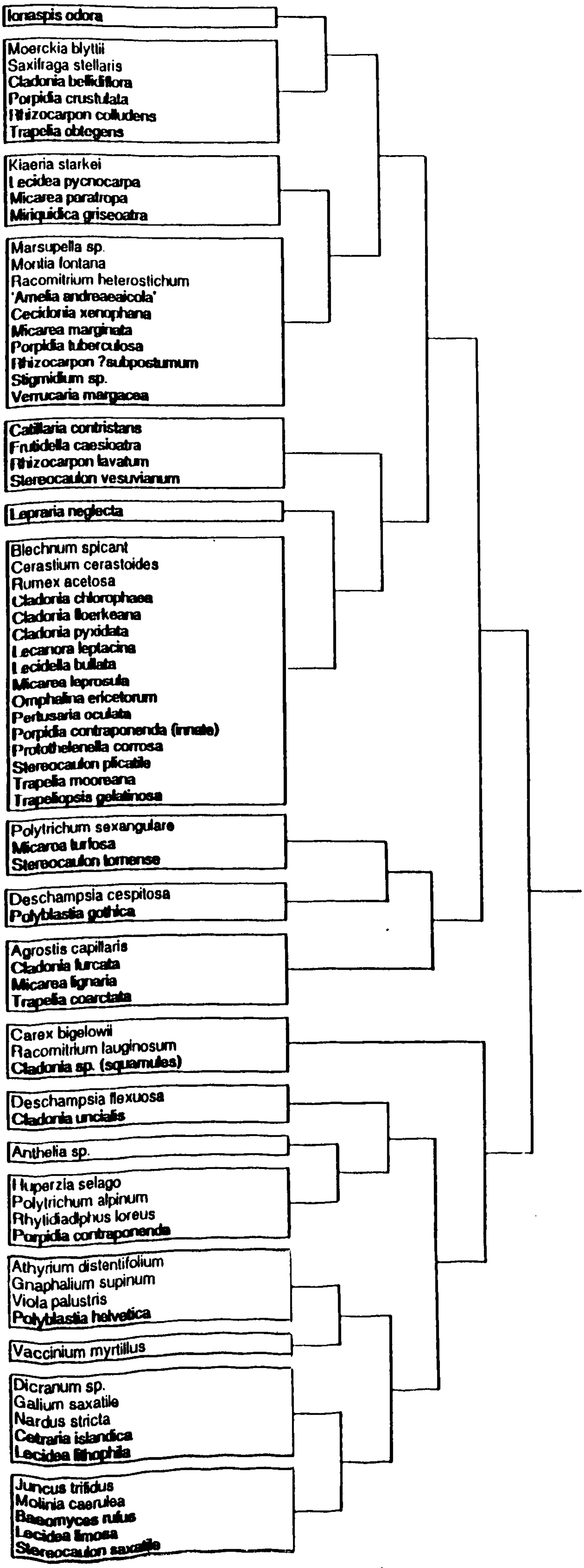
Table 5•5. Species recorded from transect above snow-bed on Aonach Mór

Vascular Plant Cover (%)	5	10	50	75	60
Bryophyte Cover (%)	80	75	30	15	30
Lichen Cover(%)	5	10	15	5	7
Rock Cover (%)	10	15	20	10	10
Average size of rocks (cm)	5-10	5-10	10	10-20	5-10
Vascular Plants					
Deschampsia cespitosa	2	3	6	8	8
Gnaphalium supinum	1	1	3	2	1
Saxifraga stellaris	.	1	3	1	.
Huperzia selago	.	.	1	1	.
Carex bigelowii	.	.	2	4	4
Deschampsia flexuosa	.	.	.	.	1
Bryophytes					
Polytrichum sexangulare	8	7	6	5	4
Marsupella sp.	5	2	2	.	.
Anthelia sp.	4	3	2	3	4
Moerckia blyttii	1	3	1	.	.
Racomitrium heterostichum	2	2	3	2	.
Polytrichum alpinum	.	1	3	1	3
Racomitrium lanuginosum	.	.	1	1	.
Dicranum sp.	.	.	1	1	3
'bright green liverwort'	.	.	.	.	3
Lichens					
Stereocaulon tornense	4	4	4	4	4
Ionaspis odora	1	2	1	2	.
Rhizocarpon 'colludens subsp. rufoatrum'	2	2	1	2	2
Porpidia contraponenda	3	4	1	2	2
Micarea paratropa	1	2	2	3	3
Verrucaria margacea	2	3	1	1	.
Porpidia crustulata	4	4	3	.	3
Micarea marginata	1	1	.	.	.
Porpidia macrocarpa	2	.	2	.	2
Stereocaulon saxatile	1	.	.	.	1
Rhizocarpon sp.	1	.	.	.	1
Trapelia placodioides	1	.	.	.	.
Rhizocarpon 'colludens'	.	2	2	2	.
Rhizocarpon lavatum	.	2	.	1	1
Agonimia tristicula	.	1	.	.	.
Cladonia subcervicornis	.	1	.	.	.
Micarea turfosa	.	1	1	1	3
Cladonia bellidiflora	.	.	1	1	.
Trapelia obtegens	.	.	1	1	.
Stereocaulon vesuvianum	.	.	1	1	.
Lepraria neglecta	.	.	1	1	.
Polyblastia helvetica	.	.	1	.	1
Lecidea lithophila	.	.	.	1	1
Porpidia tuberculosa	.	.	.	1	.
Frutidella caesioatra	.	.	.	1	.
Rhizocarpon 'sublavatum'	.	.	.	1	.
Cecidonia xenophana	.	.	.	.	1
Polyblastia gothica	.	.	.	.	1
Catillaria contristans	.	.	.	.	1

Baeomyces rufus	.	.	.	.	1

Fig. 5•7. TWINSPAN dendrogram of species recorded from transect above area of prolonged snow-lie on Creag Meagaidh.

a) all groups



b) lichens only

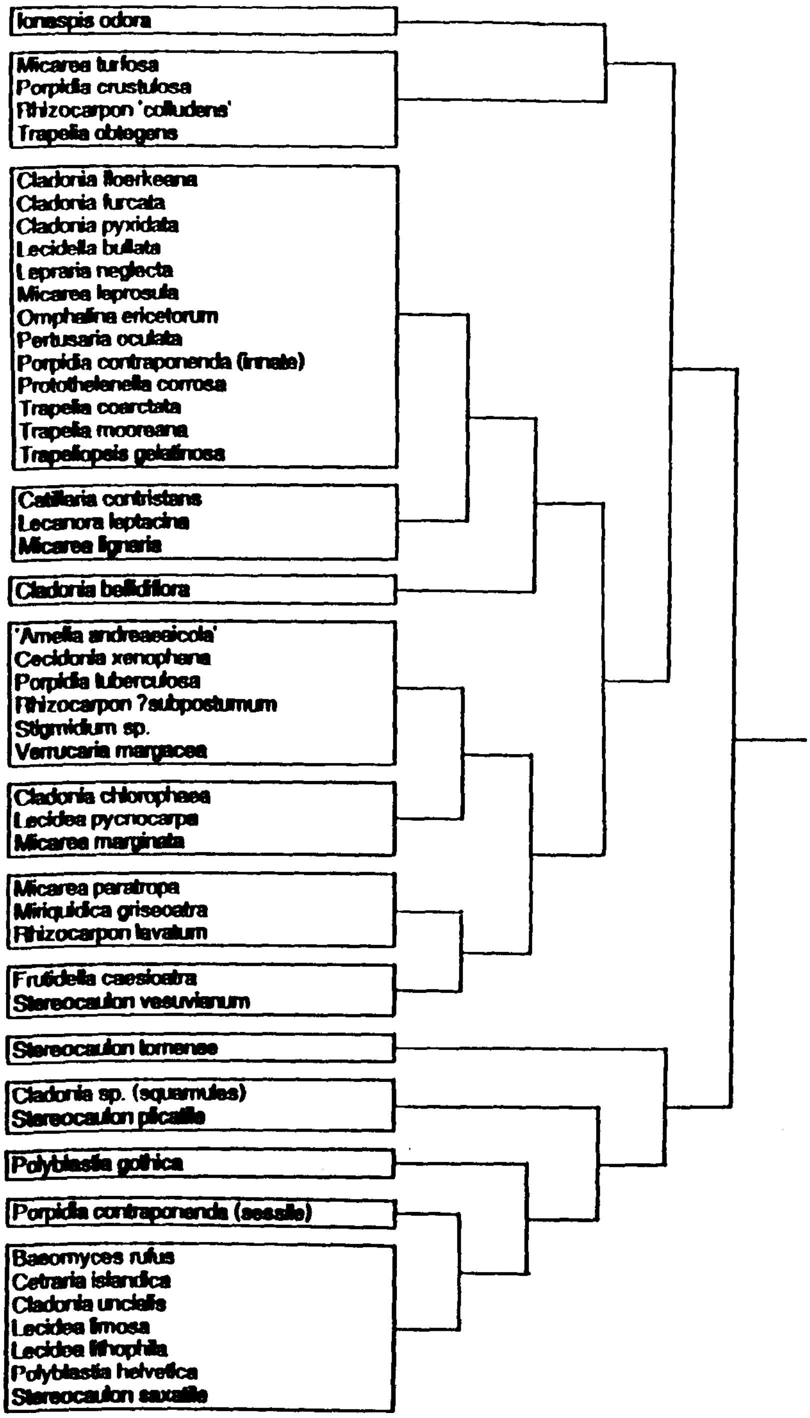
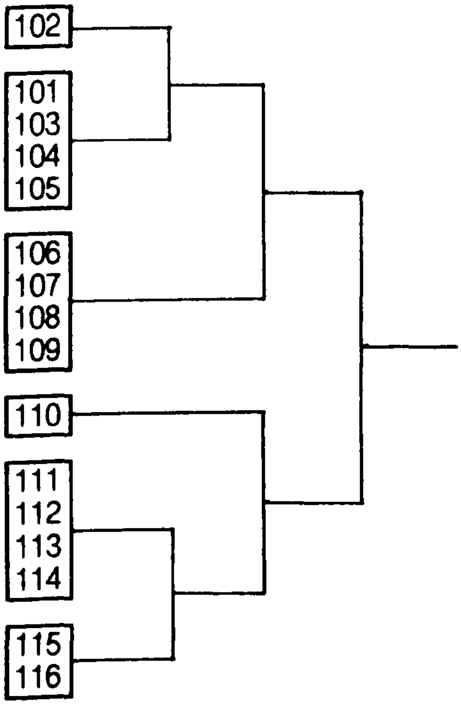


Fig. 5•8. TWINSPAN dendrogram of relevés from transect above area of prolonged snow-lie on Craeg Meagaidh.

a) all groups



b) Lichens Only

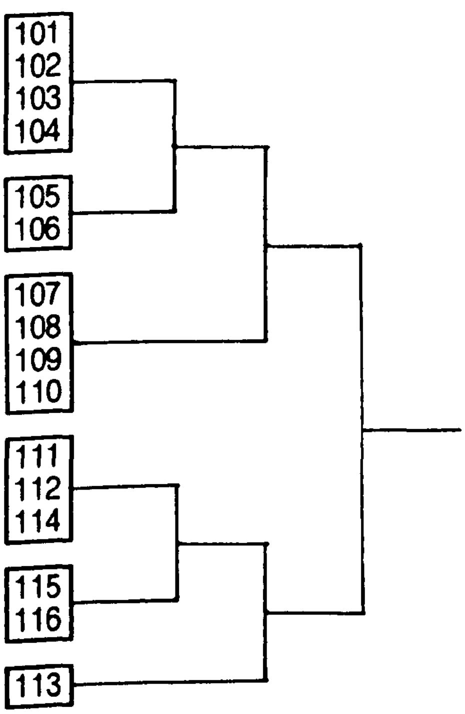
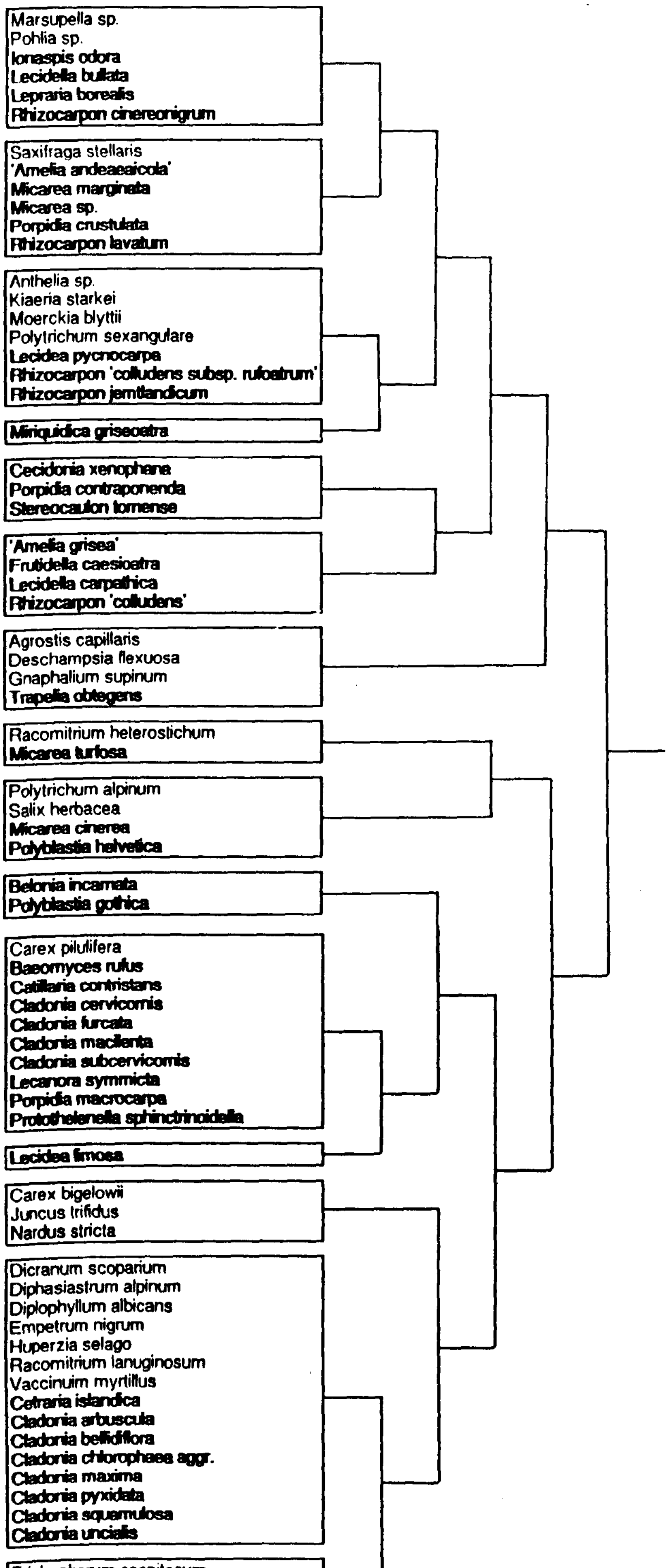


Fig. 5-9. TWINSPAN dendrogram of species recorded from transect above area of prolonged snow-lie at Ciste Mhearad on Cairn Gorm.

a) all groups



b) lichens only

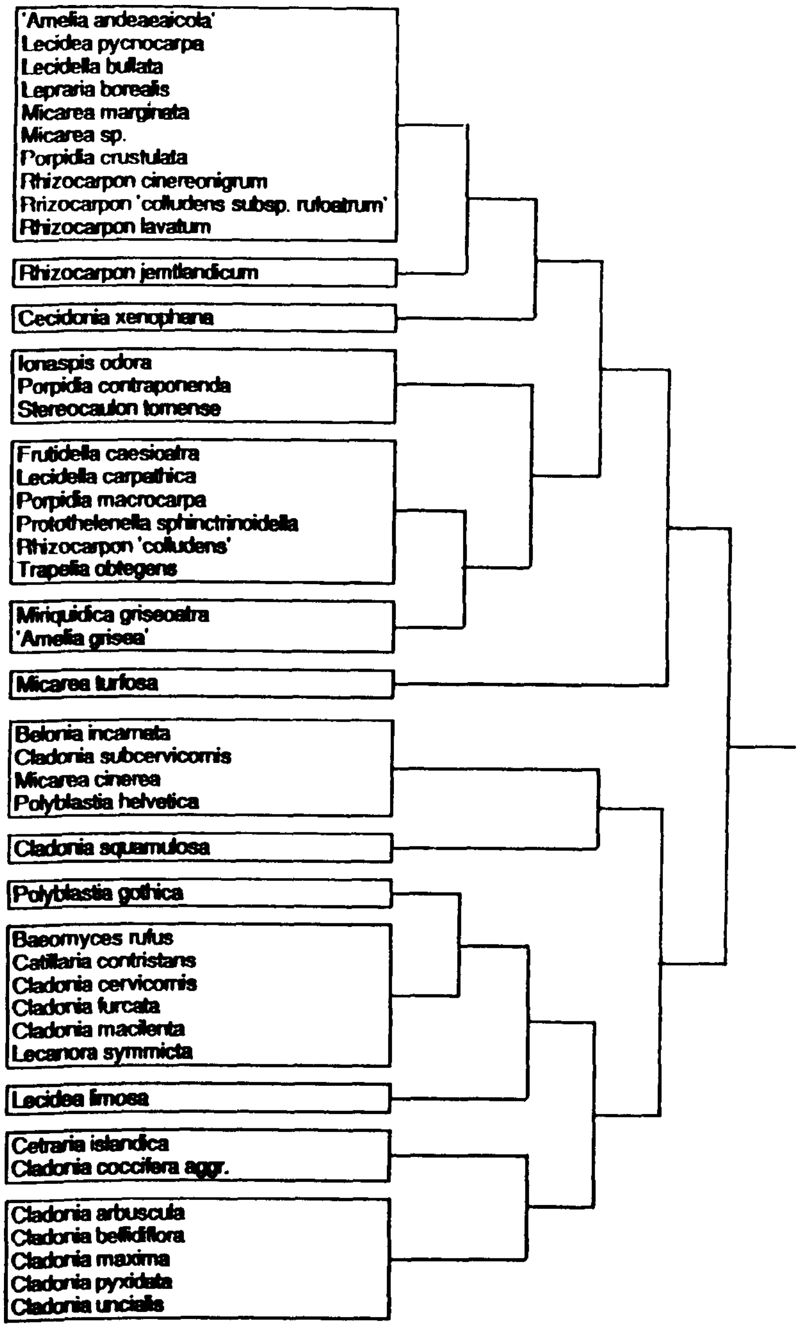
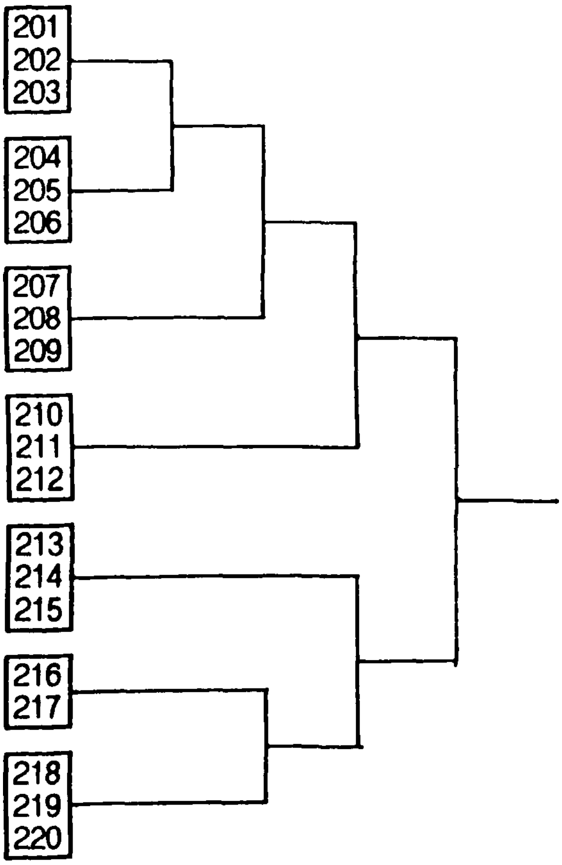


Fig. 5·10. TWINSPAN dendrogram of relevés from transect above area of prolonged snow-lie at Ciste Mhearad on Cairn Gorm.

a) all groups



b) Lichens Only

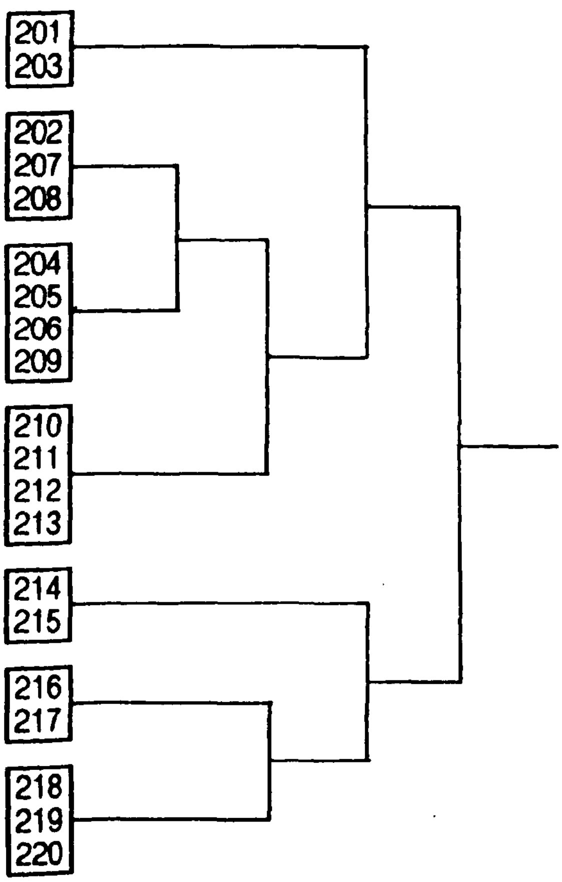
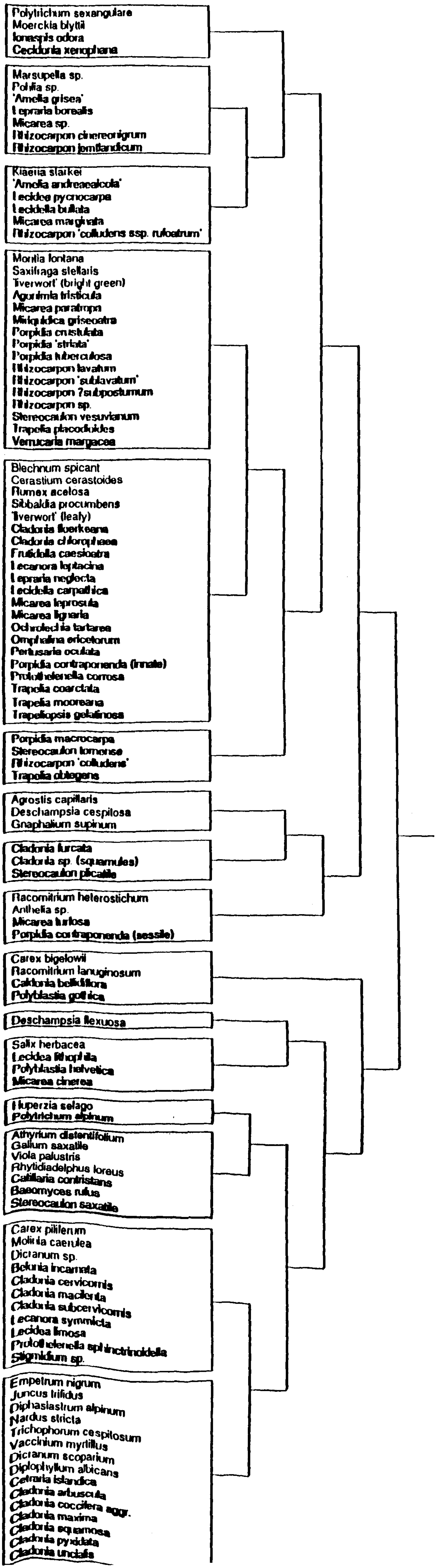


Fig 5•11. TWINSPAN dendrogram of combined species data collected from transects above areas of prolonged snow-lie.

a) all groups



b) lichens only

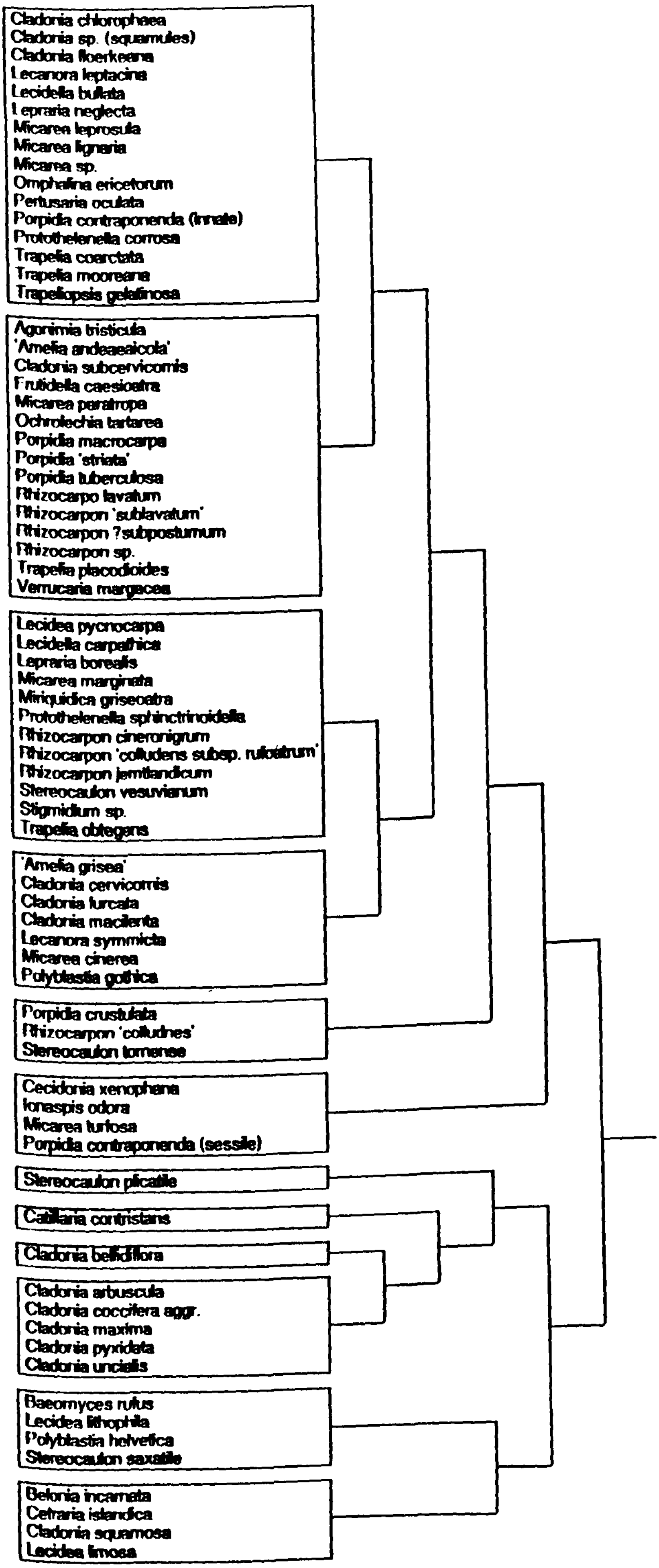
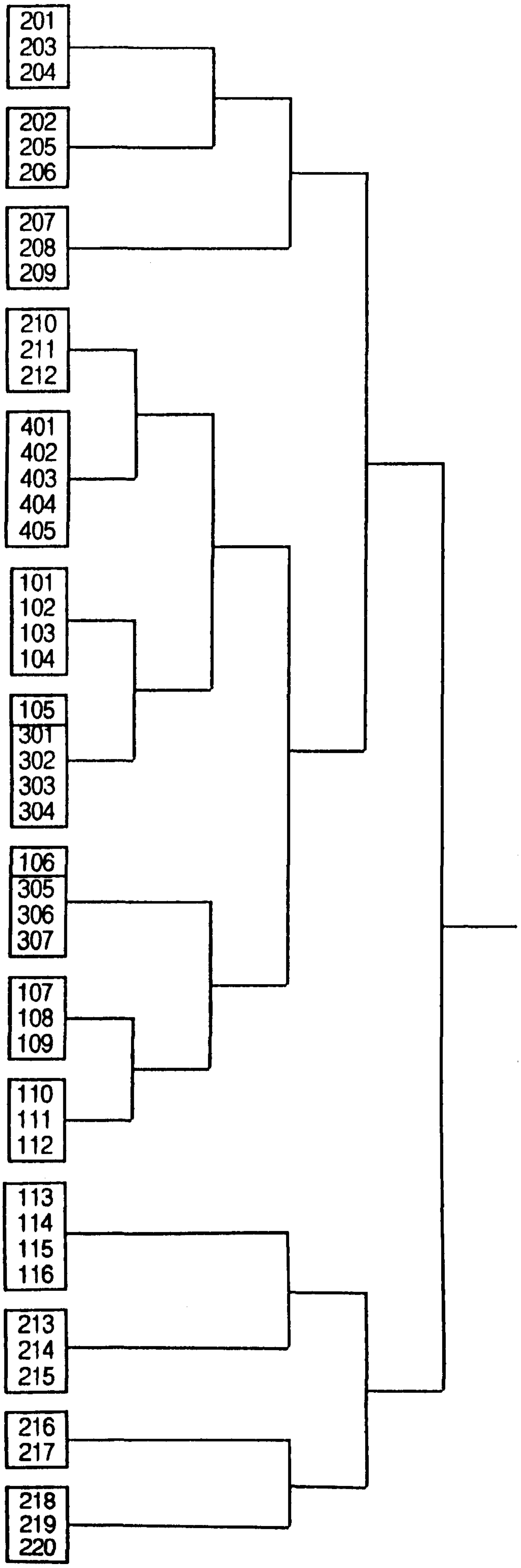
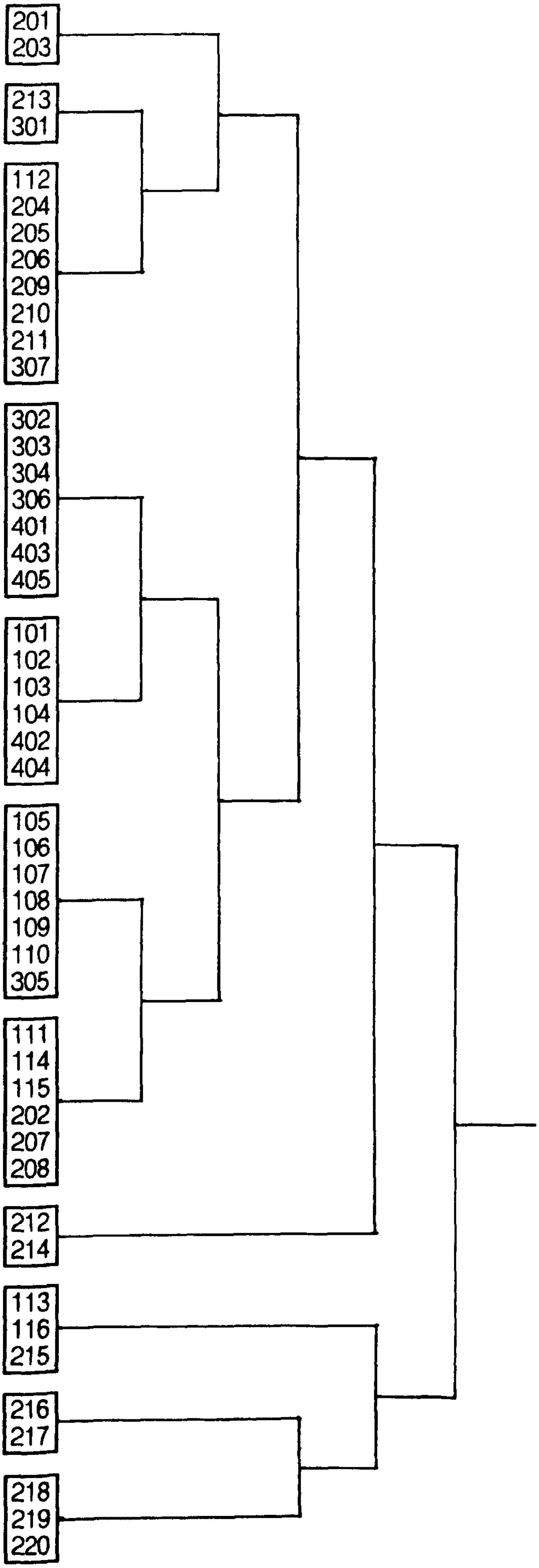


Fig. 5•12: TWINSPAN dendrogram of combined relevés from transects above areas of prolonged snow-lie.

a) all groups



b) lichens only



5•3•2 Saxicolous lichen vegetation

The saxicolous data collected from Creag Meagaidh and Ciste Mhearad are presented in Tables 5•6 & 5•7 and the TWINSPAN analysis of the Ciste Mhearad data in Fig. 5•13.

Table 5-6. Species recorded from relevés on boulders on eastern (uncovered) section of snow-bed on Creag Meagaidh.

Lichen Cover (%)	95	90	50	75	60	65	75	95
Bryophyte Cover (%) *	6	30	30	25	40	30	15	5
Bare Rock (%)	5	<1	20	3	5	5	10	5
Slope (°)	3	5	10	2	7	0	5	0
Aspects (°)	250	320	350	180	350	-	260	-
Andreaea spp.	8	5	3	3	3	3	4	1
Racomitrium heterostichum	1	3	5	5	5	5	2	3
R. lanuginosum	.	.	1	.	1	1	1	.
Gleocapsa sp.	5	3	.	.	.	.	.	.
Micarea paratropa	3	3	4	1	3	2	3	.
Toninia squalescens	7	3	1	.	.	1	1	.
Frutidella caesioatra	3	2	.	1	2	.	1	.
Miriquidica griseoatra	.	6	5	7	4	3	.	.
Lecanora leptacina	5	3	2	4	.	.	.	.
Lecidella bullata	2	1	.	.	.	3	.	.
Ionaspis odora	.	3	.	.	.	.	1	.
Porpidia crustulata	.	.	1	.	1	.	.	.
Hymenelia lacustris	.	.	.	.	1	.	6	.
Cladonia bellidiflora	.	.	.	.	1	.	1	.
Euopsis pulvinata	.	.	.	.	1	.	.	.
'Amelia andreaeaicola'	.	.	.	.	.	2	.	.
Rhizocarpon lavatum	.	.	.	.	.	2	.	.
Amygdelaria pelobotryopn	.	.	1	.	.	.	.	.
Rhizocarpon anaperum	.	.	.	1	.	.	.	.
Trapelia obtegens	.	.	.	.	1	.	.	.
Stereocaulon leucophaeopsis	.	.	.	.	1	.	.	.
Protothelenella corrosa	.	.	.	.	1	.	.	.
Pilophorus strumaticus	.	.	.	.	.	.	1	.
Rhizocarpon colludens s. lat.	1	2	2	4	4	3	1	1
Stereocaulon tornense	2	1	1	.	1	1	1	1
Lepraria neglecta	2	3	1	3	4	.	.	1
Stereocaulon vesuvianum	.	1	3	.	3	.	1	2
Rhizocarpon geographicum	.	.	.	.	.	.	.	5
Lecidea lithophila	.	.	.	.	.	.	.	5
Lecanora polytropa	.	.	.	.	.	.	.	6
Lecidea lactea s. lat.	.	.	.	.	.	.	.	6
Umbilicaria cylindrica	.	.	.	.	.	.	.	3
Porpidia cinereoatra	.	.	.	.	.	.	.	1
Fuscidea kochiana	.	.	.	.	.	.	.	1
Aspicilia cinerea	.	.	.	.	.	.	.	1

* Bryophyte cover is an indication of visible bryophytes. It does not include the area of bryophytes covered by lichens.

Table 5•7. Lichens recorded from boulders above an area of prolonged snow lie at Ciste Mhearad on Cairn Gorm.

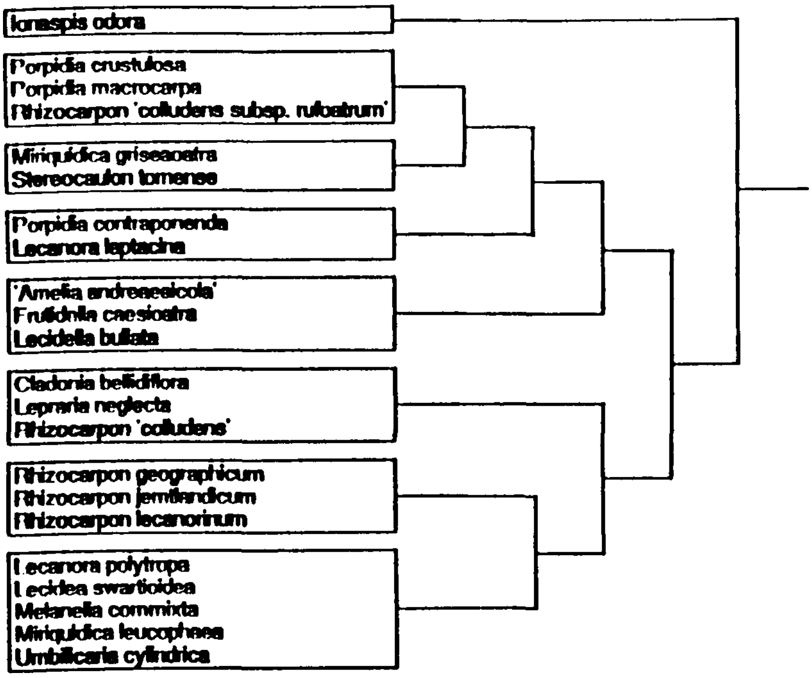
Distance from edge of snow-bed (m.)	1.5	5.0	9.20	11.5	14.7	15.8	18.8	24.8	32.0	34.0	41.0	45.0	50.0
Maximum hight of boulder (m.)	nd	nd	0.25	0.2	0.25	0.25	0.3	nd	0.2	0.25	0.4	0.4	0.2
Lichens present													
Ionaspis odora	x	.	.	.	.	.	.	.	.	.	.	.	.
Miriquidica griseoatra	.	x	x	x	x	x	.	.	.	.	.	.	.
Porpidia contraponenda	.	x	x	x	x	.	.	x	.	.	.	.	x
Stereocaulon tornense	.	x	x	.	x	.	.		.	.	.	.	.
Frutidella caesioatra	.	x	.	x	x	x	.	x	x	x	.	x	x
Porpidia crustulata	.	x	.	.	.	.	.	.	.	.	.	.	.
Rhizocarpon 'colludens subsp. rufoatrum'	.	x	.	.	.	.	.	.	.	.	.	.	.
Porpidia macrocarpa	.	x	.	.	.	.	.	.	.	.	.	.	.
Lecanora leptacina	.	.	x	x	x	x	x	.	.	.	.	.	.
Lecidella bullata	.	.	x	x	x	x	.	x	x	.	.	x	.
'Amelia andeaeaicola'	.	.	x	x	x	.	.	.	.	.	.	x	x
Rhizocarpon 'colludens'	.	.	x	.	.	.	.	.	.	.	x	.	x
Rhizocarpon geographicum	.	.	.	.	.	x	x	x	x	x	x	x	x
Lepraria neglecta	.	.	.	.	.	x	x	.	.	.	.	.	x
Cladonia bellidiflora	.	.	.	.	.	x	.	.	.	.	.	x	.
Rhizocarpon jemtlandicum	.	.	.	.	.	.	x	x	x	.	.	x	.
Rhizocarpon lecanorinum	.	.	.	.	.	.	x	.	.	.	.	.	.
Melanelia commixta	.	.	.	.	.	.	.	.	.	x	x	x	x
Lecanora polytropa	.	.	.	.	.	.	.	.	.	x	.	.	x
Lecidea swartzioidea	.	.	.	.	.	.	.	.	.	x	.	.	.
Umbilicaria cylindrica	.	.	.	.	.	.	.	.	.	.	x	.	x
Miriquidica leucophaea	.	.	.	.	.	.	.	.	.	.	x	.	.

Table 5•8. Lichens recorded from the tops of boulders above an area of prolonged snow lie at Ciste Mhearad on Cairn Gorm.

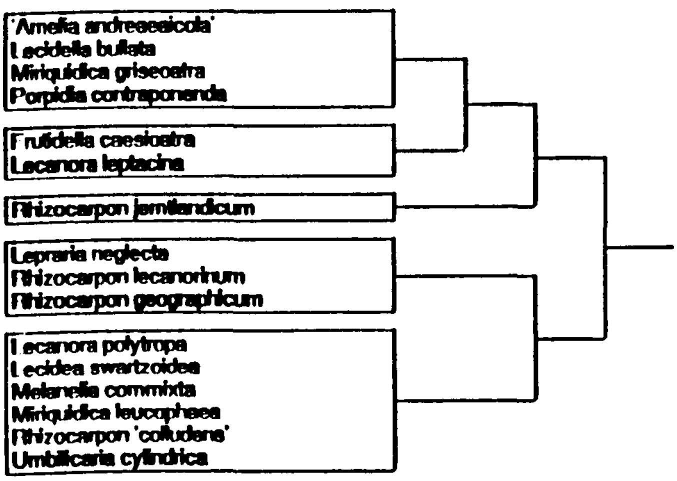
Distance from edge of snow-bed (m.)	9.20	11.5	14.7	15.8	18.8	24.8	32.0	34.0	41.0	45.0	50.0
Maximum hight of boulder (m.)	0.25	0.2	0.25	0.25	0.3	nd	0.2	0.25	0.4	0.4	0.2
Lecidella bullata	x	x	x	x	.	x	x	.	.	x	.
Lecanora leptacina	x	x	x	x	x	.	.	.	.	.	.
Miriquidica griseoatra	x	x	x	x	.	.	.	.	.	.	.
'Amelia andreaeaicola'	x	x	x	.	.	.	.	.	.	x	.
Frutidella caesioatra	.	x	x	x	.	x	x	x	.	.	.
Lepraria neglecta	.	.	.	x	x	.	.	.	.	.	x
Rhizocarpon jemtlandicum	.	.	.	.	x	x	x	.	.	x	.
Rhizocarpon geogaphicum	.	.	.	.	x	x	x	x	x	x	x
Rhizocarpon lecanorinum	.	.	.	.	x	.	.	.	.	.	.
Porpidia contraponenda	.	.	.	.	x	.	.	.	.	.	.
Lecidea swarztioidea	.	.	.	.	.	.	.	x	.	.	.
Melanelia commixta	.	.	.	.	.	.	.	x	x	x	x
Lecanora polytropa	.	.	.	.	.	.	.	x	.	.	x
Miriquidica leucophaea	.	.	.	.	.	.	.	.	x	.	.
Rhizocarpon 'colludens'	.	.	.	.	.	.	.	.	x	.	x
Umbilicaria cylindrica	.	.	.	.	.	.	.	.	x	.	x

Fig. 5·13. TWINSPAN dendrograms of lichens recorded from boulders above area of prolonged snow-lie at Ciste Mhearad on Cairn Gorm.

a) All surfaces



b) Top Only



5•4 DISCUSSION

5•4•1 General Observations

The features and plant communities of an area of prolonged snow-lie is illustrated in Fig 5•14 which shows the area investigated on Creag Meagaidh in the Central Highlands. The areas affected by prolonged snow-lie below the snow-bed are invariably water-logged and too damp to support good lichen growth (Fig. 5•15); the only species which regularly occur here are *Ionaspis odora* and *Verrucaria margacea,* both species of semi-inundated rocks at lower altitudes. Areas above the snow-bed are much drier, although still very damp, and it is here that the best developed lichen communities are to be found.

It is interesting to note that here, as at all the other snow-beds visited, the vegetation progresses from the inner, bryophyte-dominated areas, through *Nardus stricta-Carex bigelowii* grasslands to the surrounding vegetation which is *Juncus trifidus-Racomitrium lanuginosum* sedge heath not *Vaccinium myrtillus* heath as stated in the literature (e.g. Nordhagen 1936, Gjærevoll 1956, Rodwell 1992). There are two possible explanations for this discrepancy:-

a) the literature sources all refer to the vegetational progression from the snow-bed downwards.
b) the Scandinavian snowbeds occupy a more continental position where the *Vaccinium myrtillus* dwarf shrub heath will attain a greater altitude. This does not explain Rodwell's use of this progression. In this respect it would be interesting to investigate the areas of prolonged snow-lie on Lochnagar and the southern flank of Beinn a' Bhuird which are the most easterly snow-beds in the British Isles.

Creveld (1981) provided a diagrammatic sketch of an area of prolonged snow-lie, which she defined as with snow laying for 3-6 months of the year (Fig. 5•16). She mentions 11 communities, which include some chionophobic ones, but even her most chionophilic communities (i.e. Rhizocarpetum alpicolae, Lecanora-Umbilicarietum deustae and Ochrolechio-Hypogymnietum intestiniformis) are chionophobic by British standards. The position occupied by the lichen community most characteristic of areas of prolonged snow-lie

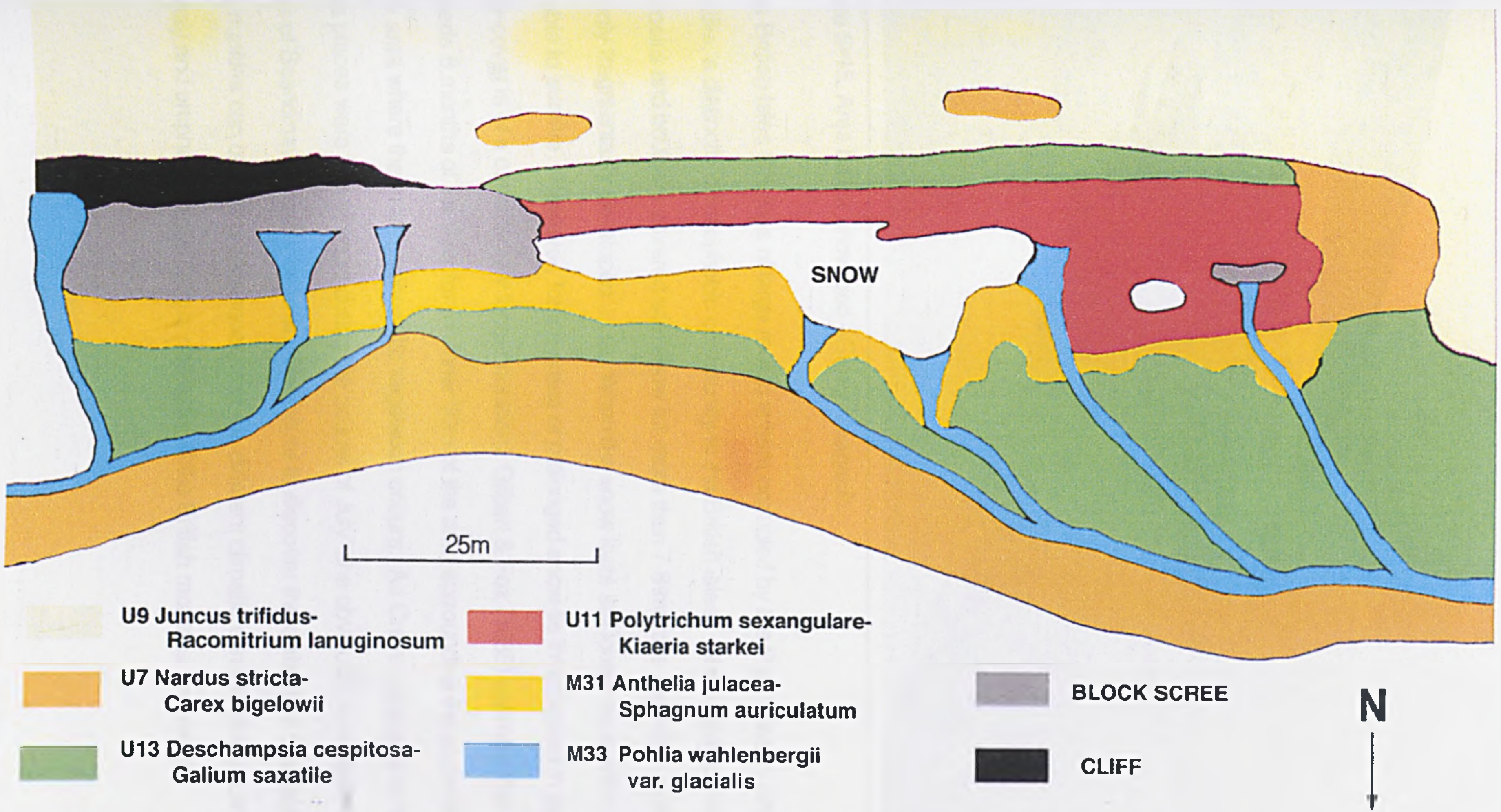
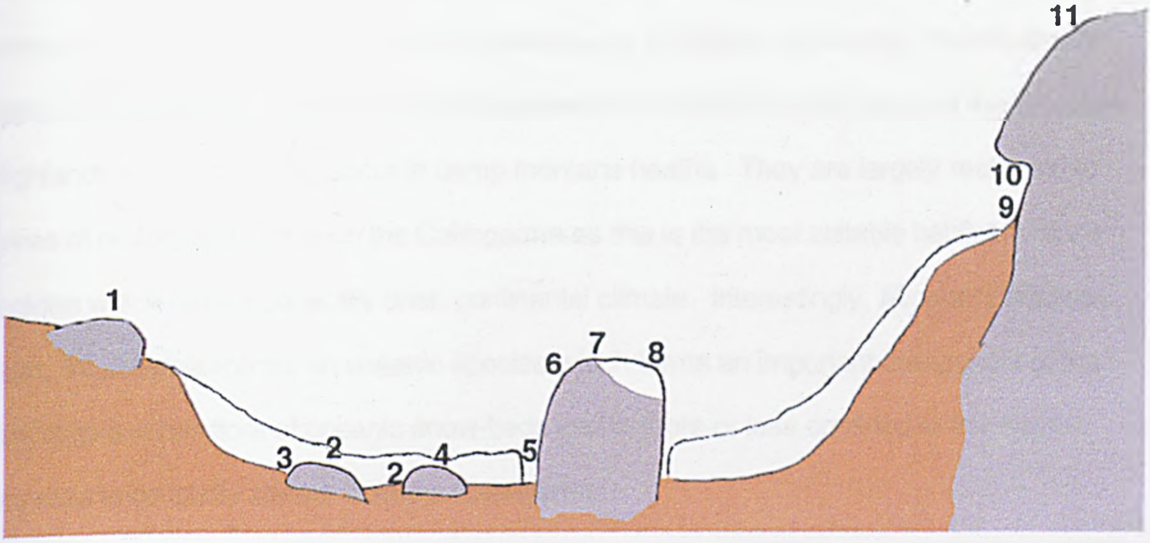


Figure 5•14. Major vascular-plant communities around the area of prolonged snow-lie on Creag Meagaidh. (Altitude 1000m, GR 27/408871).

Figure 5•15. Area below snow-bed - Creag Meagaidh.

in the British Isles (the tops of large rocks) is here occupied by the Parmelietum omphalodo-saxatilis, a distinctly chionophobic community in the British isles. She further comments that 'On rocks and boulders covered with snow for more than 7-8 months the lichen communities are only fragmentarily developed .... When the snow lasts still longer no epilithic lichens are able to survive'. However, for the areas of prolonged snow-lie investigated in Scotland, snow-cover is of a considerably longer duration. Gilbert & Fox (1985) estimate that snow-lie exceeds 8 months of the year for the inner 50m of the area surrounding the snow-bed, which is the area where the most chionophilic vegetation occurs. As Creveld states that 'in 1972 these places were free of snow during the course of July' she obviously investigated the inner areas of Scandinavian snow-beds and her failure to discover the distinctive chionophilic communities can only be a consequence of the different climatic conditions in southern Norway and emphasises the unique character of the British montane vegetation.



1 - Umbilicarietum proboscideo-hypoboreae

2 - Rhizocarpetum alpicolae

3 - Lecanora-Umbilicaretum deustae

4 - Ochrolechio-Hypogymnietum intestiniformis

5 - Rhizocarpo-Orphniosporetum atratae

6 - Umbilicarietum arcticae

7 - Ramalinetum polymorphae

8 - Parmelietum omphalodo-saxatilis

9 - Buellio-Xanthorietum elegantis

10 - Lecanoro-Acarosporetum chlorophanae

11 - Orphniosporo-Umbilicarietum rigidae

Figure 5•16. Chionophilic lichen communities in Scandinavia (from Creveld 1981).

Gilbert & Fox (1985) appreciated that their observations only applied to the Cairngorms. As a consequence, some of the taxa they identified as snow-bed specialists are more correctly species which occur in damp habitats (e.g. *Frutidella caesioatra, Protothelenella* spp., *Solorina crocea*) and are more widespread in the damp oceanic areas of the Western Highlands where they also occur in damp montane heaths. They are largely restricted to areas of prolonged snow-lie in the Cairngorms as this is the most suitable habitat in those regions which have a generally drier, continental climate. Interestingly, *Micarea paratropa* (syn. *M. subviolascens*), an oceanic species which forms an important component of the saxicolous lichen flora of oceanic snow-beds and is more or less confined to this habitat, appears to be totally absent from the Cairngorms.

Another group of lichens which Gilbert & Fox wrongly identified as snow-bed specialists was those crustose species which, being unable to compete with vigorous vascular-plant growth , occur in the intermediate *Salix herbacea* zone but are absent from the surrounding *Nardus stricta* grassland (e.g. *Catillaria contristans, Lecidea limosa, Micarea viridiatra, Stereocaulon saxatile*). As most of their previous montane work had dealt with basic rock outcrops, they had only a limited knowledge of the general lichen vegetation of acidic montane heaths in Scotland and consequently did not appreciate that these species occur, in montane areas, wherever vascular plant growth is suppressed and are a major component of the terricolous lichen vegetation of wind-swept, acid montane heaths, in particular the *Juncus trifidus-Racomitrium lanuginosum* rush heath (NVC U9).

Gilbert *et al.* (1992) emphasized that, although there were regional differences, there was a general similarity of the snow-bed vegetation in all three areas. This can now be seen to be a consequence of the selective lichens of the Cairngorm snow-beds being oceanic species which, naturally, are more widespread further west and not restricted to areas of prolonged snow-lie. They recognised that the most characteristic snow-bed lichens were those which occurred on rocks and attributed this to the higher stability of this habitat, although better drainage would appear to be of, at least, equal importance. Gilbert *et al.* (1992) also identified habitat diversity as the most important factor in promoting a rich lichen vegetation, but many of the species finding a favourable habitat will not necessarily be snow-bed species. As all the character species are saxicolous, either occurring on large rocks or small pebbles, high stability is probably the most important factor with good light, to promote rapid drying and inhibit bryophyte growth, also being important.

The factors which must be overcome by a lichen if it is to grow in the vicinity of an area of prolonged snow-lie were listed by Gilbert & Fox (1985). These are an ability to tolerate:-

a) instability (although the most characteristic species are confined to the tops of large boulders, a particularly stable habitat)
b) long periods of darkness
c) high humidity
c) temperatures around freezing point.

They also predicted that they would be poor competitors.

Other lichens not restricted to snow-beds may also be able to tolerate one or more of these factors and these will probably be those species which are locally confined to areas of prolonged snow-lie. By investigating the lichen vegetation of snow-beds from a wide area these will be eliminated and the true snow-bed specialists identified.

Species and communities are rarely restricted to a particular habitat but rather to a certain set of environmental conditions, which favour them over other species, and may be produced in a number of different habitats. It is unlikely that different habitats will produce identical conditions and so it is unlikely that the community, although having many species in common, will have exactly the same composition. This is well illustrated by the terricolous lichen vegetation which occurs in the vicinity of areas of prolonged snow-lie in the Cairngorm Mountains (see section 5•4•3•1) which also occurs in a more luxurious form on montane heaths further west and in a more modified variant in the exposed, wind-swept *Juncus trifidus-Racomitrium lanuginosum* heath (NVC U9) in the Cairngorms. It is possible to describe the fidelity of these communities to a particular habitat by applying the criteria used for assessing the fidelity of a species to a community (Table 4•1) especially if these are qualified by 'local', 'regional' or 'general' (e.g. the distinctive assemblage which includes *Lecanora leptacina, Lecidella bullata, Miriquidica griseoatra* etc. is 'faithful' to areas of prolonged snow-lie, the assemblage on soil is 'locally faithful', etc.). However, if the community is described in terms of the environmental conditions rather than its habitat (e.g. 'damp montane soils with low vascular-plant cover' rather than 'snow-bed') this is largely unnecessary.

Very few of the taxa recorded from the inner areas of prolonged snow-lie have the ability to reproduce vegetatively, although the macro-lichens occurring in the *Nardus stricta* grassland are mostly infertile. Most of the non-fertile species are sorediate generalists, i.e. *Porpidia tuberculosa, Trapelia gelatinosa, T. obtegens,* which are also frequent in other habitats, especially ones of lower altitudes. Interestingly, *T. obtegens* is rarely encountered at intermediate altitudes, and *P. tuberculosa* is rare at these altitudes in oceanic areas where it is replaced by its fertile counterpart, *P. grisea.* It does, however, appear to be more frequent in the more continental Cairngorms, from where *P. grisea* has yet to be recorded. It would appear that the primary species, *P. grisea*, has its natural habitat on montane rocks in oceanic regions with the secondary species, *P. tuberculosa*, colonizing both higher and lower altitudes and more continental areas. This supports the hypothesis that fertile species tend to have a narrow ecological amplitude and occur in habitats with a long ecological continuity whereas vegetatively reproducing ones are more able to colonize new, or sub-optimal habitats and are more widely distributed. This is a consequence of lichens being dual organisms with both bionts being present in vegetative propagules but ascospores representing only the mycobiont. The latter, therefore, need to associate with the appropriate photobiont before a new lichen thallus can be formed and this may not be present in a new area, whereas the vegetative propagule already has both bionts present. Given the advantages of vegetative reproduction for lichens (i.e. that both bionts are present), sexual reproduction is only a reasonable means of propagation when the phytobiont is in ready supply, i.e. where the species is already present.

In this case it may also be that ascospores, being smaller than vegetative propagules, are more able to find small irregularities in the substratum which afford sufficient protection from the exceptionally harsh environment. The only sorediate species which has its primary habitat in the vicinity of areas of prolonged snow-lie is *Stereocaulon tornense*, although this species also frequently supports apothecia. It is also more probably a species of damp, oceanic montane heaths than a snow-bed specialist. Recent work (Schidegger *pers. comm.*)

has shown that the asci of *Lobaria pulmonaria* require 2 weeks8 continuous hydration before viable spores are produced. If this is true for lichens in general then it may be a contributory factor to both the restriction of *Porpidia grisea* to damp oceanic areas and the prevalence of fertile species as snow-bed specialists.

5•4•2 TWINSPAN analysis

TWINSPAN arranges both the species recorded and the individual relevés into groups and indicates how closely they are related to one another. It first identifies the most significant difference in the data, divides it into two sub-groups, gives an indication of how sound the separation is and identifies indicator species for each group. It then similarly divides the resulting sub-groups and this process is repeated until each sub-division contains only one entity or until told to stop.

The dendrograms produced by TWINSPAN represent the way in which the vegetation occurring in the vicinity of late-snow beds is best grouped together to demonstrate its phyto-sociological relationships. It groups together both those species which have a similar distribution throughout the relevés and those relevés in which a similar assemblage of plant species occur. It takes no account of environmental factors and only indirectly indicates the sequential changes in the vegetation with increasing snow-lie. In particular it must be remembered that each point on the dendrogram may be rotated through 180° and although the dendrograms have been re-drawn to represent, as far as is possible, a progression from extensive to minimal snow cover this is not a product of the TWINSPAN analysis.

The TWINSPAN dendrograms for the species divide the vegetation into two main groups, a bryophyte-dominated inner area with saxicolous crustose lichen s and a vascular-plant dominated outer area with terricolous macro-lichens. This is illustrated more clearly by the dendrograms for the relevés. When all the data are grouped (Fig. 5•12) the relevés can be seen to form four distinct groups with the first division occurring between groups 3 & 4:-

1) 201-209 - the inner areas of Ciste Mhearad

2) 210-112 - bryophyte dominated area

3) 113-215 - open *Nardus stricta* grassland

4) 216-220 - closed *Nardus stricta* grassland

The reason why the inner area of Ciste Mhearad forms such a distinct group is due to the complete absence, or greatly reduced presence, of vascular-plants when compared to the other areas surveyed. This area was surveyed late in the year (late September) in a year of particularly high snow-melt; equivalent areas on the other sites were not surveyed as they were visited earlier in the year or in years with less rapid snow-melt.

Inspection of the TWINSPAN dendrograms for the relevés also shows that, when all vascular-plants and bryophytes are included in the analysis, the groupings are much more linear (i.e. adjacent relevés are grouped together) than when only the lichen data are analysed. There is a distinct progression from those closest to the snow-bed (low-numbers) to those furthest away (high numbers). This is a consequence of the greater importance of micro-habitat in determining lichen distribution than it is for vascular-plants as micro-habitats (e.g. rocks, terracettes, clumps of vascular plants) are distributed unevenly along the transect and their characteristic lichens are similarly unevenly distributed.

5•4•3 The Lichen Vegetation

The vegetation being sampled is inherently heterogeneous. In the inner, cryptogam-dominated areas this is as a consequence of the dual nature of the substratum which consists of small pebbles deeply imbedded in a bryophyte mat (Fig. 5•6) whereas further out, where the vascular plant vegetation is dominant, the vegetation is a small-scale mosaic consisting of small gaps in the vascular plant vegetation or solifluction terracettes both of which support anomalous cryptogam-dominated areas. The pebbles support a number of species which also occur on soil but as they will be freer draining than the soil the lichens will extend further into the snow-bed on pebbles than they will when growing on soil (e.g. *Frutidella caesioatra, Lepraria borealis, Lepraria neglecta*). Larger rocks also provide shelter from winds and a degree of stability to their immediate surroundings on the steeper-sloping, inner areas so that, even if the lichens actually growing on them are omitted from the analysis they still influence the terricolous vegetation and contribute to heterogeneity of the relevés. These factors must be taken into account when interpreting the groupings and relationships produced by TWINSPAN.

The relative distribution and extents of the various communities is shown in Fig. 5•17.

5•4•3•1 Terricolous Lichen Vegetation

As stated above, the first division which TWINSPAN makes, in all cases, occurs at approximately the position where the bryophyte-dominated area gives way to the *Nardus stricta* grassland. The *Salix herbacea-Gnaphalium supinum* (Fig. 5•18) dominated area which forms an intermediate zone between the two is included with the *Nardus stricta* grassland giving a rough distinction between bryophyte and vascular-plant dominated areas. Even where the *Juncus trifidus* heath was sampled (Creag Meagaidh) this was grouped with the *Nardus stricta* grassland indicating that, from a purely phyto-sociological stand-point, the latter is best considered as a chionophobic community. This does not mean that it is not affected by long snow-lie, rather that the similarities between the vegetation of the *Nardus stricta* and *Juncus trifidus* communities are much greater than those between the *Nardus stricta* grassland and the inner areas of snow-beds. The two areas will be considered separately.

1) Inner, bryophyte-dominated area

Terricolous lichens generally become sparse the closer the inner area of the snow-bed is approached due to the extremely damp conditions. The ground is permanently water-logged and this is a inhospitable habitat for lichens. The only terricolous species which occurs with any degree of regularity in this area is the common widespread montane species, *Micarea turfosa*. Other terricolous species which appear in Tables 5•2 - 5•5 as occurring close to the snow-bed (i.e. *Agonimia tristicula, 'Amelia grisea', Cladonia* spp., *Lepraria borealis*) are always associated with saxicolous habitats which are much freer draining. In addition, the *Cladonia* spp. are always poorly formed and usually lack podetia.

2) Outer, vascular plant dominated area

Two separate habitats can be distinguished in this area, which is dominated by *Nardus stricta*. Although they form an intimate mosaic these two habitats support plant communities with a significantly different structure and distribution.

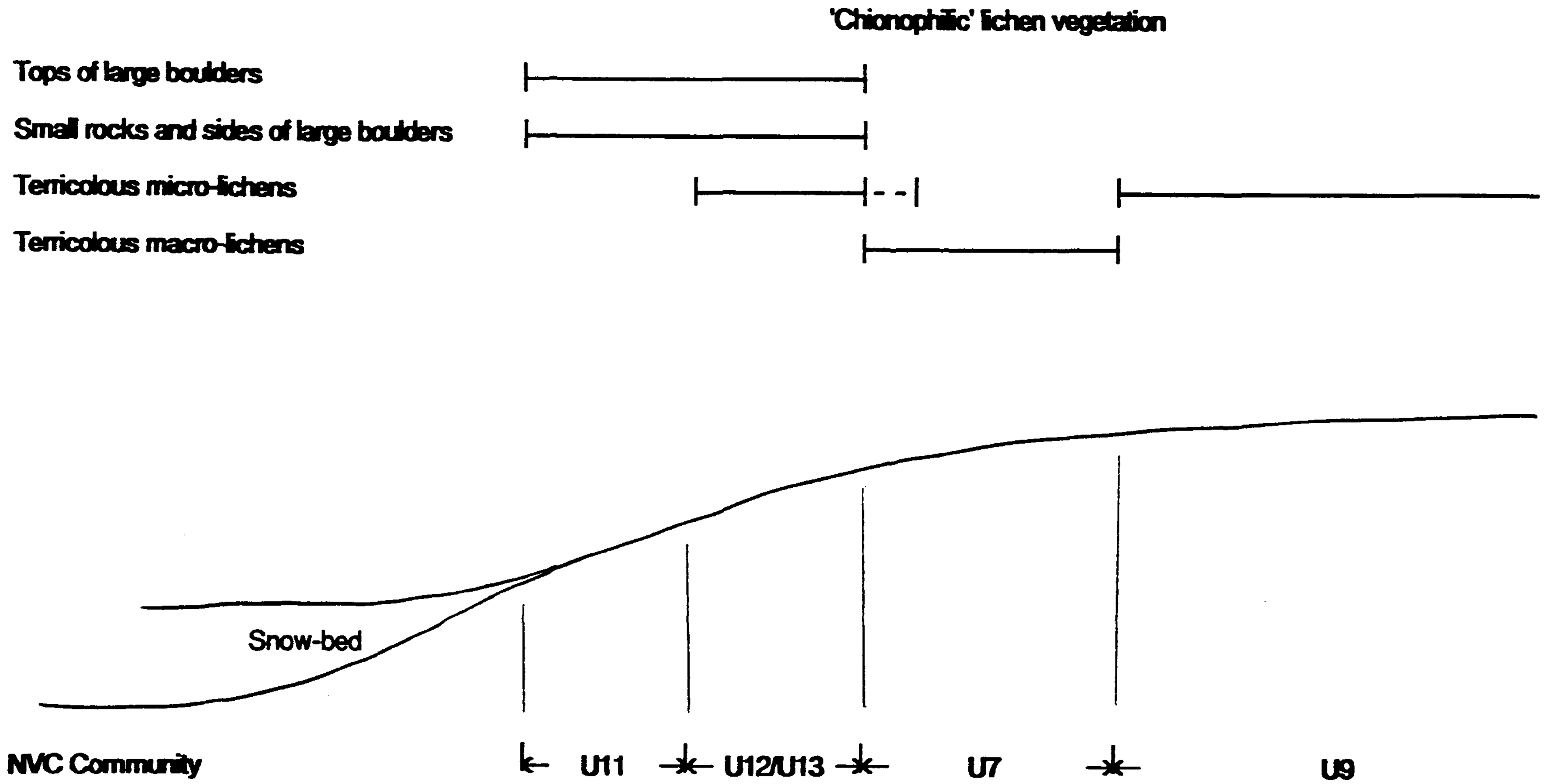


Fig. 5•17 Diagrammatic representation of the distribution and extent of chionophilic lichen vegetation in the vicinity of areas of prolonged snow-lie in the Cairngorm Mountains, north-east Scotland.

Figure 5•18. Area above Ciste Mhearad snow-bed (Cairn Gorm), showing gradation of vegetation from inner, bryophyte-dominated area, through *Salix herbacea-Gnaphalium supinum*, to the outer *Nardus stricta-Carex bigelowii* grassland.

i) Among *Nardus stricta* - The vegetation of this habitat is dominated by *Nardus stricta* (Fig. 4•13) and the lichen vegetation consists of macro-lichens which grow up among the grass sward. The most frequent of these is *Cetraria islandica* but *Cladonia* spp. also occasionally occur, the most frequent being *C. arbuscula, C. maxima* and *C. uncialis*. *C. arbuscula* and *C. uncialis* are widespread heathland species but *C. maxima* (Fig. 4•14) is, in the British Isles, restricted to damp, montane *Nardus stricta* grasslands, usually associated with areas of prolonged snow-lie. However, the western outlier on Aonach Mór (Lochaber) suggests that this is a species which has a requirement for dampness rather than being a strict snow-bed species. *Cetrariella delisei* has been reported as occurring in this community (Gilbert & Fox 1985, Rodwell 1992) but, as described in the previous chapter, its ecology is more complex. *Cladonia stricta* was also considered as part of this community by Gilbert & Fox but closer examination shows it to be most often associated with bare areas within the *Nardus stricta* sward and, consequently, better considered as part of the following community. Although it has been recorded only from the vicinity of areas of prolonged snow-lie, these areas have been given much more attention than the general montane heath and, as *C. stricta* is such an easily overlooked inconspicuous species (Fig. 5•19), it is possible that it does occur elsewhere.

Figure 5•19. *Cladonia stricta.* (Magnification x2).

The community in which these lichens occur was described by Rodwell (1992) as U7 *Nardus stricta-Carex bigelowii* grass-heath and is confined to damp montane areas, being particularly frequent around the outer areas of the vegetation affected by prolonged snow-lie. As the lichen vegetation forms an integral part of the structure of the vegetation it has to be included as a part of this community.

ii) 'bare' soil - the lichens occurring in this habitat are mostly micro-lichens which are either generalists, e.g. *Baeomyces rufus, Cladonia* spp., *Micarea leprosula, M. lignaria, Trapeliopsis gelatinosa* or generally distributed montane species, often with an oceanic bias to their distribution. The latter group predominate and include those species which show only an apparent affinity for snow beds in the Cairngorms in that they disappear in the *Nardus stricta* grass-heath due to lack of habitat as they cannot compete with vigorous vascular-plant growth. Many of these species are very small and were previously believed to be snow-bed specialists as these were the areas which had received the most attention but, largely due to the present work, they are now known to be widespread members of the terricolous montane vegetation.

This lichen assemblage inter-grades with that of the inner areas of the snow-bed described above and which is probably best considered a species-poor facies of it. It also occurs further west, e.g. on Beinn Heasgarnich (Table 4•10, relevés 86 & 90), where it is associated with a completely different NVC community (CG 12) in a chionophobic community on an exposed ridge.

That the same assemblage occurs in different NVC communities and in different habitats indicates that it should be considered as a distinct community separate from the vascular plant communities with which it occurs. Species recorded from Ciste Mhearad and Beinn Heasgarnich are listed in Table 5•8.

All but three of the species recorded from Ciste Mhearad also occurred on Beinn Heasgarnich, and those that were not recorded there were seen in this habitat elsewhere in the Breadalbane Mountains. This suggests that exposed, oceanic montane heath is the principal habitat for this community but that this assemblage finds an alternative habitat, in the generally drier Cairngorm Mountains in the vicinity of areas of prolonged snow-lie where it occurs as a species-poor variant..

This cryptogam-dominated community also occurs, in a modified form, in the *Juncus trifidus* sedge heath (see section 4•2•2•4) where some species, e.g. *Lecidea limosa* and *Lecidoma demissum*, are more frequent at the expense of the smaller species, e.g. *'Amelia grisea* and *Protothelenella sphinctrinoidella* which are usually completely absent, probably as a result of the drier conditions. In this situation the assemblage has been considered as an eastern facies of this community in which *Racomitrium lanuginosum*, typical of the community in the west, is replaced by terricolous lichens. However, the similarities between this assemblage and that of the snow-beds suggests that it may be better to consider the cryptogamic component of the vegetation separately as a facies of the latter community associated with a drier environment than the typical form. More work is required to clarify these relationships, in particular detailed bryophyte information may yield some relevant data.

Table 5•8. Lichens characteristic of soil in the vicinity of an area of prolonged snow-lie in the Cairngorms (Ciste Mhearad) and an exposed ridge on Beinn Heasgarnich

	Ciste Mhearad	Beinn Heasgarnich
'Amelia grisea'	x	.
Arthrorhaphis muddii	.	x
Baeomyces rufus	x	x
Belonia incarnata	x	x
Catillaria contristans	x	.
Chromatochlamys 'geislerioides'	.	x
Dibaeis baeomyces	.	x
Lecidea hypnorum	.	x
L. limosa	x	x
Micarea cinerea (anamorph)	x	x
M. turfosa	x	x
M. viridiatra	x	x
?Moriola sp.	.	x
Ochrolechia tartarea	.	x
Polyblastia gothica	x	x
P. helvetica	x	x
Protothelenella sphinctrinoidella	x	.
Steinia geophana	.	x
Stereocaulon condensatum	.	x
S. saxatile	x	x

As the two terricolous communities described above form a small-scale mosaic around areas of prolonged snow-lie they are not separated by the TWINSPAN analysis. They constitute the whole of the second group in Fig. 5•11 (i.e. after the first division) with the *Nardus stricta* community forming part of the penultimate group and the general heath-land community the rest. The final two groups are separated from the rest of the community as these are the species which occur more frequently in the closed *Nardus stricta* heath whereas the species in the other groups are associated more with the open *N. stricta* heath closer to the snow-bed where it inter-grades with the *Salix herbacea* dominated vegetation.

5•4•3•2 Saxicolous Lichen Vegetation

The basic distinction identified by TWINSPAN for the terricolous vegetation is not as pronounced for the saxicolous vegetation. The inner area contains many small pebbles, which form an intimate relationship with the terricolous vegetation, along with scattered larger rocks which support a very distinctive community on their upper surfaces whereas their sides support an assemblage more similar to that of the pebbles. In the outer area, the pebbles are more or less completely covered by the increased vascular-plant growth and its associated litter and the larger rocks, being raised above the level of the ground, are not subjected to as long a snow-cover as the terricolous vegetation in the same area. Consequently, although snow-bed species do occur, the saxicolous lichen vegetation in this area is largely chionophobic. The principal separation of the saxicolous vegetation, therefore, is between large rocks and smaller pebbles and these two habitats will be dealt with in turn.

i) Large rocks - this is the habitat which supports the most characteristic snow-bed lichens (Fig. 5•20). Many of the species present here are restricted to areas of prolonged snow-lie throughout their range in the British Isles and can be considered as 'Exclusive' to this habitat, i.e. *Amelia andreaeaicola'* (Fig. 5•21), *Lecanora leptacina* (Fig. 5•22), *Lecidella bullata* (Fig. 5•23) and *Miriquidica griseoatra*. This assemblage is so distinctive and has so many exclusive species that it will be necessary to describe a new alliance for it. It is particularly well-developed near the snow-bed on Creag Meagaidh (Table 5•6, relevés 1-8) and is also well-represented on rocks above Ciste Mhearad (Table 5•7). More work is required to characterise this community fully and ascertain the fidelity grades of its constituent species; in particular, data from a wider range of areas are required (including other oceanic montane areas, e.g. Norway, British Columbia), but a provisional classification of the community is given in Table 5•9.

Figure 5•20. Boulder in area affected by prolonged snow-lie - Beinn a' Bhuird. *'Amelia andeaeaicola', Lecanora leptacina, Lecidella bullata* and *Miriquidica griseoatra* on top of the boulder, *Rhizocarpon geographicum* and *R. lavatum* on the side.

Figure 5•21. *'Amelia andreaeaicola'* (Magnification x2).

Figure 5•22. *Lecanora leptacina.* Magnification x2).

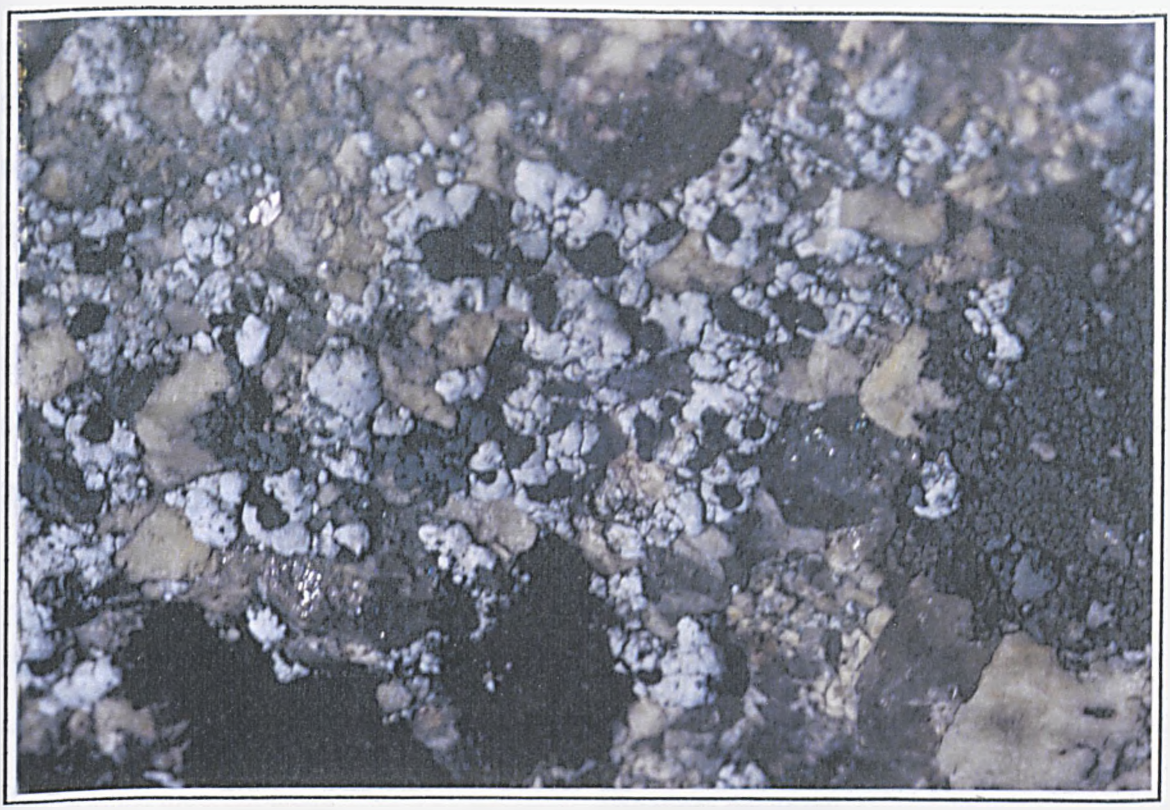


Figure 5•23. *Lecidella bullata.* (Magnification x2)

Table 5•9. Lichens characteristic of large rocks in areas of prolonged snow-lie.

Fidelity 5	*'Amelia andreaeaicola'*	Fidelity 2	*Cecidonia xenophana*
	Lecanora leptacina		*Ionaspis odora*
	Lecidella bullata		*Lecidea pycnocarpa*
	Miriquidica griseoatra		*Lepraria neglecta*
	Rhizocarpon cinereonigrum		*Rhizocarpon lavatum*
	R. jemtlandicum		*Stereocaulon tornense*
Fidelity 3	*Frutidella caesioatra*		
	Micarea paratropa		
	Porpidia contraponenda *		
	Rhizocarpon 'colludens subsp. *rufoatra'*		
	Toninia squalescens		

* There appear to be more than one entity currently included within this taxon. Further work may show that the snow-bed entity is a distinct species which should then be recognised at Fidelity 5.

This assemblage does not form a well-defined group in the TWINSPAN analysis of the main transects due to the irregular occurrence of large rocks but on the transect from boulders above the snow-bed on Ciste Mhearad (Table 5•7, Fig. 5•13) it is much more clearly defined, especially when only the tops of the rocks are considered. In Fig. 5•13 the TWINSPAN analysis clearly separates the lichens occurring on the tops of boulders into chionophilic and chionophobic species by the first division. The second division then separates a chiono-tolerant group in the chionophobic group and a less chiono-demanding group in the chionophilic group. These groups are shown in Table 5•10.

Table 5•10. Lichens recorded from the tops of boulders in the vicinity of Ciste Mhearad divided into degrees of chiono-tolerance.

Chionophilic	**Chionophobic**
'Amelia andreaeaicola'	*Lecanora polytropa*
Frutidella caesioatra	*Lecidea swartzioidea*
Lecanora leptacina	*Melanelia commixta*
Lecidella bullata	*Miriquidica leucophaea*
Miriquidica griseoatra	*Rhizocarpon 'colludens'*
Porpidia contraponenda	*Umbilicaria cylindrica*
Less-demanding	**Chiono-tolerant**
Rhizocarpon jemtlandicum	*Lepraria neglecta*
	Rhizocarpon geographicum
	Rhizocarpon lecanorinum

The inclusion of *Porpidia contraponenda* in the most chionophilic group is interesting as specimens assigned to this taxon are widespread in the Scottish Highlands and also occur at lower altitudes. However, the taxon is currently characterized by its distinctive chemistry (methyl 2'-*O*-methylmicrophyllinate) and as it shows considerable morphological variation (it was separated in the Creag Meagaidh transect into forms with 'innate' and 'sessile' apothecia - Table 5•2, Fig 5•7) it is possible that the snow-bed entity constitutes a distinct species.

Although the relevés from Creag Meagaidh could not be related to length of snow-lie, the inclusion of a relevé from a nearby rock unaffected by prolonged snow-lie does allow the lichens present to be roughly divided into chionophilic, chionophobic and impartial species.

The restriction of this community to the upper surfaces of large boulders is probably due to the increased stability and better drainage which this habitat provides over smaller rocks. A further factor is that the tops of the larger rocks will become free of snow earlier in the year than smaller ones, thus increasing the length of the growing season for the lichens growing upon them. In addition, Fashelt *et al.* (1988) showed that the temperature of the upper surface of large boulders near a glacier were between 2C (overcast) and 8C (sunny) warmer than air temperature and between 0•4C (overcast) and 2C (sunny) warmer than the upper surfaces of small rocks. Apart from the direct effect of this higher temperature on the lichen community, the increase in temperature described by Fashelt *et al.* will cause the snow around the larger rocks to melt sooner (Fig. 5•24) increasing their growing season even further.

Figure 5•24. Rock in area of prolonged snow-lie - Beinn Dearg - supporting *'Amelia andreaeaicola'* and *Lecidella bullata* on its upper surface and with evidence of increased melting around it.

If this were an important factor affecting the distribution of snow-bed lichens then it would be expected that snow-bed species typical of this habitat would occur further out from the snow-bed than other species. There is some evidence that this does occur with *'Amelia andreaeaicola'*, *Lecidella bullata* and *Rhizocarpon jemtlandicum* being recorded up to 45m from the snow bed on Ciste Mhearad (Table 5•7), which is well into the *Nardus stricta* grassland (Table 5•3). As it is probably the coldness of the environment and the short growing season that restricts these species to areas of prolonged snow-lie it appears unlikely that increased temperature and growing season are responsible for their restriction to this particular habitat. However, it may be that other factors are involved in restricting these species to areas of prolonged snow-lie.

It is interesting to note in this respect that lichens on the sides of the boulders supporting this assemblage in the areas of intermediate areas snow-bed vegetation are often species with no special affinity with areas of prolonged snow-lie, e.g. *Rhizocarpon geographicum, R. lavatum* (Fig. 5•20, Table 5•7). As these will be covered with snow for considerably longer than the upper surface it suggests that a combination of protection from the harshness of the environment by winter snow-cover, the freer-draining conditions and the increased warmth during the summer growing season, which will also be longer, are responsible for the position of this, the most distinctive and exclusively chionophilic lichen community. It could be predicted from the above discussion that in less oceanic areas, which are drier and where winter snow-lie is more general, the conditions which favour these species would be more generally available and these species would not be restricted to areas of prolonged snow-lie but would be more generally distributed throughout the montane areas. From the limited information available (Wirth 1972, Creveld 1981, Foucard 1990, Santesson 1993) this would appear to be the case, as none of these authors associates these species with areas of prolonged snow-lie. It is also to be expected that some species with a widespread montane distribution in the Cairngorms will become restricted to the tops of large rocks in areas of prolonged snow-lie further west. Unfortunately, this habitat was not studied in detail at the western sites visited and so this must remain a matter of conjecture.

The lichens on the sides of large rocks in the inner areas of the snow-bed vegetation have more in common with the communities on smaller rocks as they occupy a much damper environment with longer snow-cover. The species most characteristic of this habitat, e.g. *Frutidella caesioatra, Lepraria* spp. (*L. caesioalba* group), *Porpidia contraponenda* and *Stereocaulon tornense* also frequently occur on either soil or small pebbles.

ii) small rocks and pebbles -

Small rocks and pebbles embedded in soil occupy an intermediate position, with respect to dampness, between the water-logged soil and the more freer drained upper surfaces of the larger boulders. The assemblage of lichens which occurs on them has some similarities with the terricolous community dominated by micro-lichens described above as many of the pebbles are covered by bryophytes and these support many of the species which also occur on soil, e.g. *Lepraria borealis, Micarea turfosa.* However, it is most similar to the assemblage of lichens which occurs on the damp sides of the larger boulders.

The most characteristic species of this assemblage is *Stereocaulon tornense* which is more or less restricted to this habitat throughout much of its range in the British Isles. *Micarea paratropa* is also often present, but as it is completely absent from the Cairngorms it appears to be more strictly a species of damp oceanic montane rocks. Also often present is *Micarea marginata* the anamorph of which has a scattered distribution in Scotland, including damp montane heaths. However, all the records from areas of prolonged snow-lie have abundant apothecia which is a very rare occurrence elsewhere. Among the other lichens usually present are a number of species which, although occurring in other habitats at lower altitudes, are usually restricted to areas of prolonged snow-lie when they occur at high altitude. These are most frequently species which occupy damp conditions, e.g. *Ionaspis odora, Trapelia obtegens, Verrucaria margacea* and are unable to withstand the dry conditions which prevail in the majority of montane situations, although *I. odora* is occasionally to be found in exposed conditions in oceanic regions and can be quite frequent on the Cambrian Quartzite of the N-W Highlands (e.g. Beinn Eighe in West Ross and Conival in West Sutherland). These species are marked with an asterisk in Table 5•11.

The TWINSPAN analysis of the relevés from Creag Meagaidh, where this community reaches its best development, makes its first division between relevés 9 & 10. Although the characteristic species of the community extend further out from the snow-bed, this is the area at which vascular plants become an important component of the vegetation and where rocks become correspondingly less significant and the vegetation they support less extensive.

The assemblage is well-represented around the Creag Meagaidh and Aonach Mór snow-beds but is less abundant at Ciste Mhearad and Beinn Dearg. However, it is not restricted to areas of prolonged snow-lie and is frequently present on small rocks and pebbles in damp, oceanic montane heaths as well as in damp coires throughout the Scottish Highlands. It is, for example, the dominant community on the summit of Carnedd Llewelyn in North Wales and in the north-facing coire of Glas Maol in South Aberdeenshire. At the latter site *Stereocaulon tornense* is replaced by the closely related, *S. plicatile*, which possibly occupies somewhat drier habitats than *S. tornense* (Fryday & Coppins 1996b). All specimens seen on Carnedd Llewelyn unfortunately lacked apothecia and so it was not possible to ascertain which species was present with complete certainty. Although the specimens had the general appearance of *S. tornense, S. plicatile* was recorded from the nearby Crib Goch in a somewhat drier situation (Fryday 1996b). Also abundant at both these two sites is *Rhizocarpon anaperum*, a species which also occurs on disused heavy-metal mine spoil in mid-Wales. There it enters a distinctive assemblage of crustose lichens of which *Stereocaulon leucophaeopsis*, also closely related to *S. tornense*, is a prominent member suggesting that this community is also related to that present in the vicinity of areas of prolonged snow-lie. The common factor linking all these habitats is low nutrient availability and a high degree of humidity.

This community still requires much attention; in particular its range and variation are poorly understood. However, a preliminary classification of the species involved is given in Table 5•11. Species are assigned to a fidelity grade with respect to the overall montane vegetation so that those species which are widespread in areas outside the montane zone but are confined to this community within it are assigned to Fidelity 4 & 5.

Table 5-11. Lichens characteristic of small stones and pebbles in the vicinity of areas of prolonged snow-lie.

Fidelity 5	**Fidelity 3**
Micarea marginata (fertile)	*Frutidella caesioatra*
Micarea paratropa	*Lecidella carpathica* *
Rhizocarpon cinereonigrum	*Porpidia contraponenda*
Stereocaulon tornense	*Protothelenella corrosa*
Trapelia obtegens *	*Rhizocarpon anaperum**
Verrucaria margacea *	*Rhizoarpon lavatum*
	Rhizocarpon 'sublavatum'
Fidelity 4	*Trapelia mooreana* *
*Ionaspis odora**	
Stereocaulon plicatile	**Fidelity 2**
	Cecidonia xenophana
	Lecidea pycnocarpa
	Rhizocarpon 'colludens subsp. *rufoatrum'*

* species which although occurring in other habitats at lower altitudes are more or less restricted to this community in the montane zone.

5•5 CONCLUSIONS

Three lichen-dominated communities, two saxicolous and one terricolous, are recognised as being associated with areas of prolonged snow-lie in the British Isles, although only one is exclusive to this habitat:-

1) Saxicolous; on upper surfaces of large boulders. Strictly confined to areas of prolonged snow-lie.
2) Saxicolous; on small pebbles, occasionally on larger rocks and then usually on the sides. Not confined to areas of prolonged snow-lie, more widespread in oceanic areas. A similar community occurs on metal-rich rocks with *S. tornense* replaced by *S. leucophaeopsis*.
3) Terricolous; associated with *Salix herbacea* and in gaps in *Nardus stricta* grassland. Better developed and more widespread in montane heaths further west. Probably related to the community which occurs in *Juncus trifidus* heath in the Cairngorms which is dominated by *Catillaria contristans, Lecidea limosa* and *Lecidoma demissum* and is possibly a sub-community of NVC U9 *Juncus trifidus-Racomitrium lanuginosum* rush heath.

The affinities of these communities to each other, as well as to montane communities in general, are unclear. The range and variability of these communities are also in need of further attention. Extensive field-work over a large area, sampling the full-range of saxicolous habitats is required to clarify these relationships.

There is little evidence that these communities occur outside the British Isles, although information from other oceanic areas is very fragmentary. Creveld (1981) makes no mention of anything resembling these communities in her section on chionophilic communities and Santesson (1993), although mentioning many of the individual species involved, makes no reference to their occurring near areas of prolonged snow-lie. Perhaps the best evidence of their occurrence elsewhere is the record of *'Amelia andreaeaicola'* from British Columbia (specimen in E), a species which has not been recorded from Scandinavia. If these chionophilic communities are restricted to the Scottish Highlands then this further emphasises the importance and uniqueness of the vegetation of the oceanic mountains of the British Isles, indicating that their vegetation must be considered in its own right rather than as a southern outlier of that of the Scandinavia mountains.

CHAPTER 6

EFFECTS OF GRAZING ANIMALS ON THE MONTANE LICHEN VEGETATION.

6•1 Introduction

6•2 Methods

6•3 Sites Visited
6•3•1 Moor House NNR
6•3•2 Snowdon NNR
6•3•3 Inchnadamph NNR
6•3•4 Ben Lawers NNR
6•3•5 Beinn Eighe NNR

6•4 Disscussion
6•4•1 Methods
6•4•2 Results

6•5 Conclusion

6•1 INTRODUCTION

It has long been known that grazing animals have a considerable effect on the terricolous lichen vegetation in boreal/Arctic regions, reindeer relying heavily on them for food, particularly in winter. Left uncontrolled, the effects of overgrazing can be devastating on the lichen vegetation. Mardon (1987) described the situation at Dvorefjell National Park, Norway where the natural east-west migration of reindeer was interrupted by the construction of a railway and a road in 1921. At this time the reindeer population was low (c. 1500 animals) and little damage resulted but the cessation of hunting during the war resulted in a population explosion to not less than 15,000 beasts, an increase which went unchecked until 1956 when the population crashed. Today, with the reindeer population back to near its pre-war level, significant recovery is taking place in the lichen heath but the differences between the two sides of the valley are still easily discernible (Figs 6•1 & 6•2). Thompson *et al.* (1987) consider that over-grazing by sheep and deer is one of the main threats to montane vegetation. It has been recognized as causing considerable damage to *Racomitrium lanuginosum* heaths in the English Lake District and Wales but the effects on montane lichen vegetation are less well studied, although these are likely to be less widespread as most grazing animals leave the higher altitudes in winter when lichens are their main source of food. However, sheep have been observed browsing the thalli of *Sphaerophorus globosus* from the tops of boulders, and in other cases there is assumed evidence of damage (Fryday 1991d).

The main effects of over-grazing on upland vegetation have been outlined by Thompson & ~~Ratcliffe~~ Brown (1992). These are:-

a) removes primary production and woody vegetation

b) local nutrient enhancement from urine and dunging

c) trampling may maintain diversity of species-rich types

d) peat-erosion increased by deer

e) locally associated with large-patch burning extending from upper fringes of sub-montane *Calluna* heaths

f) may be accompanied by local large-patch burning of woody species

Figure 6•1. Effects of over-grazing by reindeer at Dvorefjell National Park, Norway. East side of valley which has never been overgrazed.

Figure 6•2. Effects of over-grazing by reindeer at Dvorefjell National Park, Norway. West side of valley which was overgrazed until 30 years ago.

The principal grazing animal in the Scottish Highlands is the Red Deer although in some areas (e.g. Ben Lawers) sheep are also numerous. Sheep are also the main grazing animal in other montane areas of the British Isles. Smaller mammals may also damage the vegetation (e.g. rabbits, voles) but the effects of these are negligible unless the larger animals are removed. The main cause of damage is the actual grazing of the plants but the secondary effects of trampling and eutrophication due to urination and defecation by the animals will also have an effect; no attempt was been made to separate these effects in this study.

In the present study the effects of grazing were assessed by comparing the vegetation inside exclosures with that in the immediately vicinity. Unfortunately, the only long-established exclosures in Scotland are at a relatively low altitude (500-600m) and at these elevations the prevention of grazing leads to a dominance by vascular plants. Only those on the Inchnadamph NNR in Sutherland can be considered in any sense 'montane' as, although they are situated at only 250m altitude, they are far enough north and west to be in the sub-montane zone characterized by dwarf willows. However, the presence of the typical subspecies of *Empetrum nigrum* indicates that the vegetation is not 'montane'. Outwith Scotland there is an excellently positioned exclosure in Snowdonia (900m) which, unfortunately, has not been properly maintained, and several at Moor House NNR in the northern Pennines. Nowhere are there any exclosures erected primarily to investigate changes in the lichen vegetation and very few are sited on potentially lichen-rich areas.

6•2 METHODS

Exclosures at Moor House, Inchnadamph and Snowdon were visited and the vegetation inside the exclosure compared to that outside. In addition, a newly erected exclosure on Ben Lawers was sampled for future reference and the permanent quadrats on the *Nephroma arcticum* colony on Beinn Eighe were also briefly inspected.

4x4m relevés were selected at a subjectively determined, representative area within each exclosure and from a comparable area outside. All species of vascular plants, bryophytes and lichens were recorded and assigned a value on the Domin scale, except for saxicolous lichens which were given a value on the DAFOR scale.

The total lichen vegetation was then removed from a 20x20cm area of the densest lichen cover in each relevé for bio-mass determination. Each sample was cleaned of all soil and other vegetative matter, air-dried and then weighed. The lichen bio-mass in each relevé was then obtained by multiplying this figure by 400, to give a theoretical value for 100% lichen cover, and then multiplying this value by the percentage lichen cover. The increase in lichen bio-mass inside each exclosure was then calculated by dividing the bio-mass from the relevé inside the exclosure by that from the relevé outside.

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

6•3 SITES VISITED

6•3•1 Moor House NNR

Introduction

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

Most of the exclosures surveyed were in the vicinity of Great Dun Fell (Fig. 6•3) and were visited in May 1993. These are listed in Table 6•1. A further series of exclosures are located, at a somewhat lower altitude, around the main house. These are, in general, situated in areas with a poor, or non-existent, lichen vegetation (*Festuca* and *Nardus* grassland, *Calluna* heath etc.) and, consequently, are of little relevance to the present project. However, two are located on limestone and these do support a considerable lichen growth. These were visited in May 1994 and are also listed in Table 6•1. Two of the four exclosures on *Calluna* heath on the lower slopes of Hard Hill (D35-8) were also visited but lichen growth was so scarce both inside and outside the exclosures that sampling would have been of little value. A visual inspection of these exclosures indicated very little change in the vegetation inside the exclosure and it is assumed that this is because grazing on *Calluna* heath is very low. Two other exclosures near the River Tees (D20, D53) were also visited but not sampled as they did not contain any lichens. These were on *Festuca*- and *Nardus*-dominated grasslands. Lichens were also almost totally absent from the vicinity of these exclosures.

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

Figure 6•3. Large exclosure on Little Dun Fell, Moor House NNR showing the effects on the vegetation of the removal of grazing animals.

Methods

4x4m quadrats were used throughout. Soil samples were not taken from the lower altitude exclosures visited in 1994.

Results

The results obtained from the quadrats at Moor House are given in Tables 6•2 – 6•4.

Table 6•1. Relevés at Moor House NNR

	Site	Habitat	Grid Ref.	Altitude
1993				
Q1	Little Dun Fell (D43, inside)	Acid grassland	35/705,331	840 m
Q2	Little Dun Fell (D43, D42, outside)	"	35/705,331	840 m
Q3	Little Dun Fell (D42, inside)	"	35/705,331	840 m
Q4	Knock Fell (D14, inside)	Limestone grassland	35/718,313	745 m
Q5	Knock Fell (D14, outside)	"	35/718,313	745 m
Q6	Trout Beck Head (D31, inside)	Blanket Bog	35/722,318	685 m
Q7	Trout Beck Head (D31, outside)	"	35/722,318	685 m
Q8	Silverband (D13, inside)	"	35/711,310	685 m
Q9	Silverband (D13, outside)	"	35/711,310	685 m
Q10	Hard Hill (D40, inside)	Lichen-rich heath	35/725,332	685 m
Q11	Hard Hill (D40, outside)	"	35/725,332	685 m
1994				
Q12	Tree Exclosure (D16, inside)	Limestone grassland	35/757,330	550 m
Q13	Tree Exclosure (D16, outside)	"	35/ 757,330	550 m
Q14	Limestone Gorge (D19, inside)	"	35/ 756,328	550 m
Q15	Limestone Gorge (D19, outside)	"	35/ 756,328	550 m

Numbers of the exclosures (e.g. D43, D 14) are those used by Rawes *et al.* 1981, 1983.

Table 6•2 Species recorded from relevés at Moor House NNR.

Relevé (Quadrat)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Total Cover (%)	80	80	98	100	99	100	95	90	70	100	90	100	100	100	100
Rock (%)	20	20	2	0	1	0	0	0	0	0	10	0	0	0	0
Peat (%)	0	0	0	0	0	0	5	10	30	0	0	0	0	0	0
Lichen Cover (%)	20	5	2	1	1	1	<1	3	1	40	10	70	<1	40	2
Hight of Vegetation (cm)	8	2	12	15	2	17	5	12	6	25	2	1•5	3	4	2
Vascular Plants															
Equisetum ?arvense	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Selaginella selaginoides	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Achillea millefolium	.	.	.	3	.	.	.	.	.	.	.	.	.	1	2
Anemone nemorosa	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.
Calluna vulgaris	.	.	.	.	.	4	2	.	.	.	.	.	.	.	.
Campanula rotundifolia	.	.	.	.	3	.	.	.	.	.	.	.	.	.	1
Cardamine pratensis	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.
Cerastium fontanum															
ssp. holosteoides	.	.	.	.	1	.	.	.	.	.	.	.	2	.	1
Cirsium palustre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
C. ?vulgare	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Cochlearia ?pyrenaica	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.

Empetrum nigrum	.	.	.	.	.	4	2	5	1	2	.	.	.	.	.
Euphrasia officinalis aggr.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
Galium saxatile	.	3	1	2	2	.	.	.	.	4	4	3	4	4	4
G. sterneri	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Minuartia verna	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
Oxalis acetosella	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Potentilla erecta	.	.	.	2	.	.	.	.	.	.	.	.	.	1	.
Ranunculus acris	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.
Rubus chamaemorus	.	.	.	.	.	3	1	3	1	.	.	.	.	.	.
Rumex acetosa	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.
Thymus polytrichus	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
Trifolium repens	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Vaccinium myrtillus	5	4	3	3	4	3	.	4	1	4	3	1	.	1	.
V. vitis-idaea	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.
Viola lutea	.	.	.	.	2	.	.	.	.	.	.	.	.	1	.
V. riviniana	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.
Agrostis capillaris	.	2	.	4	5	.	.	.	.	.	.	4	5	4	3
Anthoxanthum odoratum	.	.	.	.	.	.	.	.	.	.	.	2	1	.	1
Carex bigelowii	4	1	8	3	.	.	.	.	.	.	.	.	.	.	.
C. caryophyllea	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
C. nigra	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.

C. pilulifera	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Danthonia decumbens	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Deschampsia cespitosa	.	.	.	4	1	.	.	.	.	.	.	.	2	.	.
D. flexuosa	8	1	8	2	.	5	5	.	.	.	2	.	.	.	.g
Eriophorum angustifolium	.	.	.	.	.	3	3	3	3	.	.	.	.	.	.
E. vaginatum	.	.	.	.	.	8	9	7	8	.	.	.	.	.	.
Festuca rubra	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
F. ovina	3	9	.	8	8	.	.	.	.	.	7	9	8	8	10
Juncus squarrosus	.	.	.	.	.	.	.	.	.	.	4	.	.	1	.
Luzula campestris	.	.	.	.	3	.	.	.	.	.	.	4	3	.	2
Nardus stricta	.	.	.	.	.	.	.	.	.	.	4	.	.	1	2
Narthecium ossifragum	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.
Trichophorum cespitosum	.	.	.	.	.	.	1	3	1	.	.	.	.	.	.
Mosses															
Aulacomnium palustre	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Campylopus ?atrovirens	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.
C. paradoxus	1	.	.	.	.	2	.	1	3	.	.	.	.	.	.
Ctenidium molluscum	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Dicranum scoparium	3	4	4	1	.	1	1	.	1	.	.	.	1	1	2
Fissidens taxifolius	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Hylocomium splendens	.	.	.	.	.	.	.	.	.	.	.	3	3	.	.
Hypnum cupressiforme	.	.	.	2	1	.	.	.	.	.	1	.	.	.	3

Mnium hornum	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
Pleurozium schreberi	.	.	2	2	.	.	.	.	.	4	2	1	1	5	4
Pohlia nutans	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Polytrichum alpinum	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.
P. alpestre	3	2	2	.	1	.	.	.	.	.	.	.	.	.	.
P. commune	.	.	2	.	.	.	.	.	.	2	.	.	1	4	4
P. formosum	.	2	.	.	1	.	1	.	.	.	.	.	.	.	.
P. piluliferum	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Racomitrium lanuginosum	1	1	.	.	1	.	.	.	.	.	1	.	.	.	.
Rhytidiadelphus squarrosus	.	.	.	2	1	.	.	.	.	1	1	2	4	.	.
Tortella tortuosa	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Liverworts															
Barbilophozia floerkei	.	.	.	1	1	.	.	.	.	.	.	2	.	3	2
Calypogeia azurea	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
C. fissa	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.
Cephaloziella sp.	1	1	.	.	.	1	.	.	.	.	.	.	.	.	.
Diplophyllum albicans	.	.	.	.	1	2	1	1	1	.	.	.	.	.	.
Frullania tamarisci	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Lophocolea bidentata	.	.	.	.	2	.	.	.	1	.	.	.	.	1	.
Lophozia ventricosa	.	1	1	1	.	3	.	1	.	.	.	.	.	.	.
Mylia taylorii	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.

Ptilidium ciliare	1	1	2	1	.	.	.	.	.	.	.	.	.	.	1
Terricolous Lichens																
Baeomyces rufus	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Cetraria aculeata *	1	1	.	.	1	.	.	2	.	.	3	2	.	1	.
C. islandica	5	1	2	.	.	.	.	1	.	.	.	2	1	4	1
Cladonia arbuscula	1	.	.	.	.	.	.	1	.	2	1	1	.	.	.
C. bellidflora	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.
C. chlorophaea	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
C. ciliata	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
v. tenuis	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.
C. diversa	1	2	.	.	2	.	1	3	2	.	1	.	.	.	.
C. floerkeana	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
C. furcata	2	1	1	.	1	.	1	.	1	3	1	1	.	2	1
C. pocillum	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
C. portentosa	2	1	1	1	1	1	.	2	.	5	4	8	1	5	1
C. pyxidata	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
C. uncialis	2	1	1	.	1	1		1	.	.	2	.	.	.	2
Micarea cinerea	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
M. lignaria	1	1	.	.	1	.	.	1	.	.	.	.	.	.	.
Ochrolechia frigida	.	1	.	.	.	.	.	1	.	.	1	.	.	.	.
Omphalina ericetorum	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.
O. hudsoniana	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.

Peltigera membranacea	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Placynthiella uliginosa	.	1	.	.	1	.	.	.	.	.	.	.	.	.	1
Thelocarpon epibolum	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Trapeliopsis gelatinosa	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
T. granulosa	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.
Saxicolous Lichens															
Baeomyces rufus	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Clauzadea monticola	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Fuscida cyathoides	.	R	.	.	.	.	.	.	.	.	R	.	.	.	.
F. kochiana	D	D	D	.	.	.	.	.	.	.	D	.	.	.	.
Gyalecta jenensis	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Lecanora intricata	R	R	R	.	.	.	.	.	.	.	R	.	.	.	.
L. soralifera	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lecidea lithophila	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.
L. plana	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
L. pycnocarpa	R	R	R	.	.	.	.	.	.	.	.	.	.	.	.
Micarea coppinsii	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.
Ochrolechia androgyna	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Opegrapha saxatilis aggr.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Parmelia saxatilis	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Parmeliopsis ambigua	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.
Pertusaria aspergilla	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.

Porpidia crustulata	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. macrocarpa aggr.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. tuberculosa	O	O	.	.	R	.	.	.	.	.	R	.	.	.	.
Protoblastenia rupestris	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Rhizocarpon geographicum	R	R	R	.	.	.	.	.	.	.	.	.	.	.	.
R. lecanorinum	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
R. obscuratum aggr.	R	O	.	.	.	.	.	.	.	.	.	.	.	.	.
R. umbilicatum	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Rimularia furvella	O	O	O	.	.	.	.	.	.	.	.	.	.	.	.
Tephromela aglaea	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Toninia aromatica	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Trapelia involuta	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Trapeliopsis granulosa	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Verrucaria hochstetteri	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.

*syn. *Coelocaulon aculeatum*

Table 6•3. Lichen bio-mass increase inside exclosures at Moor House NNR.

Relevé	Air-dry Lichen Bio-mass (g)	% Cover	Lichen Bio-mass in Relevé (g)	Relative Increase in Lichen Bio-mass
Q1	27•76	20	2220•8	x118•0
Q2	0•94	5	18•8	
Q3	45•32	2	362•6	x19•3
Q4	46•87	1	187•5	x11•0
Q5	4•27	1	17•1	
Q6	14•84	1	59•4	x>45•0
Q7	0•33	<1	<1•32	
Q8	10•89	3	130•7	x10•57
Q9	3•09	1	12•4	
Q10	37•43	40	5988•8	x20•48
Q11	7•31	10	292•4	
Q12	36•96	70	10348•8	x>21560•0
Q13	0•12	<1	<•48	
Q14	39•95	40	3692•0	
Q15	0•79	2	6•32	x1012•0

Table 6-4. pH values for quadrats investigated at Moor House NNR.

Relevé	depth (mm)	discription	pH
Q1	0	litter	4.6
	5	peat	4.3
Q2	0	litter	4.4
	5	peat	3.8
Q3	0	litter	4.6
Q4	0	necrohyphal mat	4.5
	5	litter	4.8
	10	dark, rich mineral soil	5.0
	50-60	mineral soil with good crumb structure	4.8
Q5	0	*Peltigera* sp.	5.7
	0	litter	5.5
	5	mineral soil plus humus	5.0
	10	dark, rich mineral soil	4.6
	50-60	mineral soil with good crumb structure	4.9
Q6	0-5	brown soil with poor crumb structure	3.2
	60-70	dark peat	3.5
Q7	0-5	brown soil with poor crumb structure	3.4
	60-70	dark peat	3.3
Q8	0-5	brown soil with poor crumb structure	3.5
	60-70	dark peat with roots	3.4
Q9	0-5	brown soil with poor crumb structure	3.1
	60-70	dark peat	3.3
Q10	0-5	well-structured peat with sandy grains	3.4
Q11	0	litter plus humus	4.2

6•3•2 Snowdon

Introduction

The high level exclosure on Snowdon is at an altitude of 850m immediately to the south of the low point of the ridge (bwlch) at the western end of Crib Goch (GR 23/621,551). It is on steeply sloping ground (30°) which is approximately two-thirds covered with short grasses - the other third being bare soil with small, unstable pebble scree (Figs 6•4 & 6•5).

Figure 6•4. Crib Goch (Snowdon) from the south (Llyn Glas). The exclosure is on the green patch below the lowest point of the sky-line.

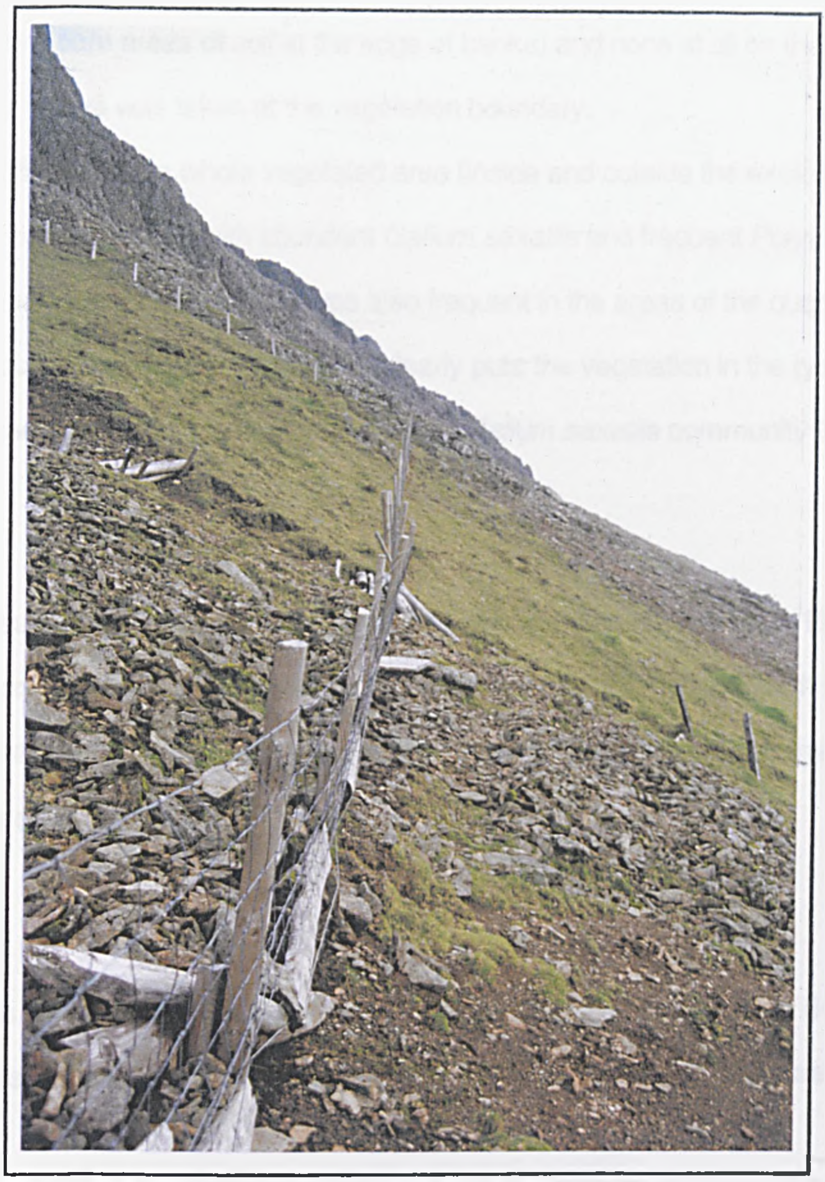


Figure 6•5. The exclosure on Crib Goch (Snowdon).

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

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

The vegetation over the whole vegetated area (inside and outside the exclosure) is dominated by coarse grasses with abundant *Galium saxatile* and frequent *Polytrichum commune*. *Racomitrium lanuginosum* was also frequent in the areas of the quadrats although it was almost totally absent elsewhere. This clearly puts the vegetation in the typical sub-community of the *Festuca ovina-Agrostis capillaris-Galium saxatile* community (NVC U4).

Methods

The exclosures have been fully surveyed and reported recently (Hill *et al.* 1992) and, consequently, only enough vascular plant information was recorded to establish the NVC communities present. As usual terricolous lichens were assigned a value on the Domin scale and saxicolous ones on the DAFOR scale.

Results

The results obtained from the exclosure on Crib Goch are given in Tables 6•5 & 6•6. The soil both inside and outside the exclosure was thin (5mm), but well structured and had a pH of 4.3.

Other Exclosures

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

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

Table 6•5. Lichens Recorded from Quadrats on Crib Goch, Snowdon.

	Q(inside)	**Q(outside)**
Vegetation Cover (%)	90	90
Lichen cover (%)	2	2
Pebbles/Soil (%)	10	10
Vegetation Height (cm.)	2	2
Terricolous		
Baeomyces placophyllus	1	.
B. rufus	.	1
Cladonia bellidiflora	.	1
C. diversa	1	.
C. floerkeana	1	.
C. furcata	1	.
C. macilenta	1	2
C. subcervicornis	3	3
C. uncialis	2	2
Dibaeis baeomyces	2	3
Micarea leprosula	.	2
M. lignaria	1	.
Stereocaulon condensatum	2	.
Trapeliopsis granulosa	1	1
Saxicolous		
Lecidea lithophila	O	.
Porpidia cinereoatra	O	O
P. crustulata	O	O
P. macrocarpa	F	O
P. tuberculosa	F	F
Rhizocarpon oederi	R	.
Rimularia furvella	.	R
Schaereria fuscocinerea	R	.
Stereocaulon plicatile	F	F
Trapelia placodiodes	R	.

Table 6•6. Increase in Bio-mass inside exclosure on Crib Goch, Snowdon.

	Lichen Bio-mass (g)	% Cover	Lichen Bio-mass in Quadrat (g)	Relative Increase in Lichen Bio-mass
Outside Exclosure	1•81	2•0	14•48	
Inside Exclosure	3•37	2•0	26•96	1•86 (86.2%)

6•3•3 Inchnadamph

Introduction

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

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

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

Methods

Due to the irregular nature of the vegetation inside the exclosures 2x2m quadrats were used here. Only one soil sample was collected.

Results

The data obtained from Inchnadamph are given in Tables 6•7 & 6•8.

pH - outside exclosure (Q3) = **5•3**

Table 6-7. Species recorded from relevés at Inchnadamph NNR

Relevé	Inside Exc. 1		Outside	Inside Exc. 2
	Q1	Q2	Q3	Q4
Cover (%)	100	100	-	-
Lichen Cover (%)	15	8	<1	20
Height of vegetation (cm)	20	15	15	25
Vascular Plants				
Calluna vulgaris	10	8	x	8
Carex binervis	3	2	.	
Empetrum nigrum subsp. nigrum	.	.	.	2
Erica cinerea	2	.	.	
E. tetralix	4	3	x	3
Eriophorum vaginatum	3	5	x	6
Juncus squarrosus	.	3	x	
Molinia caerulea	2	.	x	2
Nardus stricta	5	.	x	
Narthecium ossifragum	.	.	.	1
Pinguicula vulgaris	.	1	.	
Potentilla erecta	3	3	x	3
Trichophorum cespitosum	.	4	x	
Vaccinium myrtillus	.	.	x	
Bryophytes				
Mylia taylorii	1	.	.	
Racomitrium lanuginosum	.	2	.	6
Rhytidiadelphus loreus	.	.	2	
Sphagnum sp.	9	7	5	3
'liverwort'	3	.	.	1
'moss'	.	.	4	
Lichens				
Cladonia arbuscula	2	.	.	.
C. ciliata var. tenuis	2	.	.	1
C. coccifera aggr.	1	.	.	.
C. crispata	1	.	.	.
C. furcata	.	.	1	.

C. squamosa	.	.	1	.
C. portentosa	5	4	2	5
C. uncialis	4	2	.	1
Micarea lignaria	.	1	.	.

Notes:

1) Large raised hummocks of *Sphagnum* with clumps of *C. portentosa* and, less often, *C. ciliata* and *C. uncialis* form a continuous carpet under the *Calluna vulgaris* canopy. *Listera cordata* c. 2cm outside this quadrat.
2) No Domin scores for vascular plants for this quadrat.
3) Large clumps absent. Lichens strongly associated with bryophyte hummocks.

Table 6•8. Bio-mass results from Inchnadamph NNR.

Relevé	**Lichen Bio-mass (g)**	**% Cover**	**Lichen Bio-mass in Relevé (g)**	**Relative Increase in Bio-mass**
Q1	23•7	15	355•5	175•1
Q2	44•69	8	357•5	176•1
Q3	2•03	<1	<2.03	

6•3•4 Ben Lawers NNR

Introduction

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

Of the four exclosures, two are on Creag an Lochain (E1 & 2) and have been in position since 1987, one is on the south side of the bealach between Meall Garbh and Meall Greigh and was erected in 1989 (E3) and one encloses a large area of the Edramucky Burn and was erected in 1990 (E4). In addition two 1m exclosure cages have been in position below Creag Loisgte since 1987 for monitoring *Gentiana nivalis*, although these are no longer in position.

The two exclosures on Creag an Lochain, although the longest established, are at a relatively low altitude (550m) and dominated by higher plants. As no terricolous lichens were present either inside or outside these exclosures, they were not sampled. Similarly, the *G. nivalis* cages, although at over 1000m, contained no lichens so were not sampled.

The Meall Garbh-Meall Greigh exclosure was not visited due to lack of time, adverse weather conditions and its remote location. It was also considered unlikely that it would yield any useful data (D. Mardon, pers. comm.).

The Edramucky Burn exclosure although at only 625m at its highest point did contain areas of significant terricolous lichen growth. Consequently, although it had been in position for only 3 years, it was sampled (at its highest point) as a reference point to monitor future changes of reduced grazing pressure.

Edramucky Burn (Exclosure 4)

The soil in much of the exclosure, including the area selected for sampling, was rather damp; consequently terricolous lichens were restricted to banks, where drainage was better, or were associated with low boulders. A 4m x 4m quadrat (Q1) was taken near the northern end of the exclosure (27/612,392) plus one just outside the boundary fence (Q2). It was difficult to find directly comparable areas as lichen growth was fragmentary and the area inside the exclosure, associated with a boulder mostly submerged in the soil, was much damper than that outside, associated with a dry bank.

Methods

The quadrat inside the exclosure was situated 4m in from the western boundary fence with its southern edge level with the fifth supported fence post.

A thallus of *Sphaerophorus globosus* approximately 8 cm diameter on top of a low boulder showed signs of heavy grazing (Fig 6•6). This was photographed as a base-point to assess future regeneration. This boulder was situated approximately 10 m east of the quadrat on the edge of the bank of a small burn.

Figure 6•6. Grazed thallus of *Sphaerophorus globosus* from the Edramucky Burn exclosure on the Ben Lawers NNR.

Results

Data from the quadrats in the Edramucky Burn exclosure are given in Tables 6•9 & 6•10.

Table 6•9. pH of soil samples from quadrats on Ben Lawers.

Quadrat	**Depth**	**Description**	**pH**
Q1	0 mm	litter	4•0
	5-6 cm	litter plus peat	3•8
Q2	0 mm	litter	4•0
	5-6 cm	well structued peat with sandy grains	3•8

Table 6•10. Plants Recorded from Quadrats on Ben Lawers.

	Q1 (Inside)	**Q2 (Outside)**
Cover (%)	100	100
Height of vegetation (cm)	10-20 (*Calluna vulgaris*)	15-20 (*Festuca ovina*)
Lichen Cover (%)	10	3
Calluna vulgaris	4	4
Empetrum nigrum	5	.
Galium saxatile	2	2
Polygala vulgaris	3	.
Potentilla erecta	4	2
Vaccinium myrtillus	5	7
Festuca ovina	.	7
Juncus squarrosus	3	3
Luzula campestris	.	1
Molinia caerulea	3	.
Nardus stricta	5	5
Trichophorum cespitosum	3	.
Dicranum scoparium	.	1
Pleurozium schreberi	4	4
Racomitrium lanuginosum	1	2
Rhytidiadelphus squarrosus	.	1
Sphagnum (small, red)	3	1
Sphagnum (large, green)	2	.
Cladonia arbuscula	1	.
C. diversa (C. coccifera aggr.)	1	.
C. furcata	1	1
C. portentosa	1	3
C. rangiferina	2	.
C. uncialis	2	2
Parmelia saxatilis	1	.
Trapeliopsis granulosa	.	1

6•3•5 Beinn Eighe NNR

Beinn Eighe in Wester Ross is composed mainly of Cambrian Quartzite and Torridonian Sandstone. Most of the high-ground is bare rock which supports a species-poor, largely unremarkable lichen vegetation. However, the rocks of the Moine Thrust are exposed on the very highest summits of Còinneach Mhór, Ruadh-stac Mór and Ruadh-stac Beag and here there is considerable base-enrichment from the fucoid-beds outcrops. These areas support a well vegetated grass-heath in stark contrast to the rest of the mountain (Fig. 6•7). The area of grass-heath on Ruadh-stac Beag is the principal locality in the British Isles for *Nephroma arcticum* and the only one where it has been seen in recent years.

Figure 6•7. Ruadh-stac Beag, Beinn Eighe from the north. The green area of the fucoid-bed outcrop contrasts strongly with the surrounding Cambrian quartzite.

The plants are poorly developed and apparently under a great deal of stress. Permanent quadrats were set up around the colonies in 1991 (Fig. 6•7)(Fryday 1991d) and although the site was revisited in 1994 only a casual assesment of the changes that had occurred was made (Fryday 1997).

The permanent quadrats are to be resurveyed in 1997, along with the rest of the colony, when small exclosure cages are also to be placed over some of the plants to assess the effects of a complete removal of grazing pressure on the plants.

The results of the 1994 visit, along with more details of the ecology of the site, are given in the Appendix.

Figure 6•8. The permanent quadrats on Ruadh-stac Beag, Beinn Eighe from the south.

6•4 DISCUSSION

6•4•1 Methods

The methods used for assessing the amount of damage caused by grazing are to some degree subjective. The placement of the quadrats on a 'representative' area of vegetation is liable to be biased in favour of lichen-rich areas and the assessment of percentage cover is susceptible to a considerable degree of error. However, these will be the same for both sets of quadrats (*eg.* inside and outside the exclosure) and so will be largely self-compensating.

6•4•2 Results

The overall results are so clear-cut that concerns with the objectivity of the methods are inconsequential. At Moor House there is a bio-mass increase inside the exclosures of more than 1000 fold at low altitude and between 10-20 fold at higher altitudes whereas at Inchnadamph the increase is around 170 fold. These figures are largely related to degree of montanicity, the low-level site at Moor House being upland in character whereas the high-level site and Inchnadamph are sub-montane. This is supported by the results from Snowdon, the only true montane site, which yielded merely a 1•86 fold increase; although taken in isolation even this increase (86•2%) is far from inconsequential. The increase at this site is also probably low because of the ineffective nature of the exclosure.

There is also a possible positive correlation between an increase in lichen bio-mass and lichen-rich vegetation, that is, there is a greater increase in lichen bio-mass inside exclosures on lichen-rich heaths. In the high-altitude exclosures at Moor House the increase in bio-mass is, to some extent, associated with the percentage lichen cover inside the exclosure (Table 6•3, Figs 6•9 & 6•10). This is to be expected as outside the exclosure the lichen vegetation will be grazed down to a similarly low figure whether it was originally lichen-rich or not. As none of the exclosures were specifically placed on lichen-rich vegetation this suggests that the results obtained are, if anything, under-estimates and further emphasize the need for exclosures erected specifically for lichen research.

Figure 6•9. Area of lichen-rich heath inside exclosure on Hard Hill, Moor House NNR.

Figure 6•10. Area immediately outside the exclosure pictured in Fig. 6•9, Hard Hill, Moorhouse NNR

The effects on species diversity are less clear. Many of the changes in species number and individual cover values are not significant, falling well within the range of chance occurrences and of the others sometimes there are more lichen species outside the exclosure but just as often there are more inside. Species diversity is, however, strongly correlated with the height of vegetation inside the exclosure; the lower the increase in the height of the vegetation inside the exclosure then the greater the increase in species diversity. At the first low level exclosure at Moor House (Q 12 &13) where the vegetation is lower inside the exclosure the lichen species diversity increases from 2 species to 5 whereas at the high level exclosures on Little Dun Fell where the height of the vegetation outside the exclosures is 2cm and that inside 8 & 12 the lichen species diversity falls from 12 outside to 9 & 5 respectively inside. These results are shown in Table 6•10.

Table 6•10. Relationship between increase in height of vegetation and lichen species diversity from exclosures on Little Dun Fell, Moor House NNR.

Inside/outside exclosure	Height of vegetation	Lichen species recorded
Outside	2	12
Inside (small exclosure)	8	9
Inside (large exclosure)	12	5

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

There are exceptions to this trend, most noticeably in the exclosures on blanket peat where the structure of the vegetation is very different and a closed sward is not formed inside the exclosure. Although the height of the vegetation increased significantly in both exclosures sampled, the lichen species diversity remained at the same low figure in one (although different species were involved) and increased dramatically (from 4 to 12) in the other.

Cetraria islandica and *Cladonia* subgenus *Cladina* spp. were the lichens most favourably affected by the reduction in grazing. Not only did their bio-mass and percentage cover increase but the plants were also much better formed, often occurring as large, rounded tussocks (Figs 6•11 & 6•12). The situation in the Snowdon exclosure was rather different with *Cetraria islandica* not occurring and only one thallus of *Cladonia arbuscula* of the subgenus *Cladina* being seen.. Here the main change in the vegetation was the appearance of *Stereocaulon condensatum* inside the exclosure, reflecting the montane, rather than sub-montane/upland, nature of this exclosure. It seems that this species appears in the succession from grazed to ungrazed areas, being absent from either extreme due to grazing pressure at one end of the continuum or competition from higher plants at the other. The other notable difference inside the exclosure is the increased number of *Cladonia* spp. which is significant with regards to the climax vegetation as these are usually the most numerous lichens in ungrazed grass-heaths. The most surprising aspect of the lichen vegetation at this site was the frequent presence on pebbles in the grass-heath of *Stereocaulon plicatile* which, although first collected from Cadair Idris in the last century, has recently been recorded only from the Scottish Highlands (Fryday & Coppins 1996b).

The data also show how grazing has a qualitative effect on the lichen vegetation in addition to the expected quantitative one. This is best shown from the relevés on limestone at Moor House, especially the high altitude one (Q4 & Q5) where the lichen vegetation inside the exclosures is very different from that outside; in fact it has much more in common with that inside the nearby exclosures on acidic grassland (Q1 & 3). This convergence is brought about by the lush growth of vascular plants and bryophytes which form a cushion 10-20cm thick which isolates the lichens from the limestone substratum. The surface of this cushion has a pH of 4•5 compared with the litter layer outside the exclosure with a pH of 5•5-5•7. Consequently, with reduced grazing, an acid layer builds up and the substratum becomes less of a factor in determining the composition of the lichen vegetation enabling normally calcifuge species (i.e. *Cetraria islandica, Cladonia* subgenus *Cladina* spp.) to grow over limestone.

Figure 6•11. Well-developed thallus of *Cetraria islandica*, Little Dun Fell, Moor House NNR.

Figure 6•12. Well-developed thallus of *Cladonia arbuscula*, Little Dun Fell, Moor House NNR.

This effect was also seen at Inchnadamph NNR (although it is not apparent in the data) where outside the exclosures limestone boulders and outcrops are prominent features whereas inside they are submerged beneath a luxuriant cover of predominately calcifuge species.

6•5 CONCLUSION

Although the evidence presented here for a detrimental effect of grazing animals on montane lichen vegetation appears convincing, much of it is circumstantial being an extrapolation from data obtained from upland/sub-montane situations. The limited information from the one truly montane area from which it was possible to obtain data suggests that grazing has less of an impact at higher altitudes but as these data were obtained from a lichen-poor heath, and the exclosure was not securely fenced, more direct evidence is required before reliable conclusions can be reached. In order to assess the effects of grazing on montane lichen vegetation exclosures are needed on areas of lichen-rich vegetation and the area most suitable for these would be the Cairngorms. The lichen-rich summit heath of Beinn a' Bhuird would be an ideal location for exclosures for general monitoring but a further possibility would be the Northern Spurs which are the main locality of the prostrate *Calluna vulgaris-Cladonia arbuscula* heath (NVC U13), one of which, Creagan Dubh, supports the only substantial colony of *Alectoria ochroleuca* in the British Isles (Fryday 1997). This species forms a major component of lichen-rich heaths in Scandinavia and the erection of exclosures or small exclosure cages over part of the colony would yield invaluable information, not only on the effects of grazing, but also on the status of this species in the British Isles.

The effects of grazing animals on montane lichen vegetation can be summarized as:-

a) Decrease in bio-mass, particularly of fruticose lichens.
b) Fragmentation of colonies so these are smaller and do not form luxuriant cushions.
c) Increase of crustose species due to lack of competition from vascular plants.
d) Increase in influence of the substratum due to destruction of deep vascular plant and

bryophyte layer.

e) Under certain circumstances there may be an increase in lichen diversity.

CHAPTER 7

CONCLUSIONS

7•1 Introduction

7•2 The Past

7•3 The Present

7•3•1 Taxonomy

7•3•2 Distribution and Ecology

7•3•3 Phytosociology

7•3•3•1 Terricolous Communities

7•3•3•2 Saxicolous Communities

7•3•4 Areas of Prolonged Snow-lie

7•3•5 Effects of Grazing Animals

7•4 The Future

7•1 INTRODUCTION

Lichens make a major contribution to the botanical bio-diversity of montane areas. To consider bio-diversity of montane vegetation and not include lichens is to seriously distort the true situation. More than 700 taxa have been recorded from the Scottish mountains - compared with 121 vascular plants (Ratcliffe 1991) - with 275 of these considered to be montane specialists.

7•2 THE PAST

Prior to 1982 there was very little recent published information concerning the montane lichen vegetation of Scotland. The Scottish mountains had been occasionally visited by lichenologists but although some of this work was published (James 1965) much of it remained undocumented or appeared only as unpublished reports (James 1976, Coppins 1978, 1979).

Modern work on Scottish montane lichens began with Dr Gilbert who, with various co-workers, visited Coire Cheap in the Ben Alder range (Gilbert, Fox & Purvis 1982), the Cairngorms (Gilbert & Fox 1985), N-W Sutherland (Gilbert & Fox 1986), Ben Lawers (Gilbert, Coppins & Fox 1988), Ben Nevis (Gilbert, Fryday, Giavarini & Coppins 1992) and Caenlochan (Gilbert & Coppins 1992), describing the lichen vegetation and making numerous ecological observations.

Dr Gilbert concentrated his limited time on the potentially most rewarding sites and it was then necessary to put this information into a context of the overall Scottish montane lichen vegetation. The present author joined Dr Gilbert on his last two surveys and subsequently undertook a more intensive investigation carrying out short-term surveys of Glen Coe, Kintail, Ardmeanach, Torridon, Knoydart, Southern Cairngorms, Sutherland and Creag Meagaidh.

7•3 THE PRESENT

The work to date has provided much descriptive ecological information but little quantitative data. The present research was an attempt to rectify this situation and had three main objectives

a) to investigate the lichen vegetation surrounding areas of prolonged snow-lie.

b) to add lichen data to the major montane National Vegetation Classification (NVC) communities (Rodwell 1991, 1992).

c) to assess the effects of grazing on montane lichen vegetation.

7•3•1 Taxonomy

It soon became clear that I was working with a developing taxonomy that needed to be stabilized before any meaningful ecological study could be attempted and that identification was often hindered due to the lack of suitable keys. Consequently, taxonomy and identification became a major part of the research. This has resulted in 24 known species being added to the British flora (including 4 species of *Lecidea* s. str. and 3 each of *Porpidia* and *Rhizocarpon*) and four others being rediscovered, these not having been recorded from the British Isles since, at least, 1960 and often not since the last century. It has proved impossible to identify a great number of other collections and approximately 50 of these are either frequent or distinctive enough for it to be sure that they represent undescribed taxa. These include 3 species of *Lecidea* s.str, 7 *Porpidia* spp. and 5 *Rhizocarpon* spp. Twenty of these undescribed taxa, including one completely new genus, are now well enough understood to be formally described (Fryday & Coppins 1996a & b, Fryday *in prep.*, Fryday & Coppins *in prep.*). *Lecidea, Porpidia* and *Rhizocarpon* are three of the most numerous and abundant lichen genera in montane areas and the discovery of a number of species either new to Britain or science (Table 7•1) has implications for the study of the botanical bio-diversity of montane eco-systems.

A number of keys to difficult genera have also been produced (i.e. *Lecidea, Porpidia* and *Rhizocarpon* (Fryday 1996a)) as well as a key to sterile crustose saxicolouse and terricolous species (Fryday & Coppins 1997). It is hoped that these will facilitate the identification of saxicolous lichens by both lichenologists and non-specialists and further promote the study of montane lichen vegetation.

Table 7•1. Species of *Lecidea* s. str., *Porpidia* and *Rhizocarpon* new to Britain or science.

Genus	Number new to Science	Britain	Total
Lecidea s. str.	3	4	7
Porpidia	7	3	10
Rhizocarpon	5	3	8

7•3•2 Distribution and Ecology

A comparison was made between the lichen vegetation of the western, oceanic mountains of the British Isles and those further east (i.e. the Cairngorms) with a more continental climate. It was shown that the lichen vegetation of the eastern mountains, although richer in terricolous species, was far poorer in saxicolous ones and that there were far more taxa with a western distribution than an eastern one. It was also shown that the majority of the undescribed taxa, most of which were saxicolous, were to be found in the oceanic mountains. This emphasises the importance of both saxicolous lichens, as a major contributor to botanical bio-diversity in the oceanic mountains, and of the oceanic lichen vegetation of the British Isles which has a number of apparently endemic species and possibly occurs only on the western side of the Scottish Highlands. This contrasts with the terricolous lichen vegetation of the Eastern Highlands which can be seen as a species-poor outlier of the extensive lichen-rich heaths found in Scandinavia. Contrary to popular belief, lichens are far more important in the western mountains than in the east, both intrinsically and as contributors to botanical bio-diversity. They are important in the eastern mountains only if their role as a structural element of the terricolous vegetation is being considered.

It was also observed that some species which were terricolous in the east (e.g. *Frutidella caesioatra, Pertusaria oculata, Stereocaulon saxatile*) became saxicolous (or grew over bryophytes on boulders) in the west. This is a consequence of the damper oceanic climate which makes soil in the west too wet to support good lichen growth but conversely creates more favourable conditions in habitats that are too dry in the east.

7•3•3 Phytosociology

7•3•3•1 Terricolous Communities

Data from a wide range of montane communities (*Calluna vulgaris/Cladonia arbuscula* heath NVC H13 (Rodwell 1991)) to *Juncus trifidus/Racomitrium lanuginosum* rush-heath NVC U9 (Rodwell 1992)) from many sites in the Scottish Highlands (including Lochnagar, Beinn Heasgarnich, Creag Meagaidh, Aonach Mór and Beinn Dearg) were collected using 4x4 or 2x2 m relevés, recording all lichens and vascular plants and the most frequent bryophytes.

The results indicate that terricolous montane macro-lichens can usually be accommodated within the general framework of recognized NVC communities. However, in some cases the areas with the greatest lichen cover are the transition zones between NVC communities and these could be considered as major noda and worthy of recognition as distinct communities. The best example of this is a distinctive assemblage dominated by *Cetrariella delisei* which forms relatively extensive patches in the Eastern Cairngorms on the edge of *Nardus stricta/ Carex bigelowii* grass-heath.

Lichens are only a regular and important factor in the terricolous vegetation in the Eastern Highlands (i.e. the Cairngorms) and so the majority of the relevés were collected from this area. Three NVC communities were concentarted on, all of which were well covered:-

a) H13 *Calluna vulgaris-Cladonia arbuscula* heath

b) H19 *Vaccinium myrtillus-Cladonia arbuscula* heath

c) U9 *Juncus trifidus-Racomitrium lanuginosum* rush heath.

Also sampled were;-

d) U10 *Carex bigelowii-Racomitrium lanuginosum* moss heath.

This was of little interest in the Cairngorms as the continuous cover of *R. lanuginosum* allowed little room for lichens. Further west, however, it can be more species-rich, especially in the *Silene acaulis* sub-community, as it is in this community that *Nephroma arcticum* occurs (see Appendix).

e) U8 *Carex bigelowii- Polytrichum alpinum* heath.

f) U11 *Salix herbacea-Racomitrium heterostichum* snow-bed.

Both U8 and U11 appeared to support the same assemblage of crustose lichens which occurred in U9 *Juncus trifidus-Racomitrium lanuginosum* heath, both in the Cairngorms and further west (Mam Sodhail), as well as on leached calcareous soil in the Breadalbane mountains. This appears to be the the most widespread assemblage of terricolous lichens in the Scottish Highlands and its distribution, ecology and variation deserves further investigation.

7•3•3•2 Saxicolous Communities

As cryptogam-dominated communities were not included in NVC, saxicolous substrata were mostly excluded from this study. Relevés were chosen to contain areas supporting homogeneous stands of terricolous vegetation and rocks and boulders were mostly excluded so that data for saxicolous habitats were collected only circumstantially. However, saxicolous substrata (i.e. rocks, boulders, screes and crags) are the most important lichen habitats in montane areas, the vegetation often forming assemblages in which lichens are the dominant plant type (5 relevés from Ben Lawers yielded 55 lichens but only 9 vascular plants).

The topography of the substratum is a major determining factor in the structure of saxicolous communities. Whereas vascular plant communities are essentially three-dimensional systems occupying a two-dimensional space (i.e. they occupy a significant space above an essentially flat surface) the opposite is true for micro-lichen dominated communities - they are two-dimensional systems occupying a three-dimensional space (i.e. they are closely associated with an uneven surface). Consequently, the problems involved in sampling and describing their phytosociology are different from those of vascular plants and, to a lesser degree, bryophytes and macro-lichens. This, along with the much smaller scale of these communities, means that it will be necessary to classify them separately.

7•3•4 Areas of Prolonged Snow-lie

Data were collected from four snow-beds, on Creag Meagaidh, Aonach Mór (Lochaber), Beinn Dearg (Wester Ross) and Ciste Mhearad on Cairn Gorm. At each site relevés were collected along a transect from the upper edge of the snow-bed into the surrounding vegetation. All the lichen and vascular plant taxa were recorded along with the most frequent bryophytes. These data were processed using TWINSPAN in two ways

a) all groups

b) lichens only

The TWINSPAN outputs show that terricolous (i.e. growing on the ground) macro-lichens growing among vascular plants (e.g. *Cetraria islandica*, and species of *Cladonia* subgen. *Cladina*) show good correlation with recognized NVC communities whereas micro-lichens growing on 'bare soil' and saxicolous species (on small pebbles embedded in the soil and on larger boulders) do not. This can best be explained by the importance of micro-habitat in determining lichen distribution. This is especially true of micro-lichens which occur close to the substratum and occupy a very specialized environment, often very different from that only a few centimetres away, and independent from that occupied by the vascular plants among which they occur. As terricolous macro-lichens mostly occur towards the outer limits of snow-bed vegetation it is the lichen communities occurring closest to the snow-bed which present the greatest difficulties in classification.

The most distinctive character of the saxicolous vegetation is the absence of widespread montane species (i.e. *Lecidea swartzioidea, Melanelia commixta, Lecanora polytropa, Miriquidica leucophaea, Rhizocarpon 'colludens'* ad int. and *Umbilicaria cylindrica*). It was also possible to identify the distinctive assemblage of lichens which, in the British Isles at least, is confined to siliceous rocks in the vicinity of areas of prolonged snow-lie, i.e. *Lecidella bullata, Lecanora leptacina, Miriquidica griseoatra* and *'Amelia andraeaeicola'* ad int. Two other communities were also identified which, although confined to areas of prolonged snow-lie in the east of the country, are more widespread in the damper, oceanic area of the west. These are a terricolous community composed of mainly of crustose species (e.g. *Catillaria contristans, Lecidea limosa* and *Micarea turfosa*) and a saxicolous community of small rocks and pebbles in which *Stereocaulon tornense* is prominent.

7•3•5 Effects of grazing animals

The only long-established exclosures in Scotland are at a relatively low altitude (500-600 m) and at these elevations the prevention of grazing leads to a dominance by vascular plants. Only those on the Inchnadamph NNR in Sutherland can be considered in any sense 'montane' as, although they are situated at only 250 m altitude, they are far enough north and west to be in the sub-montane zone characterized by dwarf willows. Outwith Scotland there is an excellently positioned exclosure in Snowdonia (900 m) which, unfortunately, has not been properly maintained, and several at Moorhouse NNR in the northern Pennines. Nowhere are there any exclosures erected primarily to investigate changes in the lichen vegetation and very few are on potentially lichen-rich heath.

The increase in lichen bio-mass on exclosure ranged from 1•86->20,000 fold. It was in all cases highly significant and was lower at high altitudes. At Moorhouse there was also a qualitative change in the lichen vegetation over limestone where the distinctive assemblage of calcicole species present outside the exclosure was replaced inside by calcifuge species due to a thick build up of acid litter and luxuriant vascular-plant growth, both of which mask the influence of the limestone substratum. There is also evidence to suggest a decrease in species-diversity inside the exclosures. This is correlated with the height of the vegetation as only a limited number of lichens can withstand competition from tall grasses (e.g. *Cetraria islandica* and species *of Cladonia* subgen. *Cladina*).

7•4 THE FUTURE

Lichens are an excellent tool for qualitative and quantitative ecological research. Their reliance on specific micro-habitats makes them ideal indicator species of specific habitats and, potentially, of environmental change, while the large number of taxa involved means that meaningful numerical analysis of data is possible.

Montane eco-systems are fragile and under threat from climatic change, increasing recreational pressure, the effects of grazing animals and, in the case of snow-bed vegetation at least, air-borne pollution. In order to conserve the biodiversity of these areas we need to know the extent and nature of the resource and how it is affected by various environmental factors (including biotic ones). However, montane lichens are a poorly studied group; ecological studies are still in their infancy - being largely accounts of species found in specific habitats - and there have been few attempts to describe their phytosociology, either in Great Britain (James, Hawksworth & Rose 1977) or abroad (Creveld 1981, Wirth 1972).

There is still much basic survey work to be done. Every year new species are recorded for the first time from the British Isles (25 montane species since the checklist of British lichens (Purvis, Coppins & James 1993)) and many taxa are poorly understood or even undescribed. There is also much taxonomic work still to be done; a number of important genera are in need of critical revision (e.g. *Aspicilia, Porpidia, Rhizocarpon*) and it is often impossible to name collections satisfactorily.

Lichen ecology and how biotic factors affect the lichen vegetation also require more study. This has implications for the use of lichens as indicators of climatic change as it is first necessary to identify and eliminate effects due to other factors. *Alectoria ochroleuca* at intermediate altitude in the northern Cairngorms and *Nephroma arcticum* at high altitude on Beinn Eighe both reach the extreme limit of their range in Scotland and would be ideal for monitoring climatic change. Before this can be done, however, it will be necessary to erect exclosures (including small exclosure cages) around some of the colonies and also transplant thalli to apparently suitable terrain nearby. This would identify the effects on these lichens of the total removal of grazing. It may be that without grazing the lichen cover would increase or alternatively some level of grazing may be necessary to prevent the dominance by vascular plants and the disappearance of the lichens.

However, the greatest challenge is the investigation and description of saxicolous lichen communities. This would require a major initiative as, leaving aside taxonomic and identification problems, a different approach will be required from that used in vascular plant phytosociology. Homogeneous stands of any size are so rare in saxicolous communities that they must usually be rejected as anomalous and atypical, the small-scale topology of the substrata creating numerous micro-environments each with an associated community which cannot be sampled using standard phytosociological methods. It will be necessary to develop techniques for sampling these small-scale communities before the details of saxicolous lichen communities can be determined.

Nimis (1991) reviewed the current state of lichen phytosociology and concluded that the best studies were those which

a) pay due attention to other important areas such as ecology and phytogeography.

b) study a particular habitat over a wide area.

Consequently, the major challenge facing Scottish montane lichenology is the description of the saxicolous lichen communities of the Scottish mountains, relating them to ecological factors on both a macro- and micro-habitat level and placing them in an international (especially northern European) context.

APPENDIX

DISTRIBUTION, ECOLOGY AND IDENTIFICATION OF TWO 'SCHEDULE 8' SPECIES

1 *Nephroma arcticum*

2 *Psora rubiformis*

Nephroma arcticum (L.) Torss.

Order Peltigerales. **Family** Nephromataceae.

English Name: Arctic kidney-lichen.

['Kidney' in the English name derives from the generic name (from Gr. nephros) and refers to the shape of the apothecia. However, as apothecia are unknown in this species in Britain, the name is not particularly appropriate. A better name might be 'yellow leafy ground-lichen'.]

Status

Rarity - Red Data Book category: (EN) ENDANGERED.

Occurrence in protected areas - The only site where *N. arcticum* has recently been seen (Ruadh-stac Beag) is on the Beinn Eighe NNR. It was also recorded in the 1950s by McVean on the nearby Ruadh-stac Mór (SSSI - just off the NNR) and ?Carn Eige/Mam Sodhail (SSSI, pSPA) to the north of Loch Affric.

Distribution and Abundance

World Distribution - Circumpolar in the northern hemisphere; sub-arctic to boreal, with southern outliers in the Tatra mountains (Carpathians) in central Europe, in Japan, and in New York and New England in North America (Map in McVean 1955) (James & White 1987). A similar species, *N. antarcticum*, is circumpolar in the southern hemisphere.

British Distribution - Recently seen in species-rich *Racomitrium*-heath on fucoid bed outcrop, Ruadh-stac Beag, Beinn Eighe NNR, West Ross. Previously recorded, in the 1950s, from the nearby Ruadh-stac Mór and from an imprecise locality in the mountains north of Loch Affric (Easterness).

Abundance - Approximately forty plants in one small area; all of which show evidence of being grazed, presumably by red deer. Previously recorded as small fragmented thalli at two other sites in the NW Highlands.

Ecology

Nephroma arcticum is widespread in arctic regions where it is a species of intermediate altitudes growing over bryophytes on non-basic soil and occasionally also on trees. However, all its Scottish sites are high altitude, *Racomitrium* heath and the one where it is by far the commonest - and the only one where it has been seen in recent years - is species-rich and adjacent to one of the richest areas for terricolous, montane, calcicole lichens in the British Isles.

N. arcticum was discovered in Britain during the 1950s by McVean and Ratcliffe, who described its habitat as "species-rich moss-heath ... The soil, a clay developed from certain shaly beds of rock, gave a glass-electrode meter reading of pH 7.1" (McVean 1955). Closer examination of the site, however, reveals that the actual situation is somewhat more complicated as there appear to be three distinct NVC communities (Rodwell 1991, 1992) present in the area (Fig. A•1).

The main NVC community of the montane heath on Ruadh-stac Beag is U10 *Carex bigelowii-Racomitrium lanuginosum* moss heath, *Silene acaulis* sub-community, which is here characterized by an abundance of *Salix herbacea*, large colonies of the lichens *Ochrolechia tartarea* and, the usually saxicolous, *Parmelia omphalodes*. Where the influence of the calcareous fucoid beds is strongest this gives way to an extremely rich calcareous heath referable to CG 12 *Festuca ovina-Alchemilla alpina-Silene acaulis* dwarf herb community. This community, which is on a slight, north-facing slope with shallow solifluction terracettes, is the only British locality for the lichens *Rinodina mniaraea* (Red Data Book Category 'Endangered') and *Buellia papillata* (Sommerf.) Tuck. (identified too late for inclusion in the Red Data Book), while *Schadonia fecunda* (RDB 'Vulnerable') is otherwise known in Britain only from Ben Lawers. A number of other Red Data Book species are also present. At the lower edge of this community a bank formed by a solifluction terrace supports a relatively high carpet (c. 10-15cm) of grasses and herbs referable to U14 *Alchemilla alpina-Sibbaldia procumbens* dwarf herb community.

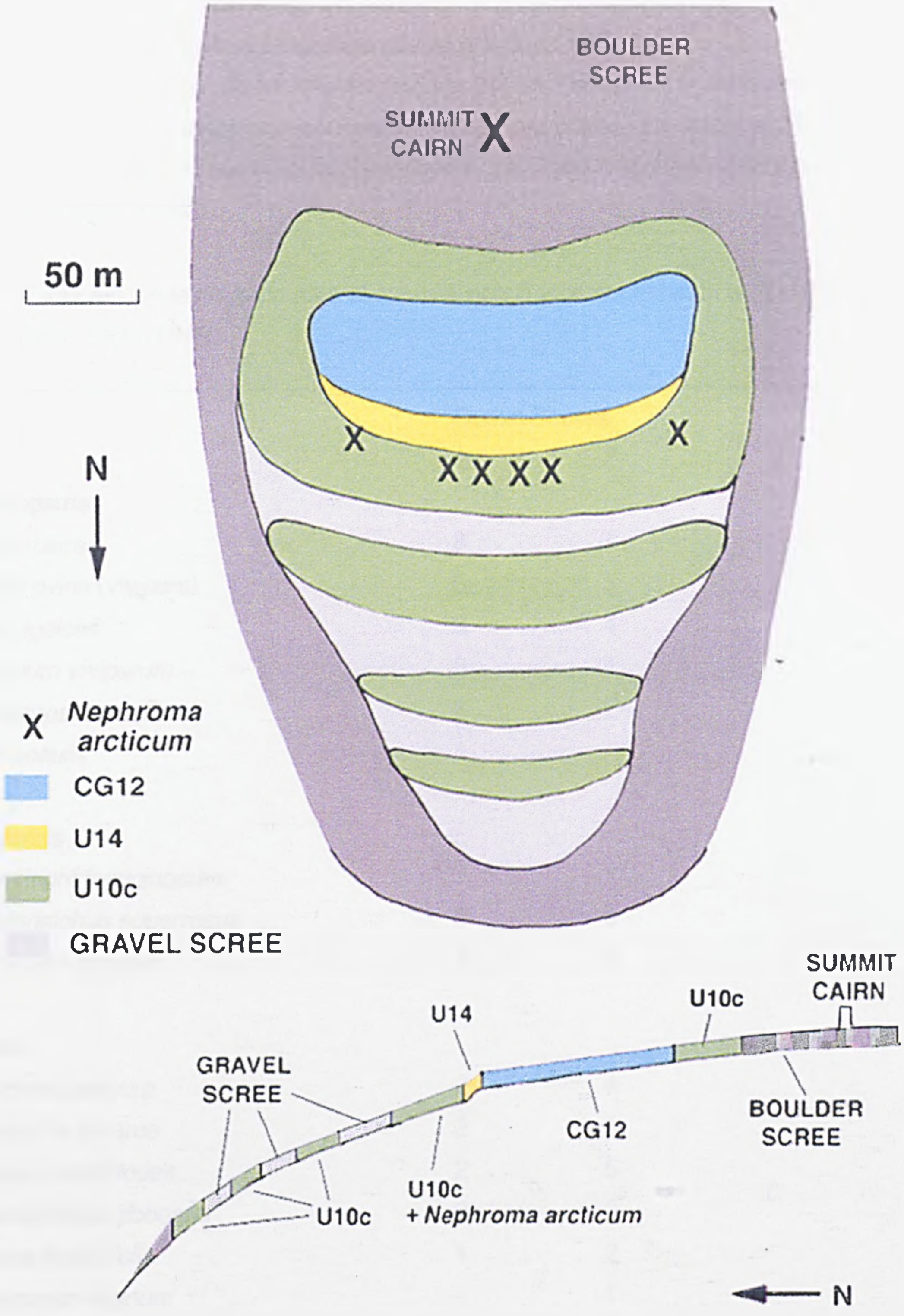


Figure A·1. Diagrammatic sketch of summit of Ruadh-stac Beag, Beinn Eighe NNR, showing distribution of NVC communities and position of *Nephroma arcticum* colonies.

Below this U10 returns and it is here that *N. arcticum* occurs in a narrow band, less than 2m wide, spread around the hillside (Fryday 1991).

The results of two 4x4m relevés taken in this area are given in Table A•1. More bryophytes undoubtedly occurred but these were outside the scope of the survey. Further species lists, including bryophytes, are given in McVean (1955) and McVean & Ratcliffe (1962).

Table A•1. Relevés from area of species-rich *Racomitrium* heath on Ruadh-stac Beag, Beinn Eighe NNR.

	Domin Scores	
	1	**2**
Phanerogams		
Salix herbacea	8	7
Festuca ovina (vivipara)	5	5
Carex bigelowii	3	4
Polygonum viviparum	3	4
Deschampsia cespitosa	2	2
Silene acaulis	1	-
Bryophytes		
Racomitrium lanuginosum	7	7
Rhytidiadelphus squarrosus	6	6
Polytrichum alpinum	4	2
Lichens		
Nephroma arcticum	2	4
Ochrolechia tartarea	2	1
Parmelia omphalodes	2	5
Sphaerophorus globosus	2	2
Peltigera lactucifolia	1	2
Stereocaulon alpinum	-	1
Alectoria nigricans	-	1
Cladonia uncialis	-	1
Cetraria islandica	-	1

Below the *N. arcticum* zone is a band of fine gravel, and these gravels then alternate with bands of U10. Despite a thorough search of the area, *N. arcticum* was not seen again.

The restriction of *N. arcticum* to the band of U10 directly below the base-rich CG12 area suggests that at this, the extreme limit of its range, its habitat requirements are somewhat more demanding than elsewhere.

Identification

Nephroma arcticum is a large, terricolous, yellow-green, foliose lichen (Fig. A•2 and illustration in Jahns 1983) and, as such, is unlikely to be confused with any other British species.

Figure A•2 *Nephroma arcticum* on Ruadh-stac Beag showing rounded lobes.

The lobes are more or less loosely attached (overgrowing mosses, other lichens and other low-growing plants), corticate on both sides,and are rounded and undulate with a margin that is usually unbroken and wavy. The upper surface is smooth to slightly wrinkled, with several rounded, warty swellings that sometimes assume a bluish colour. Inside these swellings are internal cephalodia (colonies of the cyanobacterium

Nostoc). The lower surface of the lobes is white to brown-white, but towards the centre has a distinct brownish-black tomentum (a dense mat of short hairs); there is no network of veins or rhizines (long, root-like hairs). Apothecia are unknown in the British populations.

All other European species of *Nephroma* are brown except the Scandinavian *N. expallidum*, which differs in having smaller, more dissected, lobes and a dull, green-brown thallus (bright green when wet); see James & White (1987).
Two species of, the related genus, *Peltigera* - *P. britannica* and *P. leucophlebia* - are also green and grow on the ground, but these are a darker green (brown when dry), lack a lower cortex, have a network of veins and rhizines on their lower surface and possess external cephalodia seen as small brown scales on the upper surface of the lobes.

Threats

Currently the most serious threat to the continued existence of this species is climatic change. It is at the extreme edge of its range in Scotland and it is assumed that only a slight amelioration of the climate would see its demise.
Over-grazing by deer may have been a threat in the past but present numbers on the NNR are now so low as not to be a problem. All the plants, however, show evidence of grazing; being mostly fragmentary with poor lobe development. The effect of grazing on montane heaths are unknown and it may be that a degree of grazing is required to prevent the population being over-run by vascular plants.
Trampling or other damage by hill-walkers poses little danger as Ruadh-stac Beag is just below 3000ft and so little visited. Even if recreation use did increase the only route to the summit is from the south and the population of *N. arcticum* is to the north of this and so is off the direct route.

Management

Little is required, except to maintain the present low numbers of deer on the NNR.

ACTION/RECOVERY PLAN

Objectives/prescriptions

The only site where *N. arcticum* has been seen recently, and the only one where it has ever had a viable population is on Ruadh-stac Beag on the Beinn Eighe NNR. Very little is known about the effects of deer grazing on the composition of montane heaths. Although the present population of *N. arcticum* does not appear to be under immediate threat from over-grazing - the deer numbers on the NNR having been reduced dramatically over the past few decades, from a peak of nearly 300 in 1968 to 79 in 1991 (T. Clifford, *pers. comm.*) - all the plants seen showed evidence of grazing; being cropped level with the 'turf' and with poor lobe development. It is important, therefore, that the population continues to be monitored.

It is also possible that a degree of grazing is required for the continued existence of *N. arcticum* as this will prevent the vascular plants forming a closed sward and excluding the cryptogams.

Permanent quadrats were set up around the colony on Ruadh-stac Beag in 1991 and although detailed monitoring was not possible during the most recent visit it was noted that the individual plants had changed shape (Figs A•3). It is recommended that the colony should be resurveyed as soon as possible to assess the extent of change. This would then give an indication of the frequency of future monitoring. The population on Ruadh-stac Beag is of sufficient size to permit some experimentation on the effects of grazing. The erection of some exclosure cages (1x1m) would yield some very useful information.

Transplants of *N. arcticum* to the sites where it was previously recorded (or other apparently suitable areas) are not recommended as the habitat requirements of this species in Scotland appear to be so precise that the probability of success is very low. The fucoid beds also outcrop in the area to the north of Loch Maree; in particular, at c. 1000m on Mullach Coire Mhic Fhearchair. This area has received almost no attention from lichenologists and it should be surveyed as a matter of some urgency as, if *N.*

arcticum is to be found elsewhere in Scotland, this is the most likely locality. It is also likely to be an extremely rich site for terricolous lichens in general.

Figure A•3. *Nephroma arcticum* on Ruadh-stac Beag showing changes since 1991 (overlay).

Recovery potential

On Ruadh-stac Beag *N. arcticum* has the appearance of a species under stress. It is not fertile, has poor lobe development, and the thalli are fragmentary and poorly developed. Whether this stress is due to grazing by deer or because the species is at the edge of its range (or a combination of the two) is not clear. However, to talk of 'recovery' in respect of this species is probably inappropriate as, in the recent past, it was almost certainly never more abundant than it is at present. Conservation efforts should aim to maintain the present population.

Implementation

Efforts should be concentrated on the Ruadh-stac Beag population as even if *N.*

arcticum is still present at the other two sites these are likely to be small, less viable populations. The Ruadh-stac Beag population should be re-monitored as soon as possible to assess its performance over the last few years and consideration given to the erection of exclosure cages on the site to monitor the effects of deer grazing. The fucoid bed outcrop on Mullach Coire Mhic Fhearchair should be visited at the same time.

LOCALITIES

1) **18(NG)/97.61 - Beinn Eighe**, North end of Ruadh-stac Beag (VC 105, West Ross). Alt. c. 800m, 24 June 1990, B.J. Coppins, O.L. Gilbert & A.M. Fryday. Specimen in E (*Coppins* 13762). From the same site is: Beinn Eighe NNR, moss heath, alt. 3000ft, 1953, D. McVean. Specimen in E. Lit: - McVean (1955), Fryday (1991).

Status: SSSI/NNR

Date of visit: 23.06.1994 (2 hours). **Weather:** good.

Altitude: c. 875m. **Aspect:** c. NE-NNE (330°-340°)

Access to the summit of Ruadh-stac Beag is best obtained along a little used deer track that traverses up the eastern side of the hill from the bealach between Ruadh-stac Beag and Beinn Eighe. Detailed directions to the *N. arcticum* colonies are given in Fryday (1991d).

Nephroma arcticum is concentrated in three main areas, forming a band around the northern slope of the hill (Fig. A•4). The outer two colonies are small, consisting of 8 and 10 plants respectively, but the middle colony is more extensive with over 25 plants - giving a total population of c. 45 plants. Most of the plants cover an area of c. 10-30cm in diameter, although one in the middle area extends for over 1m. However, these sizes are somewhat arbitrary as most of the plants consist of diffuse, grazed patches interspersed with *Racomitrium*-heath vegetation so that their margins are rather vague (Fig. A•5).

Figure A.4. Habitat of *Nephroma arcticum* in species-rich *Racomitrium* heath (NVC U10c) on Ruadh-stac Beag.

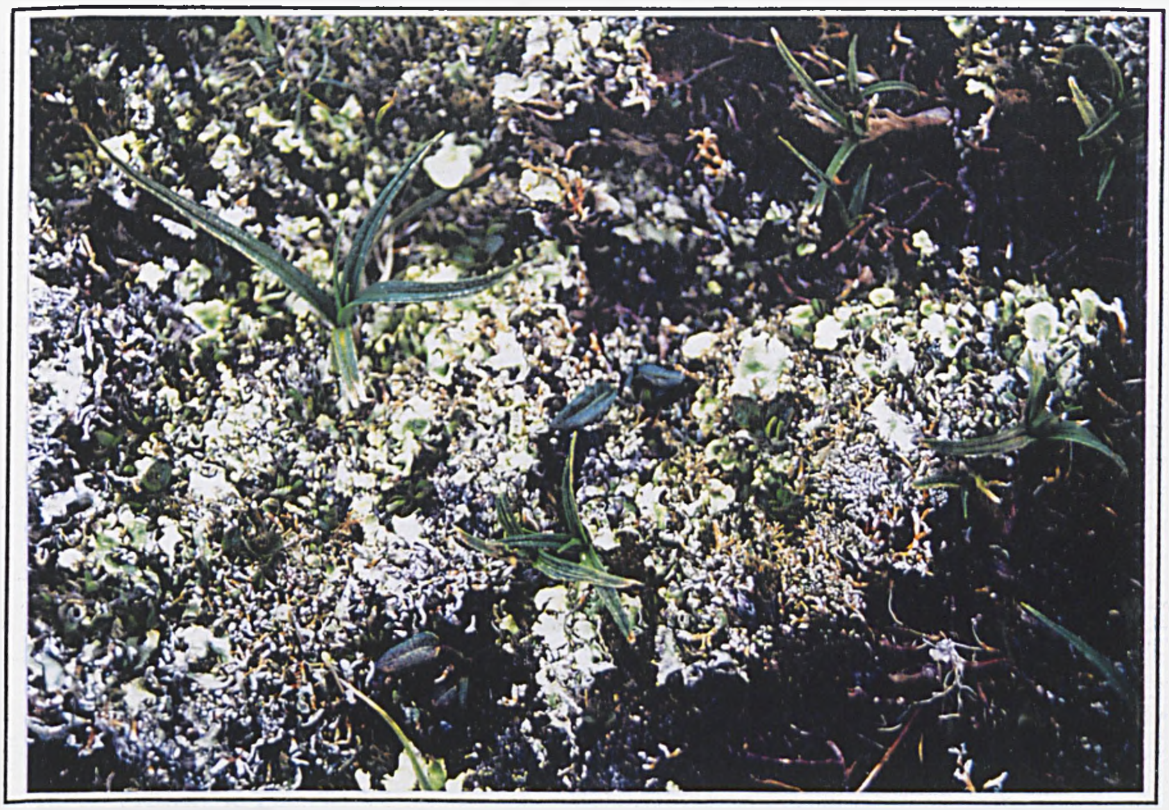


Figure A•5. *Nephroma arcticum* on Ruadh-stac Beag showing indistinct outline of plants.

The overall population size appeared little changed from the previous visit in 1991, but close inspection showed that significant changes in individual plants had taken place - some had increased in size while others had decreased (see Fig. A•5). Details of the ecology of this site are given above.

Locality Action Plan: Continued monitoring. Possible erection of exclosure cages to study the effects of deer grazing.

2) **18(NG)/95.61 - Beinn Eighe**, Ruadh-stac Mór (VC 105, West Ross). Moss-heath on mudstone outcrop, alt. c. 950û1000m, D. McVean. Lit.: - McVean (1955). Letter from D. McVean dated 25 ix 1989.

Status: SSSI.

Date of visit: 22.7.1991 (1 hours) **Weather:** good.

: 8.8.1995 (2 hours) : good.

Altitude: c. 800-1000m.

The montane heath on Ruadh-stac Mór is much more extensive than that on Ruadh-stac Beag and as the population of *N. arcticum* is apparently much smaller (McVean 1955) the chances of locating it are slim.

Locality Action Plan: *Nephroma arcticum* should be looked for at this site, if time permits, during future monitoring of the population on Ruadh-stac Beag.

1) **28(NH)/1.2 - Carn Eige/Mam Sodhail** (possibly Sgurr na Lapaich, Tom a' Croinnich), VC 96/106 (Easterness/East Ross). Alt.: 1000û1183m, D. McVean. Lit.: - McVean (1955), and letter from D. McVean dated 25 ix 1989.

Status: SSSI/pSIA.

This site was described as: "near summit of either Carn Eige or Mam Sodhail (just possibly Tom a' Choinnich or Sgurr na Lapaich). Quartz-mica schist" (McVean; letter dated 25 ix 1989) and "East Inverness-shire. At about 3500 ft on steep, unstable slopes of coarse mica-schist soil bearing fragments of moss-heath" (McVean 1955)
As the boundary between East Inverness and East Ross follows the Tom a' Choinnaich/ Carn Eige/Mam Sodhial ridge, the areas to the north and west of this, which carry extensive *Racomitrium* heath, can be discounted as they are East Ross. Also the geological map appears to show Tom a' Choinnich and Sgurr na Lapaich to be on Quartz-feldspar-granulite, so they can probably be discounted as well. This leaves the southern half of the east ridges of Carn Eige and the whole of the east ridge of Mam Sodhail as the most probable localities for this record.
Unfortunately, this narrowing down of the locality was not made until after the site was visited and so the whole area was searched.

Date of visit: 22.07.1994 (6 hours) **Weather:** bright but cold.

Although *N. arcticum* was not refound the area was found to support a rich lichen flora, which included the terricolous *Verrucaria bryoctona* (at an unusually high altitude), while *Lecanora marginata* subsp. *elata* (first British record outside the Breadalbanes), *Lecidea paupercula* and *Tephromela armeniaca* were all seen on one mica-schist boulder on the SE side of Carn Eige.

Locality Action Plan: Now that the locality of the *N. arcticum* record has been narrowed down considerably the chances of re-finding it here are greatly improved. As this is an under-worked area which appears to support a rich lichen flora a further visit to attempt to find *N. arcticum* coupled with a general lichen survey of the area, although not a high priority, should be given serious consideration.
Any future visit should also investigate Lochan Uaine in the Coire between Carn Eige and Mam Sodhail which was still partly snow-bound in late July and, slightly further afield, Sgurr na Lapaich north of Loch Mullardoch which is also on the mica schist. Similar

conditions to those on Mam Sodhail/Cam Eige (i.e. species-rich *Racomitrium* heath) also occur on the summit of Beinn Fhada, 12km to the SW, which is another possible locality for *N. arcticum*.

Psora rubiformis (Ach.) Hook.

Order: Lecanorales. **Family:** Psoraceae.

English Name: Rusty alpine psora.

[**NB.** This recently coined English name is most misleading. The epithet *rubiformis* derives from '*rubi-*' (L. *rubus* = blackberry; not *rubor* = redness) and '*-formis*' (L. = -formed). Although the species was originally described by Acharius, the name was probably suggested to him by Wahlenberg, who likened the clustered apothecia to the fruits of dewberry, *Rubus caesius*. Hence Dewberry-fruited psora would be the most appropriate English name.]

Status

Rarity - Red Data Book category: (VU) VULNERABLE.

Occurrence in protected areas - All three colonies of this plant are on the Ben Lawers NNR. Two of these are in the area owned by the National Trust for Scotland.

Distribution and Abundance

World Distribution - Arctic-alpine in Europe and North America. In Norway it occurs from Hordaland north to Finnmark, and in Sweden from Hõrjedalen to Torne Lappmark. It is widely distributed along the coast of Greenland, and in arctic Canada (Northwest Territories and Yukon). In USA it occurs in Alaska, with southern outliers in Colorado (Rocky Mts, at 3730m alt.) and Vermont (map in Timdal 1986: fig. 25).

British Distribution - Recorded only from the Ben Lawers NNR, Perthshire.

Abundance - Three colonies, none extensive but two fertile and reasonably well established.

Ecology

Psora rubiformis grows loosely attached to vertical, basic rock faces; typically on 'bare rock' but usually spreading onto associated bryophytes (?*Grimmia* sp.). All three of its British sites are on exposed, SE-facing, mica-schist crags, the sites ranging from 800-1150m; the lower limit being the estimated tree-line for the area.

Two sites, the SW Crags of Ben Lawers (Creag Loisgte) and the crags at the head of Lochan nan Cat, are well-known as localities for the rare calcareous alpine flora of Ben Lawers. The other site, the head of Coire Riadhailt on Beinn nan Eachan, is equally rich but less well known. At the first two mentioned sites *P. rubiformis* grows on ±smooth, vertical surfaces among other lichens and bryophytes but at the Coire Riadhailt site the mica-schist shows greater stratification and *P. rubiformis* is strongly associated with one, recessed stratum. This stratum is horizontal for most of its length but curves over at one end to make contact with the ground almost perpendicularly - both sloping at approximately 45°. The largest plant of *P. rubiformis* is situated near the ground but smaller ones are located all along the stratum for a distance of approximately 3.5m. *P. rubiformis* occurs nowhere else on the rock face. It is assumed that the stratum which supports *P. rubiformis* is particularly calcareous and is indicative of the precise habitat requirements of this species.

The lichen community in which *P. rubiformis* occurs includes some of the rarest lichens in the British Isles - some of its associated species are given in Table A•2. The NVC Community most closely associated with *P. rubiformis* is CG 14 *Dryas octopetala-Silene acaulis* ledge community, but this occurs on the ledges in the mica-schist crags whereas *P. rubiformis* grows on the rock face itself in a community completely dominated by cryptogams. James *et al.* (1977) mention this community (pp. 361-362) noting that "Its syntaxonomic position is in need of further study but it has clear affinities with some communities of alpine habitats in Norway of which it probably represents a species-poor facies." However, they give no further references to these Norwegian communities.

Table A•2 Lichens associated with *Psora rubiformis* at its three re-located sites on the Ben Lawers Range.

Sites: **1,** Coire Riadhailt; **2,** Creag Loisgte; **3,** Lochan nan Cat. **RDB:** - Red Data Book Category [**EN** - endangered; **L(nt)** - lower risk (near threatened); **VU** - vulnerable]

	1	2	3	RDB
Acarospora badiofusca	x	.	.	L(nt)
A. rhizobola	.	x	x	VU
?*Brigantiaea fuscolutea* (sterile)	.	x	.	L(nt)
Catapyrenium lachneum	x	x	x	
Cladonia pocillum	.	x	.	
Collema auriforme	.	x	.	
Halecania bryophila	.	x	.	*
Koerberiella wimmeriana	.	.	x	
Lecanora albescens	.	x	x	
L. atromarginata	.	x	.	VU
L. frustulosa	x	.	.	VU
Lecidea hypnorum	.	x	.	
Pannaria hookeri	x	.	.	L(nt)
Placynthium sp.	x	.	.	
Porpidia superba	x	x	x	
Protoblastenia siebenhaariana	x	.	.	
Psora decipiens	x	.	x	
Tephromela atra	.	x	.	
Thelidium papulare	x	.	.	
Toninia rosulata	.	.	x	EN+

* - New to Science (see section 2•2•2)

\+ - First modern British Record (see section 2•1•2)

Identification

Species of the genus *Psora* have a squamulose thallus and dark, convex, lecideine apothecia. *P. rubiformis* is a distinctive species within the genus being the only species to contain usnic acid, giving the thallus a greenish-yellow colour; the thalline squamules are also white pruinose, especially at the margins (Fig. A•7). All the other species of *Psora* have red to brown squamules. The apothecia are brownish black to black, sometimes faintly greenish pruinose, and frequently clustered together.

Two chemical strains are known: strain I containing usnic and gyrophoric acids (C+ red); strain II containing usnic acid only (C-). Both are known from Scandinavia (Timdal 1984) but only strain I has been identified from the British specimens. According to Timdal (1986), strain II is more frequent towards the north, both in Europe and N America.

The non-British *P. vallesiaca* (syn. *P. albilabra*) - known from the Mediterranean, central Europe and Scandinavia - is also white pruinose but the thallus is brown (lacking usnic acid) and contains norstictic acid (K+ yellow→red; Pd+ yellow). The apothecia are also completely white pruinose (absent or slightly yellow-green pruinose in *P. rubiformis*).

P. rubiformis is most likely to be confused with the basal squamules of *Cladonia* spp. (e.g. *C. symphycarpa*). However, its habitat of basic rocks is unusual for a *Cladonia* and the squamules of *P. rubiformis* are thicker, coarser and more rounded.

Threats

All three sites for *P. rubiformis* are well away from the main routes taken by hill walkers and are probably visited only by botanists - the Coire Riadhailt site is probably rarely visited at all. Accidental damage to the plants by botanists climbing on the crags is, consequently, the most serious threat as *P. rubiformis* is usually only loosely attached to its substratum and, therefore, easily dislodged.

Management

Botanists visiting the three sites should be made aware of the presence of *P. rubiformis* and requested to avoid the sensitive area.

All three populations should be monitored at regular intervals.

ACTION/RECOVERY PLAN

Objectives/prescriptions

All three sites for *Psora rubiformis* are on the Ben Lawers NNR - two on the section owned by the National Trust for Scotland and the third in an extremely out of the way, rarely visited, area on the Meall nan Tarmachan section - and so are already well protected. However, they should be regularly monitored to check their continued viability. There is a possible fourth site for *P. rubiformis* (see below), also on the NTS section of the Ben Lawers NNR, which was only briefly visited.

The NTS in both Perth (James Fenton - ecologist) and on Ben Lawers (David Mardon - ranger) should be made aware of the localities of this species.

Recovery potential

Maintenance of the present populations is the only realistic conservation goal. The three populations appear reasonably well established and in no immediate danger.

Implementation

Regular monitoring of all three populations.

LOCALITIES

1) **27(NN)/574.386 - Ben Lawers NNR**, Meall nan Tarmachan, gully at west of head of Coire Riadhailt. (VC 88, Mid-Perthshire). S-facing, mica-schist crag; alt: 850m, 1992, A.M. Fryday.

Status: NNR/SSSI.

Date of visit: 23.07.1994 (2 hours). **Weather:** good.

Altitude: c. 900m. **Aspect:** SSE (160°).

Psora rubiformis was found to be sparingly fertile, with one large plant and a number of smaller ones spread along a recessed stratum of the rock (see Fig. A•6). The largest plant is approximately 8 x 12cm, although a large section of it appears about to fall off. A comparison with the photograph of the plant taken in 1992 (Figs A•7 & A•8) shows a slight change in its extent. Further details of the ecology, as well as a list of associated lichens, are provided above.

Figure A•6. *Psora rubiformis* on Meall nan Tarmachan, Ben Lawers NNR, showing distribution of plants (marked by bamboo canes) along resessed strata in the rock face.

Locality Action Plan: Continue regular monitoring.

2) 27(NN)/633.412 - Ben Lawers, SW crags (Creag Loisgte). (VC 88, Mid-Perthshire).

Alt.: 1150m. Lit: - Gilbert *et al.* (1988).

Status: NNR/SSSI.

Date of visit: 17.08.1994 (2 hours). **Weather:** good.

Altitude: c. 1050m. **Aspect:** SE (135).

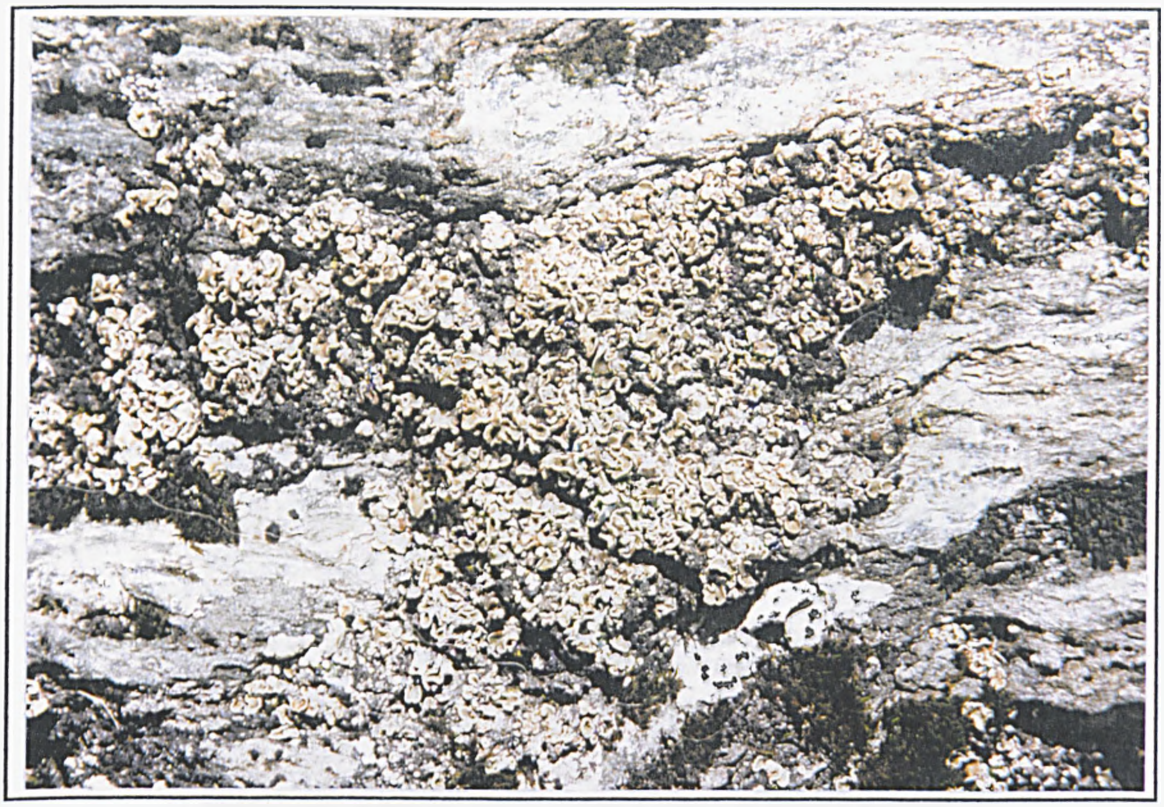


Figure A•7. *Psora rubiformis* on Meall nan Tarmachan, photographed in 1992.

Figure A•8. *Psora rubiformis* on Meall nan Tarmachan, photographed in 1994. Slight differences in extent can be seen

P. rubiformis was found overgrowing bryophytes on a ±vertical, mica-schist rock face; mostly in a shallow depression. It was abundantly fertile, with a number of good sized plants growing in one area of the crags. This is the largest, healthiest population of *P. rubiformis.* (Fig. A•9).

Figure A•9. *Psora rubiformis* on Creag Loisgte, Ben Lawers NNR. This is the best developed colony in the British Isles, it is extensive and abundantly fertile.

The main area (lowest) covers approximately 20 x 20cm with another patch nearby measuring c. 10 x 5cm and a further two, each measuring 5cm x 10cm, slightly further away. Scattered squamules of *P. rubiformis* are present in the area between these plants. Higher up there is a similar-sized patch (i.e. 20 x 20cm) with two others, c. 10 x 10cm and 10 x 5cm, nearby; again with scattered squamules in between. Further details of the ecology, as well as a list of associated lichens, are provided above.

Locality Action Plan: Continue regular monitoring.

3) **27(NN)/633.409 - Ben Lawers**, SW of summit (VC 88, Mid-Perthshire). On a boulder below SW of summit (sic). Alt.: c. 900m, 9 vii 1985, B.W. Fox [with O.L. Gilbert]. Specimen in E

Status: NNR/SSSI.

Visit: - 17.7.1995 **Weather:** good

The cited location was visited but *P. rubiformis* was not found. It is assumed that this record refers to the same site as 2 above (SW Crags - Creag Loisgte), although the grid reference and altitude place it well below this locality. Neither Professor Fox or Dr Gilbert (*pers comm.*) have any recollection of recording *P. rubiformis* from here and it is probable that confusion has arisen concerning the exact origin of the specimen. It is assumed that the location details given on the herbarium packet should read "on a boulder below SW cliffs".

Locality Action Plan: None.

4) **27(NN)/641.428 - Ben Lawers**, Lochan nan Cat (VC 88, Mid-Perthshire). Crags on NW side of coire, just south of Cat Gully, ±vertical rock face, calcareous mica-schist, alt.: c. 800m, July 1986, B.J. Coppins, O.L. Gilbert & B.W. Fox. Specimen in E (*Coppins* 11386).

Status: NNR/SSSI.

Date of visit: 17.08.1994 (2 hours). **Weather:** good.

Altitude: 760m. **Aspect:** SSE (160°).

One small, sterile plant, c. 5cm in diameter, was found at about 1m from the ground. It was overgrowing bryophytes in a shallow depression on a vertical, mica-schist rock face interspersed with *Catapyrenium lachneum* and *Psora decipiens*. A list of associated lichens is provided above.

Toninia rosulata was recorded nearby; the first record of this species in Britain this century.

Locality Action Plan: Continue regular monitoring.

Note: In addition to the localities mentioned above there are two 19th century collections of *Psora rubiformis* from Ben Lawers in BM:-

'Ben Lawers. top. July, 1864' I. Carroll. - This collection probably originated from the SW Crags (locality 2 above).

'Ben Lawers, near summit; on ground, alt: 3500ft.' J. Crombie. - This record is suspect. The altitude is correct for Creag Loisgte (locality 2 above) but the habitat is unusual for *P. rubiformis*, and Crombie is notorious for his dubious botanical records.

BIBLIOGRAPHY

Ahlmann, H. W. (1953) *Glacier variations and climatic fluctuations (Bowman Lecture).* New York: American Geographical Society.

Allee, W. C., Emerson, A. E., Park, O., Park, T. & Schmidt, K. P. (1949) *Principles of Animal Ecology.* Philadelphia: Saunders.

Armstrong, R. A. (1974) The descriptive ecology of saxicolous lichens in an area of south Merionethshire, Wales. *Journal of Ecology* **62(1)**:33-45.

Armstrong, R. A. (1978) The colonization of a slate rock surface by a lichen. *New Phytologist* **81**:85-88.

Averis, A. B. G. (1991) *A survey of the bryophytes of 448 woods inthe Scottish Highlands.* MPhil. thesis, University of Reading.

Barry, R. G. (1992) *Mountain Weather and Climate.* London: Methuen.

Barry, R. G. & Ives, J. D. (1974) Introduction. In *Arctic and Alpine Environments* (J.D.Ives & R.G.Barry, eds): 1-13. London: Methuen.

Barry, R. G. & Van Wie, C. C. (1974) Topo- and micro-climatology in alpine areas. In *Arctic and Alpine Environments* (J.D.Ives & R.G.Barry, eds): 73-83. London: Methuen.

Bates, J. W. (1978) The influence of metal availability on the bryophyte and macrolichen vegetation of four rock types on Skye and Rhum. *Journal of Ecology* **66**:457-482.

Bayfield, M. G., Urquhart, U. H. & Cooper, S. M. (1981) Susceptability of four species of *Cladonia* to disturbance by trampling in the Cairngorm mountains, Scotland. *Journal of Applied Ecology* **18**:303-310.

Benedict, J. B. (1990) Lichen mortality due to late laying snow: results of a transplant study. *Arctic and Alpine Research* **22**:81-89.

Benedict, J. B. (1991) Experiments on lichen growth II. Effects of a seasonal snow cover. *Arctic and Alpine Research* **23**:189-99.

Berg, H. (1957) Temperaturmessungen in der schneenahen Luftschicht. *La Mét* 363-369.

Beschel (1970) The diversity of tundra vegetation. In *Productivity and Conservation in Northern Circumpolar Lands.* (W. A. Fuller & P. C. Kevan, eds): 85-92. International Union for the Conservation of Nature, Morges, Switzerland.

Billings, W. D. & Bliss, L. C. (1959) An alpine snowbank environment and its effects on vegetation, plant development and productivity. *Ecology* **40**:388-397.

Billings, W. D. & Mooney, H. A. (1968) The ecology of arctic and alpine plants. *Biological Reviews* **43**:481-529.

Birks, H. J. B (1988) Long-term ecological change in the British uplands. In *Ecological Change in the Uplands* (M.B. Usher & D.B.A. Thompson *eds*): 37-56. Oxford: Blackwell Scientific Publications.

Birks, H.J.B. & Ratcliffe, D.A. (1981) *Classification of Upland Vegetation Types.* Edinburgh: Nature Conservation Council.

Birse, E. L. (1971) *Assessment of Climatic Conditions in Scotland. 3. The Bioclimatic Subregions.* Aberdeen: Macaulay Institute for Soil Research.

Birse, E. L. & Dry, F. T. (1970) *Assessment of Climatic Conditions in Scotland. 1. Based on Accumulated Temperature and Potential Water Deficit.* Aberdeen: Macaulay Institute for Soil Research.

Birse, E. L. & Robertson, L. (1970) *Assessment of Climatic Conditions in Scotland. 2. Based on Exposure and Accumulated Frost.* Aberdeen: Macaulay Institute for Soil Research.

Bliss, L. C. (1964) Photosynthesis and respiration of alpine lichens. *American Journal of Botany* **51**:870-874.

Blum, O. B. (1973) Water Relations. In *The Lichens* (V.Ahmadjian & M.E.Hale, eds): 381-400. London, New York & San Francisco: Academic Press.

Boyle, A. P., McCarthy, P. M. & Stewart, D. (1987) Geochemical control of saxicolous communities on the Creggaun Gabbro, Letterfrack, Co. Galway, Western Ireland. *Lichenologist* **19**:307-317.

Brown, A., Horsfield, D. & Thompson, D. B. A. (1993a) A new biogeographical classification of the Scottish Uplands. I. Description of vegetation blocks and their spattial variation. *Journal of Ecology* **81**:207-230.

Brown, A., Birks, H. J. B. & Thompson, D. B. A. (1993b) A new biogeographical classification of the Scottish Uplands. II. Vegetation-environment relationships. *Journal of Ecology* **81**:231-251.

Buchan, A. & Omond, R. T. eds (1905-10) The meteorology of the Ben Nevis observatories. *Transcripts of the Royal Society of Edinburgh* **Vols 42-44**.

Bührer, W. (1902) Über den Einfluss der Schneedecke auf die Temperatur der Erdoberflèche. *Meteorologiche Zpravy* **19**:205-211.

Caldwell, M. M. (1968) Solar ultra-violet radiation as an ecological factor for alpine plants. *Ecological Monographs* **38**:243-268.

Camden, W. (1789) *Britannica,* 3 vols. London: T. Payne & Son.

Cannon, P. F., Hawksworth, D. L. & Sherwood-Pike, M. A. (1985) *The British Ascomycotina: An annotated checklist.* Kew: Commonwealth Mycological Institute.

Carroll, I. (1865) Contributions to British lichenology; being notices of new or rare species observed since the publication of Mudd's 'Manual'. 1. *Journal of Botany, London* **3**:286-293.

Chapman, D. L. (1950) Ablation in the Scottish Highlands. *Meteorological Magazine* **79**:293-295.

Church, J.M., Coppins, B.J., Gilbert, O.L., James, P.W. & Stewart, N.F. (1997 ['1996'] *Red Data Books of Britain and Ireland: Lichens. Vol 1: Britain.* Peterborough: Joint Nature Conservation Commitee.

Clauzade, G. & Roux, C. (1985) Likenoj de Okcidenta Europo. Illustrita determinlibro. *Bulletin de la Société Botanique du Centre-Ouest Nouvelle série* Numéro Spécial 7:1-893.

Coppins, B. J. (1978) Lichens. In *Breadalbane Survey 1977/78,* Royal Botanic Garden, Edinburgh: 47-62, 63-73. [Manuscript.] Edinburgh: Nature Conservancy Council Scottish Headquaters.

Coppins, B. J. (1979) Lichens. In *Breadalbane Survey 1978/79,* Royal Botanic Garden, Edinburgh: 32-7. [Manuscript.] Edinburgh: Nature Conservancy Council Scottish Headquaters.

Coppins, B. J. (1983) A taxonomic study of the lichen genus *Micarea* in Europe. *Bulletin of the*

British Museum (Natural History), Botany series **11**:17-214.

Coppins, B. J. & James, P. W. (1984) New or interesting British lichens V. *Lichenologist* **16**: 241-264.

Coppins, B. J., Fletcher, A., Gilbert, O. L. & James, P. W. (1986) Field meeting in Sutherland. *Lichenologist* **18**:275-285.

Craig, G. Y (ed.) (1990) *The Geology of Scotland. 3rd ed.*. Edinburgh: Scottish Academic Press.

Creveld, M. (1981) Epilithic lichen communities in the alpine zone of southern Norway. *Bibliotheca Lichenologica* **17**:1-287.

Curl, H., Hardy, J. T. & Ellermeier, R. (1972) Spectral absorption of solar radiation in alpine snowfields. *Ecology* **53**:1189-94.

Dahl, E. (1968) *Analytical Key to British Macrolichens.* London: British Lichen Society.

Dahl, E. & Hadac, E. (1941) Strandgesellschaften der Insel Ost y Oslofjord. Ein Pflanzensoziologische Studie. *Nytt Magasin for Naturvidenskupene B.* **82**:251-312.

Davis, T. D., Abrahams, P. W., Tranter, M., Blackwood, I., Brimblecombe, P. & Vincent, C. E. (1984) Black acid snow in the remote Scottish Highlands. *Nature* **312**:58-61.

Davies, T. D., Vincent, C. E. & Brimblecombe, P. (1982) Preferential elution of strong acids from a Norwegian ice cap. *Nature* **300**:161-163.

Degelius, G. (1956) The lichen flora of calcareous substrata in southern and central Nordland (Norway). *Acta Horti gothoburgensis* **20**:35-56.

Det Norske Meteorologiske Institutt (1960) *Lufttemperaturen i Norge, 1866-1955.* **Vol 1 & 2.**

Dibben, M. J. (1980) The chemosystematics of the lichen genus *Pertusaria* in North America north of Mexico. *Publications Biological and Geological of the Milwaukee Public Museum* **5**:1-162.

Dillenius, J.J. (1742) ['1741'] *Historia Muscorum*. Oxford: Sheldonian Theatre.

Druce, G.C. & Vines, S.H. (1907) *The Dillenium Herbaria.* Oxford: Claredon Press.

Dobson, F. (1981) *Lichens: An Illustrated Guide. 2nd ed.* Richmond: Richmond Publishing Company.

Duncan, U. (1970) *Introduction to British Lichens.* Arbroath: Buncle & Co.

Du Rietz, G. E. (1924) Die Soredian und Isidien der Flechten. *Svensk Botanisk Tidskrift* **18**:371-396.

Dybeck, M. W. & Green, F. H. W. (1955) The Cairngorms weather survey, 1953. *Weather* **10**: 41-8.

Fashelt, D., Maycock, P. F. & Svoboda, J. (1988) Initial establishment of saxicolous lichens following recent glacial recession in Sverdrup Pass, Ellesmere Island, Canada. *Lichenologist* **20**:253-268.

Ferreira, R. E. C. (1959) Scottish mountain vegetation in relation to geology. *Transcripts of the Botanical Society of Edinburgh* **37**:229-250.

Ferry, B. W. & Sheard, J. W. (1969) Zonation of supralittoral lichens on rocky shores around the Dale Peninsula, Pembrokeshire. *Field Studies* **3**:41-67.

Feuerer, T. (1987). Revision Schleswig-Holsteinischer Funde der Flechtengattung *Rhizocarpon. Kierler Notizen Pflanzenkunde Schleswig-Holstein Hamburg* **19**:85-100.

Feuerer, T. (1991). Revision der europèischen Arten der Flechtengattung *Rhizocarpon* mit nichtgelben Lager und vielzelligen Sporen. *Bibliotheca Lichenologica* **39**:1-218.

Fletcher, A. (1973a) The ecology of marine (littoral) lichens on some rocky shores of Anglesey. *Lichenologist* **5**:368-400.

Fletcher, A. (1973b) The ecology of maritime (supralittoral) lichens on some rocky shores of Anglesey. *Lichenologist* **5**:401-422.

Flock, J. W. (1978) Lichen-bryophyte distribution along a snow-cover-soil-moisture gradient, Niwot ridge, Colorado. *Arctic and Alpine Research* **10**:31-47.

Foote, K. G. (1966) The vegetation of lichens and bryophytes on limestone outcrops in the driftless area of Wisconsin. *Bryologist* **69**:265-292.

Foucard, T. (1990). *Svensk Skoplavs Flora.* Stockholm: Interpublishing.

Fowler, S., Cape, J. N., Leith, I. D., Paterson, I. S., KInnard, J. W. & Nicholson, I. A. (1982) Rainfall acidity in northern Britain. *Nature* **297**:383-386.

Frank, E. C. & Lee, R. (1966) Potential solar beam irradiation on slopes: tables for 30-50° latitude. *US Deptartment of Agriculture, Forest Service Research Papers* **RM 18**. 116pp.

Friedel, H. (1952) Gesetze der Niederschlagsverteilung im Hochgebrirge. *Wetter und Leben*

4:73-86).

Fries, T. C. E. (1913) Botanische Untersuchungen im nördlichsten Schweden. *Vetenskaps Och pract. Unders. i. Lappl. Flora Och Fauna 2. Uppsala.*

Fryday, A. M. (1989) *Report on the lichen flora of the Ben Lawers NNR.* [Manuscript] Edinburgh: National Trust for Scotland.

Fryday, A. M. (1990) *An annotated checklist of the lichens recorded from the Ben Lawers NNR.* [Manuscript] Edinburgh: National Trust for Scotland.

Fryday. A. M. (1991a) A microscopic test for confluentic acid. *British Lichen Society Bulletin* **10**:31.

Fryday,A. M. (1991b) *The lichen flora of the Trotternish Ridge SSSI, Isle of Skye.* [Manuscript] Inverness: Nature Conservancy Council for Scotland.

Fryday,A. M. (1991c) *The lichen flora of the Breadalbane Mountains, Perthshire.* [Manuscript] Edinburgh: Nature Conservancy Council for Scotland.

Fryday,A. M. (1991d) *The lichen flora of a fucoid-bed outcrop on Beinn Eighe (including monitoring of* Nephroma arcticum *colonies).* [Manuscript] Inverness: Nature Conservancy Council for Scotland.

Fryday,A. M. (1991e) *A comparative survey of the lichen flora of three areas of maritime heath in East Sutherland.* [Manuscript] Inverness: Nature Conservancy Council for Scotland.

Fryday,A. M. (1992) *Lichen surveys of six NTS properties (including Glen Coe, Balmacara and the Isle of Arran).* [Manuscript] Edinburgh: National Trust for Scotland.

Fryday, A. M. (1993) *Lichen Survey of Glen Coe: A Report for the National Trust for Scotland.* Edinburgh: National Trust for Scotland.

Fryday, A.M. (1995) Night on a bare mountain. *British Lichen Society Bulletin* **76**:30-33.

Fryday, A. M. (1996) A provisional re-assessment of the non-yellow species of *Rhizocarpon* occurring in the British Isles. *British Lichen Society Bulletin* **78**:29-40.

Fryday, A. M. (1997) *Action Plans for Lower Plants: Species Dossiers for Montane Lichens.* Edinburgh: Royal Botanic Garden/Scottish Natural Heritage.

Fryday, A. M. (1996b) The lichen vegetation of some previously overlooked high-level habitats in North Wales. *Lichenologist* **28**:521-541.

Fryday, A. M. (*in prep.*) The *Rhizocarpon obscuratum* group in the British Isles. *Lichenologist.*

Fryday, A. M. & Coppins, A. M. (1994) *Lichen Survey of Torridon: A Report for the National Trust for Scotland.* Edinburgh: National Trust for Scotland.

Fryday, A. M. & Coppins, B. J. (1996a) Three new species in the Catillariaceae from the Central Highlands of Scotland. *Lichenologist* **28**:507-512.

Fryday, A. M. & Coppins, B. J. (1996b) A new crustose *Stereocaulon* from the mountains of Scotland and Wales. *Lichenologist* **28**:513-519.

Fryday, A.M. & Coppins, B.J. (1997) Keys to sterile crustose saxicolous and terricolous lichens occurring in the British Isles. *Lichenologist* **29**:301-332.

Fryday, A. M. & Coppins, B. J. (*in prep.*) *Amelia*: a new lichen genus and two new species from the Scottish Highlands. *Lichenologist.*

Galloway, D. J. (1993) Global environmental change; lichens and chemistry. *Bibliotheca Lichenologica* **53**:87-95.

Gannutz,T. P. (1970) Photosynthesis and respiration of plants in the Antarctic Peninsular area. *Antarctic Journal of the United States* **5**:49-51.

Geiger, R. (1966) *The Climate Near the Ground.* Cambridge, MA: Harvard Univ. Press.

Gilbert, O. L. (1984) Lichens of the magnesian limestone. *Lichenologist* **16**:31-43.

Gilbert, O. L. (1986) Country Diary: A day on Ben Lawers 1986. *British Lichen Society Bulletin* **59**:16-18.

Gilbert, O. L & Coppins, B. J. (1992) The lichens of Caenlochan, Angus. *Lichenologist* **24**:143-163.

Gilbert, O. L & Fox, B. W (1985). Lichens of high ground in the Cairngorm mountains, Scotland. *Lichenologist* **17**:51-66.

Gilbert, O. L & Fox, B. W. (1986) A comparative study of the lichens occurring on the geologically distinctive mountains of Ben Loyal, Ben Hope and Foinaven. *Lichenologist* **18**:79-93.

Gilbert, O.L & Fryday, A.M. (1996) Observations on the lichen flora of high ground in the west of Ireland. *Lichenologist* **28**:113-127.

Gilbert, O.L & Giavarini, V. J. (1993) The lichens of high ground in the English lake District.

Lichenologist **25**:147-164.

Gilbert, O. L., Earland-Bennett, P. & Coppins, B. J. (1978) Lichens of the sugar limestone refugium in upper Teesdale. *New Phytologist* **80**:403-8.

Gilbert, O. L., Fox, B. W. & Purvis, O. W. (1982) The lichen flora of a high-level limestone-epidiorite outcrop in the Ben Alder range, Scotland. *Lichenologist* **14**:165-74.

Gilbert, O. L., Coppins, B. J. & Fox, B. W. (1988) The lichen flora of Ben Lawers. *Lichenologist* **20**:201-43.

Gilbert, O. L., Fryday, A. M., Giavarini, V. J. & Coppins, B. J. (1992) The lichen vegetation of high ground in the Ben Nevis range, Scotland. *Lichenologist* **24**:43-56.

Gjærevoll, O. (1950) The snow-bed vegetation in the surroundings of Lake Torneträsk, Swedish Lapland. *Svensk Botanisk Tidskrift* **44**:387-440.

Gjærevoll, O. (1956) *The Plant Communities of the Scandinavian Alpine Snow-beds.* Trondheim: Bruns Bokhandel.

Gloyne, R. W. (1955) Some effects of shelter-belts and windbreaks. *Meteorological Magazine* **84**:272-81.

Gloyne, R. W. (1967) Wind as a factor in hill climates. In *Weather and Agriculture.* (J. A. Taylor, ed.): 59-67. Oxford: Pergamon.

Gloyne, R. W. (1968) Some climatic influences affecting hill land productivity. In *Hill Land Productivity, British Grasslands Society Symposium no. 4. Aberdeen, 1968* (I.V.Hunt, ed.): 9-15.

Gowan, S. P. (1989) The lichen genus *Porpidia* (Porpidiaceae) in North America. *Bryologist* **92**:25-59.

Gowan, S. P. & Ahti, T. (1993) Status of the lichen genus *Porpidia* in Eastern Fennoscandia. *Annales Botanici Fennici* **30**:53-75.

Green, F. H. W. (1964) The Climate of Scotland. In *The Vegetation of Scotland.* (J. H. Burnett, ed.): 15-35. Edinburgh & London: Oliver & Boyd.

Gregory, S. (1954) Accumulated temperature maps of the British Isles *Publications of the Institute of British Geographers.* **20**:59-73.

Grime, J.P. (1977) Evidence for the existance of three primary stratagies in plants and its relevence to ecological and environmental theory. *Americal Naturalist.* **111**:1169-1194.

Hansen, E. S. (1978) Notes on occurrence and distribution of lichens in south east Greenland. *Meddelelser om Grønland* **Bd.204, Nr.6.**

Harding, R. J. (1978) The variation of the altitudinal gradient of temperature within the British Isles. *Geografiska Annaler Series A* **60**:43-49.

Harding, R. J. (1979a) Radiation in the British uplands. *Journal of Applied Ecology* **16**:161-170.

Harding, R. J. (1979b) Altitudinal gradients of temperature in the Northern Pennines. *Weather* **34**:190-202.

Harrison, S. J. (1973) *An ecoclimatic gradient in north Cardiganshire, west-central Wales.* Unpublished PhD dissertation, Univ. Coll. Wales, Aberystwyth, Dept of Geography.

Hawksworth, D. L. & Rose, F. (1976) *Lichens as Pollution Monitors. [Studies in Biology no. 66]* London: Edward Arnold.

Hawksworth, D.L. & Seaward, M.R.D. (1997) *Lichenology in the British Isles 1568-1975. An Historical and Bibliographical Survey.* Richmond: Richmond Publishing Company.

Hawksworth, D.L., James, P.W. & Coppins, B.J.(1980) Checklist of British lichen-forming, lichenicolous and allied fungi. *Lichenologist* **12**:1-115.

Hertel, H. (1975) Beiträge zur Kenntnis der Flechtenfamilie Lecidieaceae VI. *Hertzogia* **3**:365-406.

Hertel, H. (1995) Schlüssel für die Arten der Flechtenfamilie Lecideaceae in Europa. *Bibliotheca Lichenologica* **58**:137-180.

Hertel, H. & Knoph, J.-G. (1984) *Porpidia albocaerulescens* eine weit verbreitete, doch in Europa seltene und vielfach verkannte Krustenflechte. *Mitteilungen der Botanischen Staatssammlung München* **20**:467-488.

Hertel, H. & Rambold, G. (1990) Zur Kenntnis der Familie Rimulariaceae (Lecanorales). *Bibliotheca Lichenologica* **38**:145-189.

Hill, M. O., Evans, D. F. & Bell, S. A. (1992) Long-term effects of excluding sheep from hill pastures in North Wales. *Journal of Ecology* **80**:1-13.

Hoffman, F. R., Nowak, & Winkler, S. (1974) Substrate depenence of calcareous and silicate rock inhabiting lichens of the Island. CIOVO, Yugoslavia. *Journal of the Hottori Botanical*

Laboratory **38**:313-325.

Hooker, T. N. (1980) Factors affecting the growth of Antarctic crustose lichens. *British Antarctic Survey Bulletin* **50**:1-19.

Hooker, W.J. (1821) *Flora Scotica*. Vol. 2. London: Constable

Hough, A. M. (1986) *Acid Deposition at Elevated Sites, a Review.* Harwell, United Kingdom Atomic Energy Authority.

Jahns, M. J. (1983) *Collins Guide to Ferns, Mosses & Lichens of Britain and North and Central Europe*. London: Collins.

James, P.W. (1965) Field meeting in Scotland. *Licehnologst.***3**:155-172.

James, P.W. (1976) *A lichen survey of north-west Sutherland.* Manuscript. Report to the World Wildelife Fund.

James, P. W. & White, F. J. (1987) Studies on the genus *Nephroma* I. The European and Macaronesian species. *Lichenologist* **19**:215-268.

James, P. W., Hawksworth, D. L. & Rose, F. (1977) Lichen communities in the British Isles: a preliminary conspectus. In *Lichen Ecology* (M.R.D.Seaward, ed.): 296-413. London, New York, San Francisco: Academic Press.

John, E. (1989) An assessment of the role of biotic interactions and dynamic processes in the organization of species in a saxicolous lichen community. *Canadian Journal of Botany* **67**:2025-2037.

Johnson, W. (1881) The lichens of Cumberland. *Transactions of the Cumberland Association for the Advancement of Science* **6**:129-157.

Kappen, L. (1973) Response to Extreme Environments. In *The Lichens* (V. Ahmadjian & M. E. Hale, eds): 381-400. London, New York & San Francisco: Academic Press.

Kershaw, K. A. (1983) The thermal operating-environment of lichens. *Lichenologist* **15**:191-207.Kershaw, K. A. (1985) *Physiological Ecology of Lichens*. Cambridge: Cambridge University Press.

Kimble, G. (1951) *The Weather.* London: Penguin Books.

Knoph, J.-G. (1984) Vorarbeiten zu eine Monographie der euthallinen Arten der Flechten gattung *Porpidia* (Porpidiaceae, Lecanorales) Europas, mit besonderer Berücksichtigung des Alpengebietes. *Institut für Systematische Botanik der Universität München.*

Knowles, M.C. (1929) The lichens of Ireland. *Proceedings of the Royal Irish Academy.* **38B**:179-434.

Körber, G. W. (1861). *Parerga Lichenologica.* Breslau.

Kreutz, W. (1938) Das Windschutzproblem. *Bioklimetische Beiblätter der Meteorologischen Zeitschrift* **5**:10-16.

Lange, O. L. (1965) Der CO2-Geswechsel von Flechten bei tiefen Temperaturen. *Planta* **64**: 1-19.

Lange, O. L. (1966) CO2 Geswechsel der Flechte *C. alicornis* nach langfrisigem Aufenthalt bei tiefen Temperaturen. *Flora Jena* **156**:500-502.

Larson, D. W. (1980) Patterns of species distribution in an *Umbilicaria* dominated community. *Canadian Journal of Botany* **58**:1269-1279.

Larson, D. W. & Kershaw, K. A. (1975) Studies on lichen-dominated systems. XI. Lichen heath and winter snow cover. *Canadian Journal of Botany* **53**:621-626.

Laundon, J. R. (1986). Studies in the nomenclature of British lichens II. *Lichenologist* **18**:169-177.

Lawrey, J.D. (1991) Biotic interactions in lichen community development: a reweiw. *Lichenologist* **23**:205-214.

Leighton, W. A. (1869) Notulae Lichenologicae No. XXX. Further notes on the lichens of Cader Idris, North Wales. *Annales and Magazine of Natural History, series 4* **4**:201-5

Longton, R. E. (1988) *The Biology of Polar Bryophytes and Lichens.* Cambridge: Cambridge University Press.

Mackenzie-Lamb, I. (1940). Lichenological Notes from the British Museum Herbarium - IV. *Rhizocarpon* sect. *Catocarpon* in the British Isles. *Journal of Botany* **78**:129-138.

Mani, M. S. (1962) *Introduction to High Altitude Entomology. 1-73.* London: Methuen.

Manley, G. (1943) Further climatological averages for the northern Pennines, with a note on topographical effects. *Quarterly Journal of the Royal Meteorological Society* **69**:251-61.

Manley, G. (1971) Scotland's semi-permanent snows. *Weather* **26**:458-71.

Mardon, D. (1987) *A Botanical Training Visit to Norway, 1986.* (Manuscript) Edinburgh:

National Trust for Scotland.

Martindale, J.A. (1886- 1890) The lichens of Westmoorland. *Naturalist, Hull*

Mayrhofer, H. & Poelt, J. (1985) Die flechtengattung *Microglaena* sensu Zahlbruckner in Europa. *Herzogia* **7**:13-79.

McClatchey, J. (1996) Spatial and altitudinal gradients of climate in the Cairngorms - Observations from climatological and automatic weather stations. *Botanical Journal of Scotland* **48**:31-49.

McVean, D. N. (1955) *Nephromium arcticum* (L.) Fr., a lichen new to Britain. *Transcripts of the British Mycological Society* **38**:213-216.

McVean, D. N. (1963) Snow cover in the Cairngorms 1961-62. *Weather* **18**:339-42.

McVean, D. N. & Ratcliffe, D. A. (1962) *Plant Communities of the Scottish Highlands.* (*Monographs of the Nature Conservancy No 1*). London: H.M.S.O.

Meteorological Office (1952) *Climatological Atlas of the British Isles.* London: Meteorologial Office.

Meteorological Office (1975a) Maps of mean and extreme temperature over the U.K. 1941-1970. *Climatological Memoranda* **73**.

Meteorological Office (1975b) Maps of mean vapour pressure and of frequencies of high relative humidities over the U.K. 1941-1970. *Climatological Memoranda* **75**.

Meteorological Office (1984) Climate of Great Britain: Wales. *Climatological Memoranda* **140**.

Muhr, L.-E. & Tønsberg, T. (1989) *Rimularia fuscosora*, a new corticolous, sorediate lichen from north western Europe. *Nordic Journal of Botany* **8**:649-652.

Müller, H. G.(1953) Zur Wärmebilanz der Schneedecke. *Meteorologische Rundschau* **6**:149-143.

Niebel-Lohmann, A. & Feuerer, T. (1992) Die Gettung *Pertusaria* (*Lichenes*) in Schleswig-Holstein. Morphologie, Taxonomie und Verbreitung. *Mitteilungen aus dem Institut für Allgemeine Botanik in Hamburg* **24**:199-252.

Nimis, P. L. (1991). Developments in lichen community studies. *Lichenologist* **23**:215-115.

Nimis, P. L. (1993) *Monografie 12: The Lichens of Italy - an annotated catalogue.* Torino: Museo Regionale di scienze Naturali.

Nordhagen, R. (1928) *Die vegetation und flora des Sylengebietes. Skrifter utgitt av Det Norske Videnshaps-Akademi.* Oslo: Dyburad.

Nordhagen R. (1936) Versuch einer neuen Einteilung der subalpinen-alpinen Vegetation Norwegens. *Bergens Museums Årbok 1936. Nr 7.*

Nyberg, . (1938) Temperature measurements in an air layer very close to a snow surface. *Geografiska Annaler* **20**:234-275.

Oke, J. (1972) *Boundary Layer Climates.* London: Methuen.

Oliver, J. (1960) Upland climates in South Wales. In *Hill Climates and Land Usage.* (J. A.Taylor, ed.): 6-14. Aberystwyth: Univ. Coll. Wales, Dept of Geography.

Oliver, J. (1964) A study of upland temperatures and humidities in South Wales. *Transcriptions of the Institute of British Geographers* **35**:37-54.

Orange, A. (1995) The British species of *Lepraria* and *Leprolema*: chemistry and identification. *British Lichen Society Bulletin* **16**:1-9.

Pearsall (1950) *Mountains and Moorland.* London: Collins.

Pentecost, A (1980) The lichens and bryophytes of rhyolite and pumice-tuff rock outcrops in Snowdonia, and some factors affecting their distribution. *Journal of Ecology* **68(1)**:251-267.

Pentecost, A. (1987) The lichen flora of Gwynedd. *Lichenologist* **19**:97-166.

Perry, A. H. (1976) Synoptic Climatology. In *The Climate of the British Isles* (T. J. Chandler & S. Gregory eds): 9-38. London: Longmans.

Poelt, J. (1994) Different species types in lichenized asomycetes. In *Ascomycete Sysematics: Problems and Perspectives in the Nineties* (D.L. Hawksworth ed.):273-278. New York: Plenum Press.

Poelt, J & Vezda, A (1981). Bestimmungsschlüssel europäischer Flechten. Ergänzungsheft II. *Biblitheca Lichenologica* **16**:1-390.

Poore, M. E. D. (1954a) The use of Phytosociological methods in ecological investigations. I. The Braun-Blanquet system. *Journal of Ecology* **43**:226-244.

Poore, M. E. D. (1954b) The use of Phytosociological methods in ecological investigations. II. Practical issues involved in an attempt to apply the Braun-Blanquet system. *Journal of*

Ecology **43**:245-269.

Poore, M. E. D. & McVean, D. N. (1957) A new approach to Scottish mountain vegetation. *Journal of Ecology* **45**:401-439.

Praeger, R.L. (1934) *The Botanist in Ireland.* Dublin: Hodges Figgis.

Pruitt, W. O. (1978) *Boreal Ecology.* London:Arnold.

Purvis, O. W. & James, P. W. (1985) Lichens of the Coniston Copper Mines. *Lichenologist* **17**:221-237.

Purvis, O. W. & Halls, C. (1996) A review of lichens in metel-enriched environments. *Lichenologist* **28**:571-601.

Purvis, O. W., Coppins, B. J. & James, P. W. (1993) Checklist of lichens of Great Britain and Ireland. *British Lichen Society Bulletin* **72 (Supplement)**:1-75.

Purvis, O. W., Coppins, B. J., Hawksworth, D. L., James, P. W. & Moore, D. M. (1992) *The Lichen Flora of Great Britain and Ireland.* London: Natural History Museum.

Ramdas, L. A.(1946) The micro-climate of plant communities. *Indian Ecology* **1**:1-20.

Ratcliffe, D. A. (1977) *A Nature Conservation Review, 2 vols.* Cambridge: Cambridge University Press.

Ratcliffe, D. A. (1991) The mountain flora of Britain and Ireland. *British Wildlife* **3**:1-21.

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

Raven, J. & Walters, M. (1956) *Mountain Flowers.* London: Collins.

Rawes, M. (1981) Further results of excluding sheep from high-level grasslands in the Northern Pennines. *Journal of Ecology* **69**:651-669.

Rawes, M. (1983) Changes in two high-level blanket bogs after the cessation of sheep grazing. *Journal of Ecology* **71**::219-235.

Ray, J. (1696) *Synopsis methodica stirpium Britannicarum.* 2nd Edition. London.

Riddelsdell, H.J. (1905) Lightfoot's visit to Wales in 1773. *Journal of the Botanical Society of London* **43**:290-307.

Rikkinen, J. (1995) What's behind the pretty colours? A study on the photobiology of lichens.

Bryobrothera **4**:1-239.

Rodgers, R.W. (1990) Ecological strategies in lichens. *Lichenologist* **22**:149-162.

Rodwell, J. S., ed. (1990) *British Plant Communities. 1: Woodlands and Scrub.* Cambridge: Cambridge University Press

Rodwell, J. S., ed. (1991) *British Plant Communities. 2: Mires and Heaths.* Cambridge: Cambridge University Press.

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

Rose, F. (1976) Lichenological indicators of age and environmental continuity in woodlands. In *Lichenology: Progress and Problems* (D. H. Brown, D. L. Hawksworth & R. H. Baily, eds): 279-307. London: Academic Press.

Rose, F. (1992) Temperate Forest Management: its effects on bryophyte and lichen floras and habitats. In *Bryophytes and Lichens in a Changing Environment.* (J. W. Bates & A. M. Farmer, eds):211-233. Oxford: Oxford University Press.

Rothero, G. P. (1990) *Survey of bryophyte-dominated snow-beds, 1989: The Cairngorms and Aonach Mór.* (Unpublished Report). Edinburgh: Nature Conservancy Council.

Rothero, G. P. (1991a) *Survey of bryophyte-dominated snow-beds.; Part two, 1990.* (Unpublished Report). Edinburgh: Nature Conservancy Council.

Rothero, G. P. (1991b) *Bryophyte-dominated Snow-beds in the Scottish Highlands.* MSc thesis, University of Glasgow.

Roux, C. (1990) Echantillonage de la végétation lichénique et approche critique des méthodes de relevé. *Cryptogamie, Bryologie et Lichenologie* **11**:95-108.

Samuelsson, G. (1917a) Studien über die Vegetation der Hochgebirgogenden von Dalarne. *Nova Acta Regiae Societatis Scientiarum Upsaliensis Seria IV.* **4**: Nr. 8.

Samuelsson, G. (1917b) Studien über die Vegetation bei Finne in inneren Hardanger. *Nytt Magasin foer Naturvidenskapene*, **55**.

Santesson, R. (1993) *The lichens and lichenicolous fungi of Sweden and Norway.* Lund: SBT-förlaget.

Sauberer, F. & Dirmhirn, I. (1958) Das Strahlungsklima. In: *Klimatographie von Osterreich.*

3(1):13-1102. Vienna:Osterreichische Akademie der Wissenschafen, Denkschrift.

Schreiner, E. & Hafellner, J. (1992) Servediose, corticole Krustenflechten im Ostalpenraum. 1. Die Flechtenstoffe und die gesicherte Verbreitung der besser bekannten Arten. *Bibliotheca Lichenologica* **45**:1-291.

Schwab, A. J. (1986) Rostfärbene Arten der Sammelgattung *Lecidea* (Lecanorales) Revision der Arten Mittel- und Nordeuropas. *Mitteilungen der Botanischen Staatssammlung München* **22**:221-476.

Scott, M. G. & Larson, D. W. (1985) The effect of winter field conditions on the distribution of two species of *Umbilicaria*. 1:CO2 exchange in reciprically transplanted thalli. *New Phytologist* **101**:89-101.

Shreve, F. (1924) Soil temperature as influenced by altitude and slope exposure. *Ecology* **5**:128-36.

Sipman, H. J. M. (1983) A monograph of the lichen family *Megalosporaceae. Bibliotheca Lichenologica* **18**:1-241.

Smith, L. P. (1950) Variations of mean air temperature and hours of sunshine on the weather slope of a hill. *Meteorological Magazine* **79**:231-3.

Stace, C. (1991) *New Flora of the British Isles.* Cambridge: Cambridge University Press.

Stocker, O. (1923) Klimamessungen auf kleinstem Raum an Wiessen-, Wald-, und Heidepflanzen. *Berichte Deutsche Botanische Gesellschaft* **41**:145-50.

Stocker, O. (1931) Transpiration und Waserhaushalt in verschiedener Klimazonen. 1. Untersuchungen an der arktischen Baumgrenze in Schwedisch-Lappland. *Jahrbuecher fuer Wissenschaftliche Botanik* **75**:494-549.

Sugden, D. E. (1977) Did glaciers form in the Cairngorms in the 17th and 18th centuries? *Cairngorm Club Journal* **18**:189-201.

Taylor, J. A. (1976) Upland climates. In *The Climate of the British Isles* (T. J. Chandler & S. Gregory, eds): 9-38. London: Longmans.

Tehler, A. (1983) The genera *Dirina* and *Roccellina* (*Roccellaceae*). *Opera Botanica* **70**:1-86.

Thompson, D. B. A. & Brown, A. (1992) Biodiversity in montane Britain: habitat variation, vegetation diversity and some objectives for conservation. *Biodiversity and*

Conservation **1**:179-208.

Thompson, D. B. A., Galbraith, H. & Horsfield, D. (1987) Ecology and resourses of Britain's mountain plateaux: land use conflicts and impacts. In *Agriculture and Conservation in the Hills and Uplands,* (M. Bell & R. G. H. Bunce, eds) 22-31. Grange-over-Sands: Institute of Terrestrial Ecology.

Timdal, E. (1984) The delimitation of *Psora* (Lecideaceae) and related genera, with notes on some species. *Nordic Journal of Botany* **4**:525-540.

Timdal, E. (1986) A revision of *Psora* (Lecideaceae) in North America. *Bryologist* **89**:253-275.

Timdal, E & Holten-Hartwig, J (1988). A preliminary key to *Rhizocarpon* in Scandinavia. *Graphis Scripta* **2**:41-54.

Tønsberg, T. (1992) The sorediate and isidiate corticolous crustose lichens in Norway. *Sommerfeltia* **14**:1-331.

Turner, D. & Dillwyn, L.W. (1805) *The Botanist's Guide through England and Wales,* 2 vols. London: Phillips & Fardon.

Turner, H. (1958) Maximaltemperaturen oberflèchennèher Bodenschichten an der alpinen Walgrenze. *Wetter und Leben* **10**:1-12.

Turner, H. (1980) Types of micro-climate at high elevations. In *Mountain Environments and Sub-alpine Tree Growth.* Tech. Pap. No. 70, Forest Res. Inst. (U. Benecke & M.R. Davies, eds): 1-26. Wellington: , New Zealand Forest Service.

Vestergren, T. (1902) Om den olikformiga snöbetäckningens inflytande pä vegetationen i Sarjekfjällen. *Botaniska Notiser Lund.*

Walton, D. W. H. (1984) The Terrestrial Environment. In *Antarctic Ecology* (R. M. Laws, ed.) vol. **1**:1-60. London: Academic Press.

Warren-Wilson, J. (1959) Notes on wind and its effect in arctic-alpine vegetation. *Journal of Ecology* **47(2)**:415-427.

Watson, W. (1925) The bryophytes and lichens of arctic-alpine vegetation. *Journal of Ecology* **13**:1-26.

Weller, C. & Holmgren, C. (1974) The microclimate of the Arctic tundra. *Journal of Applied Meteorology* **13**:854-862.

Wheldon, J.A. & Wilson, A. (1915) The lichens of Perthshire. *Journal of Botany, London.* **53, *Supplement***:1-73.

Whitehead, F. H. (1951) Ecology of the altipiano of Monte Maiella, Italy. *Journal of Ecology* **39**:330-55.

Whitten, D. G. A. & Brooks, J. R. V. (1972) *The Penguin Dictionary of Geology.* London: Penguin Books.

Wirth, V. (1972) Die Silikatflechten-Gemeinschaften im ausseralpinen Zentraleuropa. *Dissertationes Botanicae* **17**:1-306.

Wirth, V. (1987). *Die Flechten Baden-Württembergs.* Stuttgart, E. Ulmer.

Wirth, V. (1995). *Die Flechten Baden-Württembergs.* Stuttgart, E. Ulmer.

Wolfe, J. N., Wareham, R. T. & Scofield, H. T. (1949) Microclimates and macroclimate of Neotoma, a small valley in central Ohio. *Bulletin of the Ohio Biological Survey.* **8, no. 1**:1-267.

Wong, P. Y. & Brodo, I. M. (1973) Rock-inhabiting lichens of the Frontenac Axis, Ontario. *Canadian Field Naturalist* **87**:255-259.

Woodin, S. J. (1988) Acidic deposition and upland conservation: an overview and the way ahead. In *Ecological Change in the Uplands* (M.B. Usher & D.B.A. Thompson eds): 355-363. Oxford: Blackwell Scientific Publications.

Woolhouse, M.E.J., Harmsen, R. & Fahrig (1985) On succession in saxicolous lichen commnities. *Lichenologist* **17**:167-172.

Yarrington, G. A. & Green, W. G. E. (1966) The distribution pattern of crustose lichens on limestone cliffs at Rattlesnake Point, Ontario. *Bryologist* **69**:450-461.