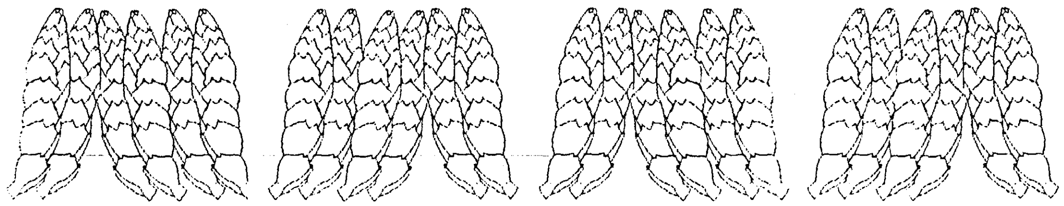
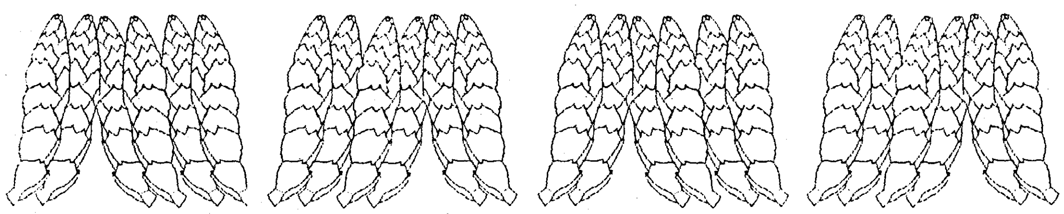


BRYOPHYTE-DOMINATED SNOW-BEDS IN THE SCOTTISH HIGHLANDS



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CONTENTS

The Bryophyte-dominated snow-beds of the Scottish Highlands

Summary

This study presents a report on the flora of the most extreme of the areas of late snow lie in the Scottish Highlands where bryophytes tend to dominate the vegetation. 58 snow-bed sites were surveyed throughout the Highlands and all phanerogams and bryophytes recorded along with their relative abundance; examples of these surveys are given in an appendix. In addition, the vegetation on 141 samples was recorded along with various environmental factors. The sample and site data were then analysed using TWINSPAN and DECORANA to produce a classification and ordination of both snow-bed sites and snow-bed plant communities.

The site classification produced a division into four groups of sites which is broadly based on habitat differences between snow-beds in deep, craggy coires and those on more open plateau sites, and on climatic differences between those sites in the oceanic western hills and those in the relatively more continental east. The physical character of the sites is described as is the climate they experience, particularly the effects of snow accumulation and these factors are related to the vegetation. A number of rare species occur in the snow-beds and the status of these in

Britain and Europe is indicated. The small size of the sites and thus the very small total area of this habitat is demonstrated and some conservation priorities suggested.

From the classification and ordination of the samples, three bryophyte dominated snow-beds are proposed and described: the *Polytrichum sexangulare - Kiaeria starkei* snow-bed, the *Marsupella brevissima - Anthelia juratzkana* snow-bed and the *Pohlia ludwigii* snow-bed. In addition three further chionophilous communities are described and linked to fuller explanations in the National Vegetation Classification - the *Carex bigelowii - Polytrichum alpinum* sedge heath, the *Deschampsia cespitosa - Galium saxatile* grassland and the *Pohlia wahlenbergii var glacialis* spring. The plant associations described are compared with previous work on snow-bed vegetation in the Scottish Highlands and the similarity between, and relative poverty of, Scottish snow-beds and those on acid soils in Europe, particularly Scandinavia, is indicated.

1. Introduction

1.1. Snow-fall and snow-melt.

The vegetation types of the Scottish Highlands have attracted the attention of various workers since the turn of the century, the most complete surveys being those of McVean and Ratcliffe (1962) and the Nature Conservancy Council's National Vegetation Classification (Rodwell 1987). Both of these surveys emphasise the importance of the differential deposition, accumulation and melting of snow in determining the pattern of vegetation in the mountains and in this emphasis they follow Scandinavian and Central European phytosociologists (Braun-Blanquet 1913; Rübel 1912; Gjaerevoll 1956; Dahl 1956). The fact of unequal distribution of snow will be apparent to anyone who has walked in the mountains in winter and it has its origin in a complex process of deposition and redeposition, both during and after snowfall. Wind is the agent of erosion and transport, the stronger the wind the more snow will be moved. On a cold, windy day after recent snow fall, the observer will note incessant snakes of wind-blown snow at ankle level and occasionally will be enveloped in a maelstrom of snow and ice particles in the strongest gusts. In a full gale the air is full of ice particles and even the process of drawing breath becomes problematic.

The ice crystals are redeposited in those areas where the wind energy decreases, on lee slopes that exist in hollows and coires. As the stronger winds tend to be reasonably consistent in direction, usually from the west or south-west (Manley 1952), this process leads to the accumulation of snow, year after year, in the same areas, particularly those with an easterly or north easterly aspect. The other side of this process is the stripping away of much of the snow from the more exposed parts of the hills. The redistribution of snow means that, when melting begins, the first areas to be snow free are the most exposed sites with a southerly aspect, both because of the higher insolation and because large accumulations of snow are unusual on slopes of this aspect. The melt will proceed on this basis, gradually freeing larger areas of snow depending on aspect and snow accumulation, until the next snowfall.

The redistribution of snow means that figures for the number of days with snow lying in the Highlands (Page 1982, p.57) only reveal a part of the story. The Scottish Highlands have an oceanic climate with limited annual variation in temperature and a high precipitation spread fairly evenly throughout the year (Page 1982, p.48; Manley 1952). On the highest hills this precipitation can occur as snow at any time of the year but significant snow-fall is limited to the months between October and April. During this period some days or even weeks of complete snow cover on the mountains are to be expected (Green 1968) and the duration of this period will depend on the general weather pattern. In a normal winter the general snow cover will disappear with the onset of mild Atlantic weather systems moving in from the west; mild, wet and windy weather, typically associated with the warm front of an Atlantic depression, is very efficient at removing snow, much more so than the 'warm day - cold night' type of weather which may occur in the spring.

The snow line varies markedly during the winter, even in the Cairngorm mountains, despite their large area of high ground and relatively continental climate. Records over the period 1941 - 1970 show that there was a general snow cover for more than 100 days per year in the Cairngorms (Green 1968) but these statistics mask the fact that snow cover experienced by the vegetation, because of the processes outlined above, may last for only a few days or for most of the year.

1.2. Snow-fall and vegetation

The redistribution of snow and the cycle of snowfall and thaw have a profound effect on the pattern of vegetation in the Scottish mountains. Snow cover provides an excellent thermal blanket and a cover of as little as 20cms will provide a buffer against the diurnal variation in temperature apparent at the snow surface (Geiger 1959) and minimum temperatures at the soil surface will normally be close to

$0^{o}C$ or a few degrees below (Dahl 1956). Plants are protected from frost damage during the period when this hazard is most severe and in the spring, the cold covering will prevent premature flushing in a period when longer, warmer days are often combined with sharp night frosts. A good illustration of this is provided by the fern *Athyrium distentifolium* which is frost sensitive and yet forms sometimes extensive stands in areas of late snow lie (Page 1988).

Persistent snow cover will lead to a curtailment of the growing season so an increasing number of plants will be unable to survive as the length of snow lie increases. The moisture regime within the areas of snow lie and on slopes below them will also be affected as precipitation is made available more evenly as a result of snow melt. Plants under snow are also protected from physical damage by wind blown sand and ice particles, damage which can be very severe given the windy nature of the Scottish mountains; winds in excess of 125 knots have been recorded on Cairngorm summit (Green in Nethersole Thompson and Watson 1981) and paint is rapidly stripped from equipment placed in exposed spots, both by sand and wind-blown ice particles. Another facet of this process is the accumulation of wind blown mineral and plant debris on the surface of snow patches and thus providing a 'top dressing' for the vegetation below after thawing. This may also be an important means of dispersal for bryophyte fragments which can propagate and establish new populations.

Plants growing in areas that are stripped clear of snow will have none of these buffering effects and need to contend with large temperature variations in the soil and, on higher sites, the cryoturbation that occurs as a result of this (Dahl 1956). Such sites tend to be on ridges or open slopes with a southerly aspect and so are exposed to the desiccating effects of the wind, without the benefit of snow melt, thus the vegetation must have the capacity to endure spells of physiological drought.

Though the process of snow accumulation and eventual melting reveals snow patches of a similar pattern year after year, sufficiently so for some of them to acquire local names, variation in snow depth and duration of snow lie is continuous and very complex. On any one day during the winter or spring, the boundaries between the areas that have snow and those that do not are precise but the average effect of snow lie, as revealed by the pattern of vegetation, shows no hard divisions. The plant populations which make up the vegetation exhibit a continuum from the more exposed, snow free areas to those where snow lies longest. This gradual effect of late snow lie may occur over a short gradient, particularly where there is a sharp break in slope and can be beautifully illustrated in the Cairngorms and other hills in the Northern Highlands by looking at cushions of *Silene* *acaulis*, a plant which copes with both exposed sites and sites with moderately late snow lie. Plants on the exposed sites have set seed while those near remaining snow have flowers not yet open and on the slope in between there are plants at intermediate stages.

While acknowledging the continuous nature of the change in the pattern of vegetation, the process of description necessitates the imposition of limits and the attaching of labels. Plants and plant communities which exhibit a preference for sites that are free of snow much of the time are termed chionophobous while those that exhibit a preference for sites where snow persists are termed chionophilous. Sites that contain chionophilous plant communities are termed snow beds, whether or not they contain snow at the time. In their monograph, McVean and Ratcliffe (1962) identify 22 chionophilous noda (their basic vegetation unit) in the Scottish Highlands. To put this in context, Gjaerevoll in his work on Scandinavian snow bed vegetation (Gjaerevoll 1956) describes over 100 snow-bed sociations; though the designation of plant communities as chionophilous and the basic vegetation units may differ slightly, the relative poverty of Scottish snow-bed vegetation is clear.

Areas in snow-beds with roughly comparable snow cover regimes may have different plant communities because of other important physiological factors such as the base status of the soil, the moisture regime, substrate size, soil stability, slope and aspect. All these factors as well as the length of snow cover can vary considerably over short distances within even a small snow bed and this is reflected in the pattern of vegetation which can be very complex, particularly in those snow beds with a range of snow cover. No detailed work has been undertaken in Scotland to examine the relationship between length and depth of snow cover and existing plant communities but the broad effects are generally accepted and these are expressed in McVean and Ratcliffe (1962). In the Cairngorms, where this sequence is best developed, the change with increasing snow cover is from *Vaccinium* heath with *Empetrum hermaphroditum* to *Nardus* grassland with *Scirpus caespitosa*, then to dwarf herb communities with patchy grass or sedge cover and finally to communities dominated by bryophytes (Ratcliffe in Nethersole-Thompson and Watson, 1981). Similar communities with similar relationships occur in Scandinavia, especially in the more oceanic area of western Norway, but are largely absent from the Alps.

1.3. Distribution of snow-bed vegetation in Britain

The distribution of chionophilous communities in Britain reflects the distribution of high ground and the south to north gradient apparent in the number of days with lying snow (Page, 1982). So, although a number of the species typical of chionophilous communities occur in the mountains of North Wales, snow cover is too unreliable here to have an effect on the vegetation. Snow cover is more persistent on the Lakeland fells and particularly on the highest part of the northern Pennines but again there are no definite snow bed communities. McVean and Ratcliffe mention small areas of chionophilous vegetation in the 800m high Moffat Hills in the Southern Uplands, an area where the number of days with lying snow is less than in the northern Pennines, indicating the importance local physiographic and climatic effects.

Snow-influenced vegetation is widespread in the Scottish mountains except on the most oceanic hills of the extreme west. It has a rather limited occurrence in the most southerly hills and reaches its most extensive development in the Central Highlands, the band of mountains, often between 1000m and 1300m in height, which stretches from Glencoe in the west to Lochnagar and Ben Avon in the east. The bryophyte-dominated snow-bed communities which form the subject of this study have an even more restricted distribution as they depend on a reliable snow cover for a much more extended period. Again, no data exist on the precise relationship between the existence of bryophyte-dominated snow-beds and the length of snow lie but observation of late lying snow patches, which have been objects of interest for many years, and with which these communities are always associated, suggests that persistence of snow cover until the beginning of June in an average year is a necessary condition for their occurrence. The climatic and topographical conditions which produce patches of snow that persist into early summer and beyond are reasonably clear. The critical factors seem to be aspect, altitude, the presence of a significant break in slope and the existence of a sufficient area of high ground to provide the source of lying snow for erosion, transport and redeposition and these are dealt with in some detail below.

1.4. Importance of late snow-beds

The vegetation of these late snow beds is of considerable interest for several reasons. Plant communities dominated by bryophytes are unusual and tend to indicate extreme conditions which limit the growth of vascular plants; another British example would be the ombrotrophic mire communities of the north and west. These snow beds also provide a link to the more extensive arctic- alpine vegetation of continental Europe and show some affinities to more definitely arctic communities. They contain a number of species which are of extremely limited distribution in Britain and Europe, including several which will be in the British Bryophyte Red Data Book (Stewart in prep) and some which are considered to be endangered in Europe (Schumacker 1988). The vegetation appears to be natural in the sense that anthropogenic factors can have played little part in its development and present condition as there is little to attract large grazing animals and the sites are too high and too remote to be subject to management. One proviso here is that snowflakes are effective scavengers of atmospheric pollutants and any process which concentrates snowfall presumably also concentrates these pollutants, which are then released as the snow melts (Woodin 1988). There is at least the possibility that this may be a modifying effect though no investigation of this has yet been undertaken. The late snow bed vegetation is dependant upon snow fall in conjunction with wind pattern and topography; few plant communities have such a simple relationship with climate. Any change in snow cover and its reliability as a result of changes in weather patterns due to global warming, will be followed by relatively rapid changes in the composition of late snow bed vegetation which would appear to have little if any inherent buffering capacity.

1.5 Previous work on Scottish snow-bed bryophytes

Despite these points of interest, bryophyte-dominated snow beds have received little detailed attention from bryologists in the past. Both Macvicar (1910) and Smith (1912) described bryophyte communities from areas of late snow lie which demonstrate that the interest of the habitat had been recognised. Watson (1925) in his description of the bryophyte and lichen vegetation on Ben Lawers also produced lists of bryophytes from snow-beds. The works of Poore (1955), McVean and Ratcliffe (1962) and most recently the National Vegetation Classification (Rodwell, 1987) all include bryophyte communities but the major thrust of all three analyses precluded a thorough treatment of these small areas. All these treatments of bryophyte-dominated snow-beds are discussed more fully in Chapter 4.9.

This relative lack of interest could have several causes. The sites are generally small in size and remote from the nearest road and by their nature attract the worst weather; worthwhile study will often involve a bivouac and some fortitude in the face of the elements. Perhaps more important are the problems of identification posed, for, while some species are readily identifiable in the field, others involve a degree of familiarity with both the whole range of species within a genus and also the plasticity of some common species which also occur in this extreme habitat. Also of importance must be that, in the past, these sites have been considered to be under little threat in conservation terms.

1.6 The scope of the study

The aims of this study, which was funded by the Nature Conservancy Council are:-

1) To describe the range of bryophyte dominated snow bed sites in the Scottish Highlands and the species that occur on them,

2) to describe the bryophyte communities that make up the vegetation and relate these to the descriptions already in existence for this country and for similar habitats in Europe.

3) to give a brief description of the frequency of occurrence of bryophyte species that seem to be restricted to, or have most of their known British sites, in extreme snow beds and to discuss the importance of snow bed sites in conservation terms.

2. Methods

2.1 Site Selection

Patches of late lying snow can be seen on many of the higher hills throughout the Scottish Highlands and a comprehensive survey would be a considerable undertaking. Many of these patches are not consistently late lying from year to year and the dominant vegetation is composed of vascular plants, normally with a strong bryophyte understory and of fragmented stands closely allied to the bryophyte communities of the more extreme snow beds. Only those areas with sites having extensive areas of bryophyte dominated vegetation were considered.

There were several constraints on site selection; as the survey was funded by the Nature Conservancy Council the itinerary of sites had to be agreed with them but in practice this affected the timing of surveying rather than the selection of sites. Time was a major constraint as only two summer periods were available for the work and work could not begin until sufficient snow melt had occurred to uncover a large enough proportion of the site to make a survey of the vegetation a meaningful exercise. In practice this meant that surveying could not begin until the second half of July and even then the chance occurrence of unusually late snow lie in the summer of 1990 caused problems. The usual pattern of snow melt means that snow patches continue to decay well into the autumn but fresh lying snow is possible from the beginning of September onwards. All the higher western hills had a few inches of snow in the first week of September, 1990. These early snow falls rarely persist long but further limit the time period available for survey.

The other constraint was the desire to have both a reasonable geographic spread of sites and sufficient coverage of the largest and most important sites. These aims are somewhat contradictory and relatively large late snow bed sites in the Cairngorms and in the Central Highlands were missed out in order to survey more marginal sites in other areas. Snow beds are always high up in the hills and often far from vehicular access, to the extent in some cases of requiring one or two nights camping or bivouacking. This meant that there were logistical constraints also on the time available for fieldwork and on the possibility of repeat visits.

A list of possible sites was compiled using my own knowledge of areas of late lying snow, field notes on Highland plant communities compiled by D. A. Ratcliffe (1956-59) and annotated maps and aerial photographs produced by the Upland Survey Unit of the Nature Conservancy Council in Scotland. This list was then modified in the light of the constraints outlined above and final selection for a full survey left to an on the spot decision. Despite the imponderables involved in this selection process only one area scheduled for survey was omitted, a casualty of the early snow fall in September, 1990.

2.2 Site Survey

Having decided upon a list of areas to be visited, the next crucial decision was on what to include, that is what sites were worthy of survey and what criteria were to be used to determine their boundaries. The problems involved in making this decision are discussed below but the minimum requirement was a sufficient area of bryophyte dominated vegetation, not necessarily continuous, containing populations of various indicator species. In practice, four indicator species were used, bryophytes acknowledged as occurring exclusively in areas of late snow lie (Smith 1978, 1990; Arnell 1954; Macvicar 1926; Schuster 1980; Gjaerevoll 1956; Diersson 1984):

Kiaeria starkei
Polytrichum sexangulare
Pleurocladula albescens
Marsupella brevissima

All of these species do not occur on every site, but the presence of two indicator species was used as a normal minimum requirement. The minimum size of a site depended on the size and proximity of other snow beds. This meant that the acceptable minimum size and continuity of bryophyte cover was greater in the Cairngorms than in say, the Northern Highlands where the sites are smaller and more widespread.

At each site the altitude, general aspect and slope were noted along with details of substrate and drainage. A full species list of both vascular plants and bryophytes was compiled and specimens of the more critical bryophyte taxa collected for later identification. Unfortunately it was not possible to include the important lichen populations in this survey (Gilbert & Fox 1985). The abundance of each species recorded was also recorded on the five point non-linear DAFOR scale favoured by the Nature Conservancy:

D)ominant	5
A)bundant	4
F)requent	3
O)ccasional	2
R)are	1

As part of the work required by the NCC, a detailed description of the snow bed vegetation was made and illustrative photographs taken of both the site and the plant communities. The full results of this facet of the survey are contained in two NCC reports (Rothero 1990, 1991) but four site reports are given in Appendix 1 as an example of the nature of the work. The site by species matrix was then classified using two-way indicator species analysis (TWINSPAN) after the removal of species with 3 or less occurrences (Hill 1979a; Gauch 1982; Malloch 1988). A partitioning of the sites by species abundance was carried out using detrended correspondence analysis, DECORANA (Hill 1979b; Gauch 1982; Malloch 1988)

2.3 Plant Community Analysis

The large geographic spread of snow bed sites and the difficulty of access combined with the time constraints detailed above, meant that the method of sampling the stands of snow bed vegetation had to be simple and rapid. Some form of random sampling was ruled out as too time consuming and a preferential sampling approach was adopted. This choice invalidates any statistical testing but the data can still be treated by multivariate analysis giving results that are purely descriptive but adequate for the scope of this study (Gauch H G, 1982). A brief pilot survey was made in late June 1989 using some of the more accessible Cairngorm sites and a more detailed preliminary study made of the snow bed in Ciste Mhearad, Cairngorm (Grid Ref. 38/012045) in mid July of the same year. This enabled an impression of the range of bryophyte dominated communities involved to be gained, making the selection of representative stands of vegetation a more straightforward process.

The preliminary study also presented an opportunity to decide on the size of sampling area. For the classifications of snow bed communities discussed above a variety of sampling areas were used, the most commonly used in the British hills being a quadrat size of 2m x 2m. It was apparent at the outset that, for the patchwork of stands of vegetation that are a feature of snow beds, this size of quadrat was far too large, particularly for the hepatic-rich communities. An attempt was made to reach an objective decision on a minimum area by constructing species-area curves (Kershaw 1973) but the cut-off point at the flattening of the curve was far from clear, still necessitating a subjective decision, and was clearly different in the differing stands of vegetation. In the hepatic rich vegetation a sample area of 2cm x 2cm often has 7 or 8 species and not uncommonly 10 or 11, and this would not be significantly higher in a sample size of $1m^{-1}$, but in the moss-rich sedge heath vegetation a larger minimum area would be more appropriate, simply because of the difference in size between stems of *Marsupella* species at a few millimetres in length and stems of *Carex bigelowii* up to 20cm in height.

A further practical problem militating against too large a sample area was the difficulty in identifying some of the bryophyte species in the field, necessitating the collection of specimens for subsequent identification with the microscope; this is particularly the case if the weather is foul. Linked to this is the problem of assigning an abundance level to a species which is not recognisable in the field and which may be intimately mixed with other very similar-looking species. Short of wholesale removal of the vegetation within the quadrat, the only feasible approach seemed to be the removal of 2cm x 2cm pieces of the problematic stands, again preferentially, the number removed depending on the area of the vegetation presenting a problem. These pieces could then be labelled and species names and abundance levels assigned later, again under the microscope. With some misgivings, this latter approach was finally adopted.

Given the variation in size scales between the different stands of vegetation and the logistical problems involved in the collection and identification of hundreds of specimens, a sample area of 50cm x 50cm was deemed a reasonable compromise, given that a relatively large number of samples would be taken in those stand types showing the most variation (Gauch 1982).

For each sample the slope, aspect and altitude were recorded along with the grid reference. In addition the size of substrate particles and the amount of irrigation were also recorded on a simple, subjective 3 point scale shown below.

Score	Substrate size	Irrigation
1	sand - fine gravel	+/- dry
2	coarse gravel - small stones	mesic
3	large stones visible	moisture visible

For the samples taken in 1990 a soil sample was collected for pH measurement made by standard methods (Moore and Chapman 1986) using a dual glass calomel electrode. This gave 38 pH readings in total. Plant abundance was recorded using the Domin scale.

The plant abundance values were entered into a sample by species data matrix and the samples and species assigned to groups using two-way indicator species analysis, TWINSPAN (Hill 1979a; Gauch 1982; Malloch 1988). Ordination of the data matrix was carried out by detrended correspondence analysis, DECORANA (Hill 1979b; Gauch 1982; Malloch 1988). Species with 3 or less occurrences were omitted from the data but all samples were used for TWINSPAN and for the initial DECORANA. Because of the spread of the data, notably to include *Pohlia wahlenbergii var glacialis* springs and *Deschampsia cespitosa - Galium saxatile* grassland, the bulk of the DECORANA information was compressed, making graphical interpretation of the first two axes difficult. To overcome this problem a second DECORANA run omitted samples from these two communities, as determined by the TWINSPAN table.

On many sites there were large areas of both block scree and bed-rock, both having important bryophyte populations but both habitats involve considerable sampling problems largely because of the very irregular surface they present and the short, steep microclimatic gradients which result from this (Bates 1982). In this study no samples were taken from either community as it was felt that the time involved would curtail the major thrust of the work. However some detailed observations are made concerning the populations of such habitats and their relationship with other snow bed communities.

2.4 Taxonomy and Terminology

Vascular plant names follow Clapham, Tutin and Moore (1987) and bryophytes Corley and Hill (1981) except for the genus *Andreaea* wich follows Murray (1988). There were a few taxonomic problems; part of the way through the survey it became apparent that differentiating between *Pohlia nutans* and *Pohlia drummondii* was not always simple in the field and would not yield much significant information so both are lumped under *Pohlia nutans* in the analysis. *Anthelia juratzkana* and *Anthelia julacea* were another pair of species that caused some problems (Smith 1990, Schuster 1974). Fortunately in those snow-bed stands where *Anthelia* is an important constituent, fertile shoots were common and all were assignable to *Anthelia juratzkana*. In the wetter areas where there are also large stands of *Anthelia*, perianths were not found, despite some searching, and on this negative evidence these stands were assigned to *Anthelia julacea*. (But see Smith 1990 p90, Schuster 1974)

Much more intractable were the difficulties associated with *Cephalozia bicuspidata ssp ambigua*, a very rare plant, but one associated with late snow-lie. There seemed to me to be a continuous variation from plants that were 'good' *Cephalozia bicuspidata ssp bicuspidata* through to tiny, black plants with small cells that keyed out to *Cephalozia bicuspidata ssp ambigua*. Reference to the herbarium in the Royal Botanic Gardens in Edinburgh showed that I was not alone in my confusion as specimens there labelled *Cephalozia bicuspidata ssp ambigua* were as diverse as *Cladopodiella francisci* and *Nardia breidleri*. Various authors express different opinions about the status of *Cephalozia bicuspidata ssp ambigua* (Smith 1990; Schuster 1980) and a paper by Kozlicka (1981) which shows that it is a good species is unfortunately not clear on the characters which differentiate it from *Cephalozia bicuspidata ssp bicuspidata*. In the species lists and analysis below *Cephalozia bicuspidata ssp ambigua* is used for plants that key out to *Cephalozia ambigua* in Smith (1990) but this should be viewed with some caution. Specimens of the rarer species of the *Gymnomitriaceae* were verified by Jean Paton, who also provided much useful advice and encouragement.

The terms 'community' and 'association' are used as equivalents and do not imply a status that would equate to the 'Association' of continental phytosociologists. Plant communities mentioned in the text other than the snow-bed associations which are the subject of the study are those described in the National Vegetation Classification (Rodwell 1987) except where otherwise stated.

3 The Sites

3.1 Distribution

A list of all 58 snow beds surveyed is given in Table 3.1 and full descriptions of each site complete with species lists and a brief analysis of the vegetation are contained in two Nature Conservancy Council reports (Rothero, 1990, 1991). To give an indication of the work involved, descriptions of four sites are given in Appendix 1. A full list of the plant species that occur on the 58 sites and the number of sites on which they occur is contained in Appendix 2. Most of the sites are situated in that band of high mountains that stretches from Ben Nevis and the Glencoe hills in the west to the Cairngorms and Lochnagar in the east. The sites west of the A9 are in what is known as the Central Highlands while the eastern hills are generally known by their largest group of hills, the Cairngorms. The only sites surveyed in the Southern Highlands, the hills south of Rannoch Moor, were on Ben Lawers; further site visits in this area were planned, notably to Ben Laoigh, but September snowfall prevented further work in the time available. Further north, six sites were surveyed in the Western Highlands, in the hills centred on the glens of Affric, Cannich and Strathfarrar. North again, a further four sites were visited in the Northern Highlands, beyond Strath Carron and Strath Bran.

Chapter 3 The Sites

Table 3.1. List of Snow Beds Surveyed in 1989 and 1990

No	Name of Site	Grid Ref	Survey Date
1	Ciste Mhearad, Cairngorm.	38/012045	20/07/89
2	Hollow S of Ciste Mhearad, Cairngorm.	38/013042	20/07/89
3	Coire Domhain, Cairn Lochan.	28/991023	21/07/89
4	Lower Garbh Uisge Beag, Ben Macdui.	28/99-00-	22/07/89
5	Upper Garbh Uisge Beag, Ben Macdui.	28/98-00-	23/07/89
6	N Slope of Ben Macdui.	28/990001	23/07/89
7	Coire an t'Snaechda, Beinn a Bhuird.	37/093980	25/07/89
8	Above Dubh Lochan, Beinn a Bhuird.	37/092992	25/07/89
9	North of N Top, Beinn a Bhuird.	38/095010	26/07/89
10	Burn W of Garbh Coire, Beinn a Bhuird	38/104016	26/07/89
11	Upper Allt an Eas Mhor, Ben Avon.	38/132014	26/07/89
12	Upper Coire an Lochan Uaine, Cairn Toul.	27/96-97-	02/08/89
13	Garbh Coire Mor, Braeriach.	27/941980	03/08/89
14	Gully E of Garbh Coire Mor, Braeriach.	27/943983	03/08/89
15	Above Falls of Dee, Braeriach.	27/942991	03/08/89
16	Garbh Coire Daidh, Braeriach,	27/944988	03/08/89
17	Upper Garbh Uisge Mor, Ben Macdui.	27/99-99-	05/08/89
18	Hollow below Bealach 1232m, Ben Macdui	27/998988	05/08/89

19	Lochan Buidhe, Cairn Lochan.	28/986010	10/08/89
20	N Feith Buidhe, Cairn Lochan.	28/989019	10/08/89
21	Above Creag Dubh, Beinn Mheadhoin.	38/024024	12/08/89
22	Barns Coire, Beinn Mheadhoin.	38/024013	12/08/89
23	Coire an Lochain, Braeriach.	28/942002	13/08/89
24	Coire Ruadh, Braeriach.	28/948002	13/08/89
25	Above Coire an Lochain, Braeriach	27/946999	13/08/89
26	Coire an Lochain, Cairn Lochan.	28/981026	21/08/89
27	N Coire an Lochain, Aonach Mor.	27/193738	22/08/89
28	S Coire an Lochain, Aonach Mor.	27/193736	22/08/89
29	Gully E of Top of Aonach Mor.	27/196731	25/08/89
30	Ben Wyvis.	28/466686	17/07/90
31	Coireag Barr an Fhialaidh, Sgurr Mor Fannich	28/205717	18/07/90
32	Fuar Tholl Mor, Sgurr Mor Fannich	28/205713	18/07/90
33	Beinn Dearg	28/256815	20/07/90
34	Mam Sodhail above Loch Uaine	28/120255	21/07/90
35	Tom a Choinich	28/165262	21/07/90
36	Sgurr na Lapaich	28/163348	22/07/90
37	Sgurr nan Clachan Geala	28/162343	22/07/90
38	Toll an Lochain, An Riabhachan	28/138353	22/07/90
39	Upper Allt Coire Chuirn, A'Bhuidheanach Bheag	27/65-75-	24/07/90
40	Ben Alder Plateau	27/49-72-	27/07/90
41	Upper Garbh Coire, Ben Alder	27/499710	27/07/90

42	Aisre Cham, Geal-charn	27/480749	28/07/90
43	Geal-charn Plateau	27/476745	28/07/90
44	Coire Boideach, White Mounth	37/233845	03/08/90
45	Upper Glas Allt, White Mounth	37/241846	03/08/90
46	Glas Allt, Coire an Daimh Mhoile	37/246846	03/08/90
47	Cairn Bannock	37/222827	04/08/90
48	Beinn Fhada	28/016194	11/08/90
49	Coire na Ceannain, Grey Corries	27/261750	12/08/90
50	Church Door Buttress area, Bidean nam Bian	27/142543	13/08/90
51	An Aghaidh Gharbh, Aonach Beag	27/20-71-	17/08/90
52	Coire na Ciste, Ben Nevis	27/159716-162717	18/08/90
53	Ben Nevis Plateau	27/158713	18/08/90
54	Coire West of Summit, Creag Meagaidh	27/40-87-	20/08/90
55	Top of Easy Gully, Coire Ardair	27/432877	20/08/90
56	Puist Coire Ardair	27/437873	20/08/90
57	An Stuc, Ben Lawers	27/637433	10/09/90
58	Ben Lawers	27/636413-640413	10/09/90

Site	Min hgt(m)	Max hgt(m)	Aspect(^{0})	Slope(^{0})	Area(Ha)
1	1100	1100	50	20	0.8
2	1060	1060	110	25	0.2
3	1100	1100	55	20	1.9
4	1030	1100	50	20	4.9
5	1100	1160	50	5	0.7
6	1150	1200	15	15	0.1
7	1100	1140	50	25	2.0
8	950	980	60	15	0.6
9	1110	1150	40	15	0.4
10	1100	1110	50	20	0.2
11	1060	1080	70	20	0.2
12	1000	1140	25	25	1.8
13	1030	1090	90	35	4.8
14	1120	1220	115	35	0.2
15	1180	1200	90	5	0.3
16	960	1040	90	30	0.8
17	1150	1250	30	20	6.8
18	1150	1230	60	20	0.4
19	1090	1120	20	25	1.9
20	1110	1140	140	25	0.5
21	1000	1020	40	20	0.4
22	1080	1130	115	20	2.3
23	1000	1060	20	30	0.6
24	1150	1250	20	35	0.4
25	1190	1200	0	5	0.2
26	1000	1140	25	30	2.1
27	1100	1150	110	30	0.8
28	1100	1150	50	35	0.8
29	970	1220	65	30	1.1
30	950	980	80	25	0.5
31	890	900	50	30	0.2
32	940	970	75	30	1.1
33	970	1100	75	35	2.0
34	910	1020	65	35	0.4
35	1050	1090	75	40	0.6
36	900	950	105	25	1.0
37	980	1000	70	20	0.7
38	900	950	80	25	0.4
39	850	950	0	30	0.4
40	1050	1080	80	5	3.2
41	950	1000	75	30	1.5
42	1000	1050	65	30	2.5
43	1080	1090	50	5	1.6
44	1040	1060	115	25	0.5
45	1030	1040	40	15	0.5
46	980	1000	40	25	0.2
47	930	950	30	30	0.1
48	980	1000	30	35	0.5
49	870	900	65	20	0.2
50	900	1100	25	30	4.0
51	900	1150	50	25	5.2
52	900	1180	45	30	5.0
53	1200	1210	355	5	0.4
54	950	1000	30	25	2.7
55	950	1020	25	35	2.3
56	900	1000	20	25	1.4
57	980	1000	25	25	0.2
58	1050	1200	10	20	2.9
Mean	1020	1085	55	25	1.4
Range	850	1250	355-140	5-40	0.1-6.8

Table 3.2 Physical character of snow-bed sites

3.2 Physical Character

Details of height, aspect, slope and area are given in Table 3.2. The mean height of all the snow-beds surveyed is approximately 1050m, with a maximum height on Ben Macdui (Site 17) at 1250m and a lowest limit at 850m in the Drumochter Hills (Site 39). More than half of the sites have their minimum height at or above 1000m and all of the largest sites with the greatest expanse of bryophyte dominated vegetation extend substantially above this level. The aspect of the sites extends in an arc from 355° round to 115°, from just west of due north to east south east with a mean aspect of 55°, approximately north east.

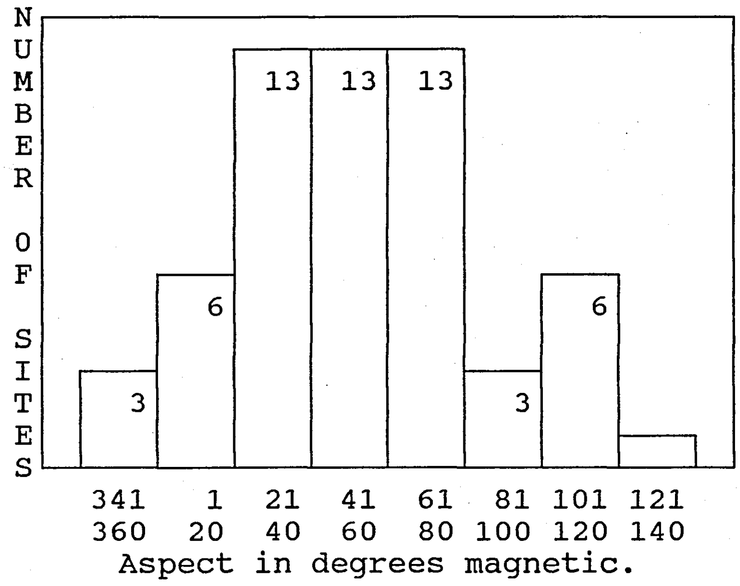

Fig. 3.1. Frequency of aspect of 58 snowbed sites

The aspect of the whole site was not always easy to measure as some sites are situated in curved hollows or in incised burns with opposing slopes and the figures represent the general aspect. In some cases this may not accurately reflect the aspect of the effective snow gathering slope but even so, the low scatter of the data is impressive. The general slope on each of the sites varies from 5^{o} to 40^{o} with an average at 25^{o} . As with the aspect of the sites, the figures given for the slope of the sites involved some averaging out of much irregularity in the topography with the aim of estimating the angle of the effective lee slope against which the snow bank is built. On a number of smaller sites in incised burns or hollows the angle of most of the site can be as low as 5^{o} but the slope which creates the drift which persists into the summer is usually much greater than this.

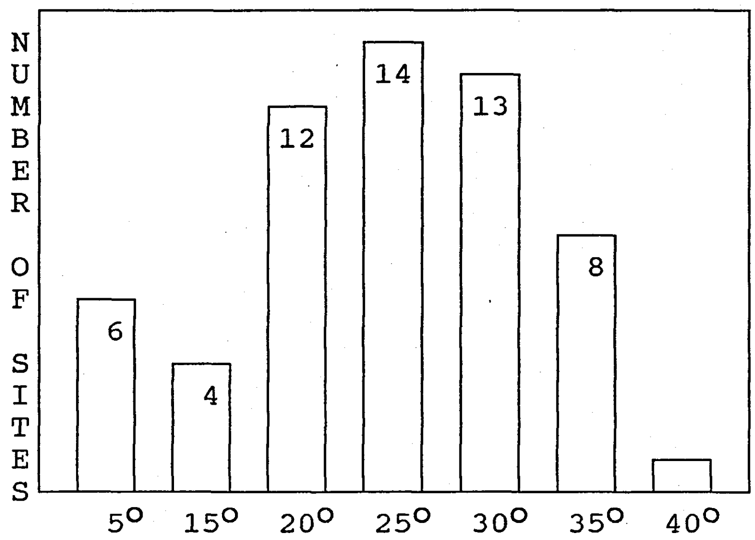

Fig. 3.2. Frequency of angles of slope on 58 snowbed sites.

Chapter 3 The Sites

Most of the sites are situated where there is an abrupt break in slope from an area where the angle of the terrain is less than 5^{o} to one where the slope is 20^{o} or more. This may be on a very large and dramatic scale as on the 3km long and 500m high 'break in slope' that forms the craggy north east face of Ben Nevis, on a more moderate scale as in several of the Cairngorm Plateau sites, or very small, less than 100m long and 20m high, like sites 10 and 11 on Beinn a Bhuird and Ben Avon in the eastern Cairngorms. Only nine sites have a general slope of less than 20^{o} and virtually all these are very high sites forming part of a high level plateau complex of late snow lie areas.

Topographically, there are two extreme types of site. Firstly there is the nivation hollow, situated on or at the edge of a plateau of high ground and associated with a low amplitude of relief, rounded features and a relatively simple structure. All the best examples of this type are in the Cairngorms, with the plateau sites of Ciste Mhearad (Site 1) and Coire Domhain (Site 3) exemplifying the typical characteristics. The second extreme topographical form is the deep coire site, backed by large steep crags, sharp breaks in slope and a complex structure. This type of site is more widespread with good examples in the Central Highlands (Sites 50, 51, 52 and 55) and in the Cairngorms (Sites 12, 13, 8 and 16). Inevitably, a large proportion of the sites exhibit features that are intermediate between these two extremes and have limited areas both of steep crags and more open rounded slopes adjacent to exposed plateau ground. As will be discussed below, these combinations of physical features have a profound effect on the distribution of the plant communities.

3.3 Climate

The climate experienced by the tops of the hills on which all snow beds are situated is extremely harsh. In his synthesis of climatic conditions in Scotland, Birse (1971) used data on accumulated temperatures above 5.6^{o}C, potential water deficit, accumulated frost and degree of exposure to divide the country into 'bioclimatic sub-regions'. All of the areas containing the sites surveyed fall within the most extreme categories, the upper and lower oroarctic zones and differ only in degree of oceanicity

Annual accumulated temperatures on all sites are less than 500 day-^{o}C per annum and are often lower than 250 day-^{o}C (Page, 1982). The mean February minimum and the mean July maximum temperatures, corrected to sea level, are below 0^{o}C and 19^{o}C respectively. In the more continental eastern hills the February minimum tends to be lower and the July maximum higher, usually by a degree or so in each case. These general figures mask more specific figures relating to sites for which there is good meteorological data. The remarkable observatory which operated on the summit of Ben Nevis between 1884 and 1903 provides some illuminating data. The mean annual temperature presented during this period was -0.3°C; this is not a reflection of extremely low temperatures during the winter but of low temperatures throughout the year. The mean hourly temperatures remained below 0°C from October through until early May and even in July the hourly mean only creeps above 6°C for a few hours in the middle of the day. The mean monthly temperatures are shown in Table 3.3.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-4.4	-4.5	-4.4	-2.4	0.6	4.3	5.0	4.7	3.3	-0.3	-1.7	-3.8

Table 3.3. Mean Monthly Temperatures (°C) recorded on the summit of Ben Nevis 1884-1903.

More recent figures for the eastern hills come from the summit of Cairngorm where in 1964 the mean annual temperature was 2.3°C, with 196 days of air frost and a continuous period of 83 days where the temperature was below freezing. More generally, all the sites are within the 80 frost day isopleth and most experience more than 100 days of frost per year (Page 1982). There is a similar situation with duration of bright sunshine on the high hills (or, conversely the duration of day-time cloudiness); all receive less than 25% of the possible sunshine hours, most receive less than 20% and the figure for the Ben Nevis observatory was 16%. There is a gradient of increasing amounts of sunshine from west to east which is perceptible even on a small scale; the summit of Braeriach in the western Cairngorms, shrouded in clouds, can often be seen from the clear tops of Beinn a Bhuird some 15km to the east.

There is a comparable gradient of decreasing precipitation from west to east. Again the general picture, (Page 1982; Ratcliffe 1968) shows all sites receiving between 1600 and 3200mm of precipitation per year and some of the western hills receiving more than 3200mm. More site specific data clarifies this trend, with Cairngorm in the east getting approximately 2500mm (Green, 1981) and the Nevis observatory figures showing a mean annual figure of 4084mm. This latter figure is probably applicable to most of the sites in the Western Highlands. There is a problem with recording precipitation high in the mountains because a significant proportion falls as snow which rarely comes straight down, and is also redistributed after snow fall has ceased, making gauge figures difficult to interpret.

The number of days with lying snow is also difficult to determine as observers are usually remote and use different criteria but one sequence of observations suggest that there is general snow cover on Braeriach summit from early January to mid April on average, ie about 100days (Green, 1968). This estimate will be true for all of the eastern hills, perhaps as far west as Ben Alder but oceanic influences and the west to east movement of the depressions strips snow more readily from the more westerly hills. Snow fall is possible at any time of the year (significant snow showers occurred on four occasions in July and August during this survey) but snow cover is normally transient except in the period between January and April. Occasionally heavy autumn falls will enable some snow beds to become established (or to be augmented) by late November or December) Snow lie is subject to considerable variation from year to year. In the winter of 1975-6 there was snow lying on Creag Meagaidh at 900m for about 100days but during the winter of 1977-8 and on through 1978, snow lay at that altitude for about 200 days (Hadley 1985). On the sites surveyed snow may persist for much longer but it is the availability of a more general snow cover for transportation and redeposition that enables these extreme snow beds to form.

The hills are the windiest part of Britain along with some exposed coastal areas. The record gust in Britain was recorded on the summit of Cairngorm, and it is likely that similar speeds could be attained by all the highest hills. More important than these extreme gusts is the duration of winds that are strong enough to shift large amounts of lying snow. Records in the Cairngorms (Green, 1981) suggest that when it is calm at lower altitudes it is also calm on the tops but that when it is windy low down, wind speeds increase dramatically as height is gained. Old figures for the Nevis observatory record an average of 261 gales (winds in excess of 34 knots or 17.2 m per sec) a year but how this figure relates to daily records is not clear. Personal experience suggests that during snow fall and in the 'unsettled' weather that characterises winter in the Highlands, winds are often strong enough to erode and transport snow from areas of deposition to areas of accumulation. As has been mentioned above, where wind energy levels are high, huge amounts of snow can be moved in a short space of time and redeposited on lee slopes.

The combination of the physical features of the late snow beds and the weather pattern experienced by the surrounding hills gives them their unique character. The steep slopes with a predominantly north easterly aspect that are a feature of most sites are at right angles to the prevailing winds blowing from between south and west, and so are recipients of much of the blown snow which is stripped from high ground upwind; there is a strong relationship between the area of high ground and the size and frequency of late snow beds. The degree of shelter is apparent even during the summer, indeed this survey would have been markedly more difficult had not the wind strength been so much less near the snow beds. The aspect of the slope also has the effect of reducing insolation and many of the snow patches can only receive direct sunlight for a few short hours during the height of summer and a proportion of this will then be reflected by the snow surface. The heat budget is reduced further by the cloudiness of the high tops, and personal observation suggests that clouds tend to form and persist longer over these northern and eastern slopes. No quantitative data are available but the micro climate near large snow beds in enclosed sites is qualitatively different compared with open, snow-free slopes nearby; there is a perceptible lowering of temperature as latent heat is absorbed by melting snow (Hadley 1985), an increase in humidity and a lowering of wind-speed. Snow accumulation can be remarkable on these sites. Some estimates give a depth of 20m for snow that has blown into Ciste Mhearaidh (Site 1) in some winters (Green, 1981); on Ben Nevis (Site 52) in April and May a bergschrund forms between the snow and the crags which can be in excess of 20m deep and snow may bank up to cover the bottom 40m of certain climbs. Even away from the Central Highlands and Cairngorms, the remaining snow on Beinn Dearg (Site 33), surveyed on 20/7/90, had a vertical depth of some 5m and a minimum snow surface to substrate depth of at least 2m.

The variation of within-site topography and edaphic conditions means that relating climatic factors to vegetation structure through processes of snow cover, irrigation and frost action are far from simple, particularly as the pattern of variation in a bryophyte sward can be very small. As is to be expected the extreme types of site are provided by the more open, 'nivation hollow' type site common in the Cairngorms and the deep coire site. The former tends to have a more uniformly finer substrate and lacks large areas of block scree and crag while the latter usually has only limited areas of finer gravels and sand and is dominated by block scree and rock outcrops. The pattern of irrigation is also different in that while both types of site are very wet when snow is melting, nivation hollow sites can have large dry areas away from drainage channels and seepage lines below remaining snow, whereas coires receive much drainage from above throughout the year but may lose much of this in porous block scree. Once the snow cover has gone, the more uniform topography of the nivation hollow provides little buffering capacity to changes in temperature and humidity beyond that given by the sheltered nature of the site whereas the sharper features and the block scree of the coire sites gives a range of protection. These differences have implications for the scope of the actions of both frost and wind; in nivation hollows with gravel substrates frost action can have a profound effect on water-logged soil while the wind can erode and transport drier material. In coires both these processes have little suitable material on which to act although fierce gusts of wind are common and frost shattering is active in producing the scree which forms much of the site.

3.4 The vegetation

Multivariate analysis of the abundance levels of plant species on the sites reveals a broad four-fold division (1a and 1b, 2a and 2b - see Fig. 3.3 and Table 3.4) which reflects the topographical differences outlined above but with a climatically derived east-west division also apparent. Table 3.4 is the final TWINSPAN classification of all 58 sites and the resulting groups of sites are given symbols on the scattergram of the first two axes of the DECORANA ordination in Fig 3.3.

It is the presence of certain indicator species that divides the second group (2) of 25 sites from the other 33 (Group 1); these species are *Rhytidiadelphus loreus, Alchemilla alpina, Cryptogramma crispa, Pohlia wahlenbergii var glacialis* and *Athyrium distentifolium*, species which are best represented in the deeper coires or on more westerly sites. The majority of the sites in Group 1 are in the east, with the most westerly sites being on the plateaux of Ben Alder and Geal-charn (Sites 40 and 43) in the Alder Forest, the Affric hills (Site 35) and on the Nevis plateau (Site 53). Most are nivation hollow sites or are sites with extensive areas of gravel or finer substrate, derived in 26 of the 33 sites from weathered granite. The features of these sites are the large expanses of both the *Polytrichum sexangulare - Kiaeria starkei* snow bed in the stable meltwater channels and,

	1b	1a	2b	2a	
	445 1133444455	111112222222	333333344445553	111222555	
	03360105456778	1234579457890125346	123467812890469	8236789125	
Andr blyt	---11---------	2123-311-222211-1-2	--1-111-----22-	1-2-1121--	000
Andr frig	--------------	---22--121---------	---------------	-1-2------	000
Andr niva	-244----------	3444323334443243334	-----1-21--2---	-33323324-	000
Cono tetr	23323232333233	3333333333333333332	232222222222322	3323222323	000
Dicr fusc	342-324-442233	3243433233233323232	---22222211-223	2422122-12	000
Dicr glac	1-21----------	1--1--1--111-2-11-2	--1---1--------	-1----1--1	000
Hypn cupr	--------------	---1-1--1----------	---------------	---1------	000
Pohl nuta	3223222-323333	4334432323343333434	-222--2-3222224	3322233222	000
Poly sexa	44343334444-43	4444344444444443444	24443333423-44-	4444443433	000
Raco aqua	----2---------	---1222--2212--2---2	-----------2---	-2-2-111--	000
Raco fasc	4332--2-4-3222	3434323233233323322	-21223-23-23333	-333122333	000
Spha capi	------22------	2-22222-2----2--2-1	--232----------	22-2-1-1--	000
Spha papi	--------2-21--	2232--2----322-----	--------2--2--2	----------	000
Ceph ambi	-11-2-1------2	21-22--2122211-2122	--11-1---1--11-	-----111--	000
Gymn infl	--------122211	-------------------	--------------1	----------	000
Gymn apic	--2-----------	---1-------------1-1-	---------------	----------	000
Mars brev	44344342433344	4443444444444444344	-2442323322243-	3423222423	000
Mars cond	22-1-1--211223	1-11-111111211-2-33	---1----2---32-	-------1-2	000
Mars spar	--------2--1--	------1------------	--------1------	----------	000
Mars spha	33-332--3233--	22333232222333232-3	-3-222--3---222	2-22233222	000
Mars spru	33332233323222	3333332223332331222	223232--3223332	3333222233	000
Nard comp	42--3-1-4-33--	4333323-333432-3--2	-2------322----	----2221-2	000
Agro capi	------------32	-----2-----2-1-----	1--------------	------1---	000
Care bige	443233434-3232	4244433333344333-22	132323223222323	3333122323	000
Care lach	--------------	---2-------1-------	---------------	---1--1---	000
Desc flex	22-2332-2322--	4233444334343234434	2222-12-2232212	3423222222	000
Fest ovin	------------22	-------2-1-2--2---1	---------------	-2-2112---	000
Junc trif	-21-22--2-11--	3333432333333333222	--1---1-131--1-	2323112222	000
Luzu arcu	--------------	2--22----212--22-21	---------------	-1--------	000
Luzu spic	-----------1--	312332-12222212---2	-----2--21---1-	221222211-	000
Sali herb	--223--4443-43	32434-3-333442-4-31	-2-32-22323--2-	---2112112	000
Scir caes	---------2----	------------2--2----	-----1---------	----------	000
Sile acau	-1-----------2	2-222-322222---3-2-	--1------1-----	-2-2111111	000
Kiae falc	33343323432343	3342334334333333222	2-4333233333332	3322222432	001
Olig herc	43333333333333	3323433333333333434	2-3333333434333	2333333333	001
Anth jura	3323333-322233	3233333332233333232	-2332222322-33-	23-2--1322	001
Ceph bicu	34333334444344	4444444444443443444	324333344444443	4444344433	001
Ceph diva	--------------	---------2-----11---	---11----------	----------	001
Nard brei	22222-222--122	122---22-212-2---32	--321-1-22--22-	-2-----222	001
Pleu albe	323322333332-3	3233-33-13332321444	--442322222133-	2432-21322	001
Nard stri	42------333232	2-222---32-3223----	---222--22221113	-22---22--	001
Ditr zona	32321-2-2-2233	22222-1122222222222	-2223--22222223	-3-1222232	010
Kiae star	44444434444444	4444444444444443444	334434444443444	4444444434	010
Raco hete	44444444444444	4444434444444444443	444444344344444	4444333444	010
Barb floe	44344444444332	4444444444444444444	44444444444344-	4444444433	010
Hoer blyt	432-3-22322-2-	43232-33333433333-1	324433333443242-	3333--3422	010
Nard scal	44434334444444	4444434444443443444	444444444444444	3444444444	010
Andr alpi	33-2----1-1---	2-3222--211---22--1	2--1-2-12--212-	-2-1--1222	011
Andr rupe	4443332333-222	4444433333333343433	223333244233333	3443333343	011
Phil font	33-12--22--22-	1223-33-3222--222-2	-24333--3-33324	-322222223	011
Pohl ludw	33343424434432	4444444344444443434	222423334444444	4443444444	011
Poly alpi	143-233-443433	22323322232323322-3	3343433-4334334	3333332333	011
Raco lanu	2332--321-2212	2-2322-22222-222322	212222133-24322	2333222333	011
Spha auri	22----221-1212	--23223-3223233---2	234--2--2-2232-	-2-2222233	011
Spha tene	---1--1-----1-	---1-----1-2-------	----------11-1-	-------112	011
Anth jula	423333232-3322	4444333433333343333	323434333333443	3433333444	011
Dipl albi	3232322222--32	333323-333332332333	32323333333333-	2333333333	011
Gymn conc	44321233--2244	2-223222222-2222222	3-3333-4432333-	3322333223	011
Loph sude	33322233344433	3223232232232332343	33433323443444-	3233333433	011
Mars adus	1-1-----1-1---	--1---1-----------1	-------2-1-----	----111-1-	011
Mars stab	323222--2-22--	32332-3333332332333	21222323232333-	-333333333	011
Scap ulig	322321232-23--	22233222333233332-3	-34323-23332433	2232333334	011
Scap undu	2213323-222---	34333232322323332-3	3-2232222-23432	3332333344	011
Desc caes	443322443-2442	33344433333333333-3	444444444443444	4443443434	011
Diph alpi	3-----------1-	--1211---1-1-------	----11112---1--	-2-----11-	011
Gnap supi	-21233-3322223	3233333233-332322-1	233223-23222222	3223222322	011
Hupe sela	31-1-2-2222222	3-34223222232222322	2-3232222-23212	24-2222222	011
Saxi stel	3-31--22222222	323322222322-33-333	333323333333333	3332333333	011
Andr muta	----------1---	1----11------------	----1-1--------	--1-1-112-	100
Plag dent	----1---------	1--4---1-32--3313-2	21---1----222-2	-334322-22	100
Scap palu	--------------	---21-1-------2---1	--1-------1--1-	---1222---	100
Call sarm	22----2-------	2--32---311----2---	--2112-22-22---	12-11-2222	101
Dicr maju	--------------	-------------1-----	---1-----------	-1-----1--	101
Drep exan	--2---2-2--2--	---2--2-322--2332-3	-22--2--1-32323	22--222124	101
Poly juni	--------------	--------------2----	1--1-----------	-------21-	101
Erio angu	--------2-----	---------1-2-1----1	---2-2----2-2-2	----------	101
Amph moug	--------------	----------------1--	---------------	----11111-	110
Blin acut	--------------	-------------------	----1-------2--	----212--2	110
Brac glac	--------------	-------------------	1------2-------	--1-1--212	110
Brac plum	--------------	---1---------------	--------1------	----1-1--1	110
Bryu weig	--------------	-------------------	--1-2------1---	---------2	110
Call stra	------------2-	---------1-------2	--12-----1--1-2	-1---11---	110
Cten moll	--------------	-------------------	----1-----12-1-	----111221	110
Dicr palu	1-------------	----------------2--	--------1--21-2	----11211-	110
Dicr scop	--1-----------	---1-----1------1--	1-1-1-----1111-	1--111-111	110
Drep unci	--------------	-------------------	--2-1------1-2-	-1--1-1-1-	110
Hete hete	--------------	------------------1	-1--1------1---	---11----1	110
Hook luce	--------------	-------------------	-----------11--	1---11----	110
Hygr ochr	------2-------	-------2--------2-2	-22-32--2--3324	2122222-22	110
Hylo umbr	--------------	---1-----1---------	3-3332-2-21312-	-1-1-11223	110
Hypn call	-1----12------	-------------------	2-3232-2-22322-	22----1333	110
Isop muel	--------------	------------------1	-----------1---	--11-----1	110
Kiae blyt	3----1---122-2	-122-2----1-212-3--	33-2-2232233322	2212333-2-	110
Lesc pate	--------------	-------------------	---------------	--1----111	110
Phil seri	--------------	-------------------	---2----1---1-2	----------	110
Plag undu	------------2-	---1-----1-----1--1	2-2222---12211-	---1-11112	110
Pleu schr	------1-------	-------------------	-12-22-1-211-1-	2--2-1111-	110
Pohl wahl	1-------------	--1---1---------2-2	-1222-2-2-13323	2232221233	110
Rhiz magn	--------------	---------1---------	--1-1---1--11--	-1----1112	110
Rhiz pung	--------------	----------------1--	222-1------2--2	1---1-1---	110
Rhyt lore	------43----2-	---2-----11--11-1-1	3433433--22333-	2212222222	110
Rhyt squa	------------1-	---------1---------	----2------1--2	-1--111---	110
Anas doni	1-------------	---1---------1-----	1-1--2---2-2-1-	-1---1---1	110
Bazz tric	--------------	-------------------	2-1-12-2-2-2-1-	-2---21---	110
Dipl taxi	11----------1-	-------------1--11-	---121---------	1--1-11122	110
Gymn obtu	1-1----1------	-------------------	--122212---12--	-----21---	110
Hygr laxi	--------------	----------------1--	------------1--	1--1-1----	110
Mars alpi	--1-112-------	1111---111-1-1-----	---2-21--------	-3-122122-	110
Mars emar	3-3112--2-2322	2-2233-23223-33-233	322333223344432	3333333444	110
Hyli tayl	1-------------	---2---------1-----	2-2--1-2-2---1-	-2---21---	110
Pell epip	--------------	-------------------	22----2-------2	---11-11--	110
Ptil cili	--------------	-------------------	-11------------	----------	110
Scap nimb	--------------	-------------------	--1----212---1-	-1------11	110
Trit quin	--------------	-------------------	--1-1----------	-2------11	110
Alch alpi	1------2---122	---2-2-2-2-1-1-----	222222222222223	-222212222	110
Athy dist	---------1----	---3-3-2-2---22-2--	2-211122212212-	3223212222	110
Blec spic	---------1----	---2-------1-1-----	1-1-211-1-----2	--12--111-	110
Calt palu	1-------------	-------------------	-1-2----1--2--1	-1-----1-2	110
Cera cera	-------2------	----------------1-1	---1----1---22-	323-221123	110
Chry oppo	--------------	-------------------	----1------21--	---1--1122	110
Coch agg.	--------------	----------------1--	--------1--2---	-111321222	110
Cryp cris	2-------------	---2-3-------------	3-2-1--3213322-	2---332332	110
Dryo dila	--------------	---1---------------	----1-------1--	-1-1------	110
Epil anag	--------------	-------------------	---------1--21-2	2-22212112	110
Oxyr digy	--------------	----------------2--	---------------	--11211122	110
Poa alpi	--------------	-------------------	---------------	----111-2-	110
Saxi rivu	--------------	------------------1	-----------2---	----21-111	110
Sibb proc	2------------2	------11-----------	1-2-22--11212-1	-1-111122-	110
Stel alsi	--------------	-------------------	-1--1---2--12-2	-1--------	110
Tara agg.	--------------	-------------------	---------------	12-111111-	110
Vero alpi	--------------	-------------------	-----------1---	12--211-1-	110
Vero serp	--------------	-------------------	---------1--1--2	------111-	110
Viol palu	2------2--21--	--12-3---2-1-------	-32-222-211--1-	3222--2222	110
Arct fulv	--2-----1----1	---2-----------2-1	-1-----111-21--	-2--111-2-	111
Hylo sple	------2-------	-------------------	121---------1---	-------111	111
Isop eleg	221------1----	-------------------	21121-1-212221-	-------212	111
Oedi grif	--1-----------	-------------------	-----------1---	----111-1-	111
Raco eric	-1------1---2-	------------1------	2-2-11-----21--	----21122-	111
Jung exse	--1-----------	-------------------	---------1-----2	----1-1---	111
Loph opac	3221-123-12222	1-13-312221--232333	323323233433332	3333333333	111
Gali saxa	------2222-22-	2-12-3-----2----1-1	-2223-3-212222-	33-2112212	111
Rume acet	-------2------	-------------------	-2-------------	--1-----1-	111
	00000000000000	0000000000000000000	111111111111111	1111111111	
	00000000000000	1111111111111111111	000000000000000	1111111111	
	00011111111111	0000000000000000111	000000000000001	0000000111	
	1b	1a	2b	2a	

Table 3.4 Classification of 58 snow-bed sites by TWINSPAN
(See text for explanation of divisions)

Sites are columns, species are rows; matrix values are pseudo-species and not DAFOR values.

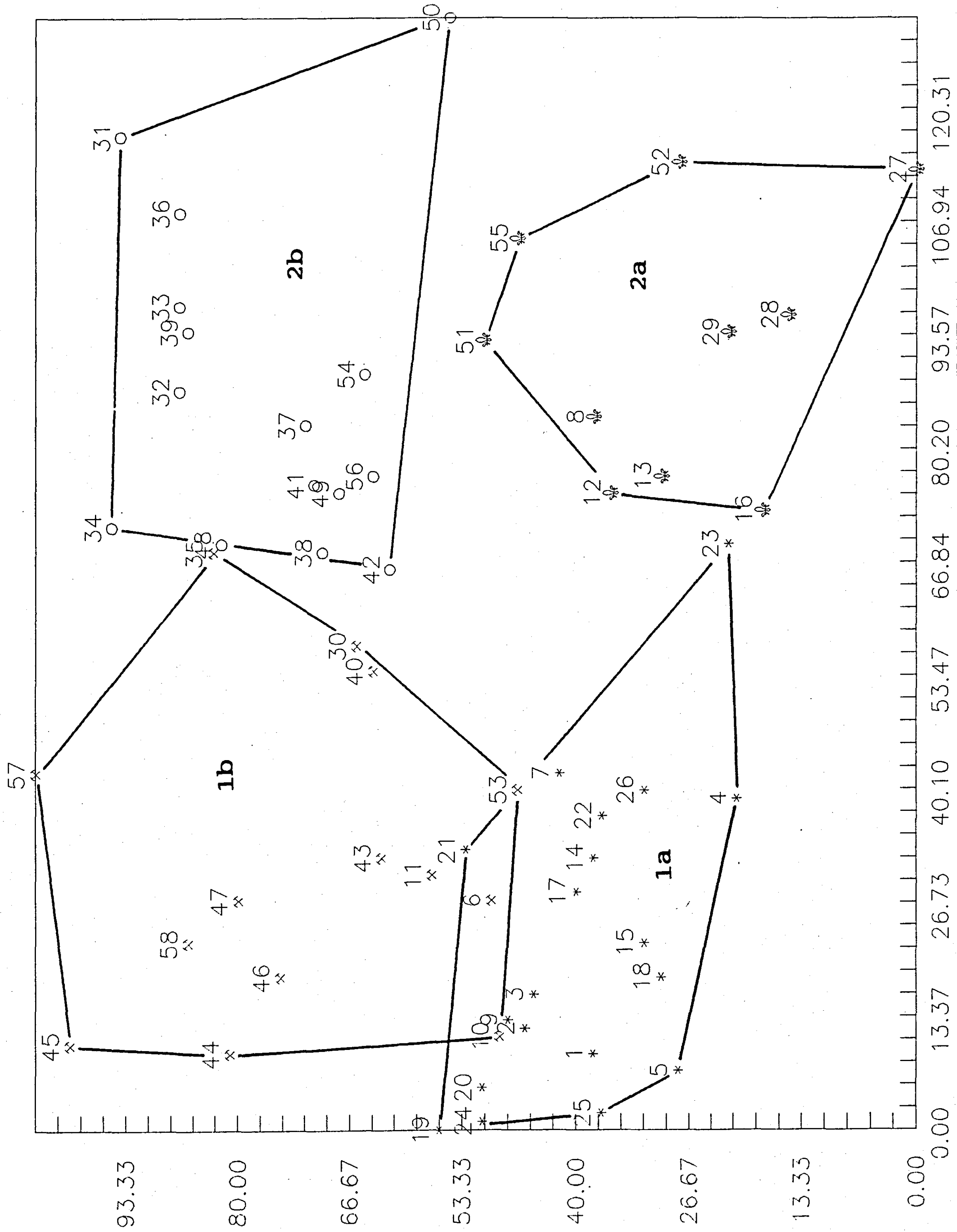

Fig. 3.3 Diagram of the first two axes of the DECORANA ordination of 58 snow-bed sites in the Scottish Highlands
(See text for explanation of groups of sites.)

particularly, the *Marsupella brevissima* - *Anthelia juratzkana* snow bed on the large areas of ground subject to frost heave and gelifluction. Frequently there is a marginal zone of *Carex bigelowii* - *Polytrichum alpinum* sedge heath.

The indicator species for Group 1a are *Andreaea nivalis*, *Luzula spicata* and good populations of *Juncus trifidus* and *Deschampsia flexuosa*. All sites in this group are in the Cairngorms and all have large areas of granite gravel and snow patches that may persist into the autumn or longer. *Andreaea nivalis* is usually abundant on these sites on alluvium as well as rocks and the stands of *Juncus trifidus* indicate the link with the Cairngorm plateau communities. Large stands of *Deschampsia flexuosa* as a late snow bed species are limited to these high sites though the occasional plant is common enough in most snow beds. Group 1b is more disparate, both in terms of the ordination and also geologically and geographically. In general the sites are less extensive and less extreme (ie lose snow cover earlier in the year on average) and the bryophyte snow bed communities, though well represented, are normally much more fragmented.

Of the 25 sites in Group 2 only 5 are in the Eastern hills, the rest all being situated on or west of Ben Alder. The combination of scree and crag and increasing oceanicity contribute to the changing floristics and the more diverse edaphic conditions, particularly the reduced role of granite substrates, must also be important. Most of the sites have a large element of crag or scree or else areas of *Deschampsia cespitosa - Galium saxatile* grassland with a rich bryophyte component. Two of the indicator species, *Athyrium distentifolium* and *Cryptogramma crispa* are primarily plants of block scree hence their importance here. *Pohlia wahlenbergii var glacialis*, another indicator is frequent on the crags and in spring-heads amongst the blocks. Finally, *Rhytidiadelphus loreus* is common as a component of the *Deschampsia cespitosa - Galium saxatile* grassland which occurs on most of the sites and often surrounds them, while *Alchemilla alpina* is frequent because of the variety of marginally less chionophilous habitat available in these more complex sites.

Group 2a is made up of the large deep coire sites on Braeriach and Cairn toul in the Cairngorms and in the Nevis area with outliers in Coire Ardair on Craig Meagaidh and on Beinn a Bhuird. The indicator species used in the classification by TWINSPAN are a diminutive *Taraxacum* species and *Oxyria digyna*, both species of the flushed bases of large crags, but species like *Saxifraga rivularis*, *Veronica alpina* and *Chrysosplenium oppositifolium* are equally useful in the field. Though the constituent species may occur, stands of *Polytrichum sexangulare - Kiaeria starkei* snow bed and particularly the *Marsupella brevissima - Anthelia juratzkana* snow bed are poorly developed and the most extensive community is often some form of *Cryptogramma crispa - Athyrium distentifolium* snow bed in the block scree, though the ferns themselves are never abundant.

The remaining sites composing Group 2b lack the extensive areas of crag which are a feature of Group 2a, except for the rather anomalous site on Bidean nam Bian in Glencoe (Site 50), but usually have areas of scree associated with more open slopes. Although block scree communities are still important, several sites have significant stands of *Polytrichum sexangulare - Kiaeria starkei* snow bed and *Marsupella brevissima - Anthelia juratzkana* snow bed. A degree of difference from similar sites in Group 1 is the development of *Deschampsia cespitosa - Galium saxatile* grassland as the most obvious vascular plant community on the sites as opposed to *Carex bigelowii - Polytrichum alpinum* sedge heath which can be a feature of the more easterly sites.

3.5 National status and conservation

These snow-bed sites are of national importance in conservation terms both because the total area of the plant communities which occur there is so small and because of the number of species which are restricted to this habitat. An estimate of the area covered by each site is given in the

Table 3.5 All Sites Ranked by Various Statistics
(See text for explanation)

Site	Area in Ha		Total spp		Snow bed spp		Rare spp		Sum of Rank	Final position	Site
1	0.8	*25*	62	*25*	15	*25*	6	*13*	88	*23*	1
2	0.2	*48*	45	*52*	14	*33*	4	*28*	161	*47*	2
3	1.9	*16*	64	*24*	16	*13*	4	*28*	81	*21*	3
4	4.9	*4*	89	*8*	18	*6*	10	*4*	22	*3*	4
5	0.7	*29*	55	*36*	11	*50*	4	*28*	143	*39*	5
6	0.1	*57*	45	*52*	15	*25*	5	*21*	155	*44*	6
7	2.0	*14*	56	*33*	12	*45*	3	*38*	130	*34*	7
8	0.6	*31*	61	*28*	14	*33*	2	*46*	138	*36*	8
9	0.4	*39*	56	*33*	19	*3*	8	*9*	84	*22*	9
10	0.2	*48*	44	*54*	14	*33*	4	*28*	163	*48*	10
11	0.2	*48*	37	*58*	11	*50*	1	*52*	208	*58*	11
12	1.8	*18*	88	*9*	15	*25*	10	*4*	56	*12*	12
13	4.8	*5*	59	*31*	16	*13*	5	*21*	70	*16*	13
14	0.2	*48*	53	*42*	15	*25*	5	*21*	136	*35*	14
15	0.3	*47*	58	*32*	14	*33*	4	*28*	140	*37*	15
16	0.8	*25*	83	*10*	16	*13*	4	*28*	76	*18*	16
17	6.8	*1*	76	*15*	17	*9*	9	*6*	31	*6*	17
18	0.4	*39*	61	*28*	16	*13*	7	*12*	92	*24*	18
19	1.9	*16*	66	*22*	16	*13*	6	*13*	64	*14*	19
20	0.5	*34*	47	*51*	14	*33*	4	*28*	146	*40*	20
21	0.4	*39*	68	*20*	18	*6*	6	*13*	78	*19*	21
22	2.3	*11*	62	*25*	14	*33*	4	*28*	97	*26*	22
23	0.6	*31*	66	*22*	18	*6*	5	*21*	80	*20*	23
24	0.4	*39*	41	*55*	15	*25*	5	*21*	140	*37*	24
25	0.2	*48*	53	*42*	16	*13*	6	*13*	116	*31*	25
26	2.1	*13*	75	*16*	22	*1*	11	*1*	31	*6*	26
27	0.8	*25*	96	*4*	14	*33*	9	*6*	68	*15*	27
28	0.8	*25*	93	*5*	17	*9*	8	*9*	48	*9*	28
29	1.1	*22*	119	*1*	19	*3*	11	*1*	27	*4*	29

Site	Area in Ha		Total spp		Snow bed spp		Rare spp		Sum of Rank	Final position	Site
30	0.5	*34*	49	*50*	11	*50*	2	*46*	180	*50*	30
31	0.2	*48*	54	*39*	10	*56*	1	*52*	195	*57*	31
32	1.1	*22*	55	*36*	10	*56*	0	*57*	171	*49*	32
33	2.0	*14*	79	*12*	16	*13*	6	*13*	52	*11*	33
34	0.4	*39*	68	*20*	16	*13*	3	*38*	110	*29*	34
35	0.6	*31*	40	*56*	11	*50*	1	*52*	189	*54*	35
36	1.0	*24*	79	*12*	15	*25*	3	*38*	99	*28*	36
37	0.7	*29*	74	*18*	15	*25*	3	*38*	110	*29*	37
38	0.4	*39*	50	*47*	14	*33*	3	*38*	157	*46*	38
39	0.4	*39*	56	*33*	7	*58*	0	*57*	187	*52*	39
40	3.2	*7*	61	*28*	15	*25*	3	*38*	98	*27*	40
41	1.5	*20*	54	*39*	12	*45*	2	*46*	150	*42*	41
42	2.5	*10*	77	*14*	16	*13*	6	*13*	50	*10*	42
43	1.6	*19*	55	*36*	16	*13*	4	*28*	96	*25*	43
44	0.5	*34*	54	*39*	13	*42*	3	*38*	153	*43*	44
45	0.5	*34*	38	*57*	11	*50*	1	*52*	193	*56*	45
46	0.2	*48*	50	*47*	12	*45*	1	*52*	192	*55*	46
47	0.1	*58*	52	*44*	12	*45*	3	*38*	185	*51*	47
48	0.5	*34*	62	*25*	13	*42*	2	*46*	147	*41*	48
49	0.2	*48*	69	*19*	13	*42*	2	*46*	155	*44*	49
50	4.0	*6*	93	*5*	14	*33*	4	*28*	72	*17*	50
51	5.2	*2*	103	*3*	20	*2*	11	*1*	8	*1*	51
52	5.0	*3*	107	*2*	17	*9*	9	*6*	20	*2*	52
53	0.4	*39*	51	*46*	16	*13*	5	*21*	119	*32*	53
54	2.7	*9*	82	*11*	16	*13*	6	*13*	46	*8*	54
55	2.3	*11*	93	*5*	19	*3*	8	*9*	28	*5*	55
56	1.4	*21*	75	*16*	17	*9*	6	*13*	59	*13*	56
57	0.2	*48*	52	*44*	11	*50*	2	*46*	188	*53*	57
58	2.9	*8*	50	*47*	12	*45*	5	*21*	121	*33*	58

first column of Table 3.5; while these figures are merely visual estimates from map outlines, they are likely to be acceptably close and are under-estimates rather than the reverse. The sum of these figures is 80.4 hectares, a very small area indeed. This survey was not exhaustive and many snow-beds sites were missed out, including some large areas in the Cairngorms and in the Nevis range but I would estimate that the sites surveyed represent somewhere between one third to one half of all bryophyte-dominated snow-beds in Britain. This gives a total area of between 160 and 250 hectares, with my experience suggesting that the former figure rather than the latter is likely to be the most accurate.

SPECIES	SITES	STATUS(UK)	STATUS(EEC)
Andreaea alpestris	1	R	?
Andreaea blyttii	27	R	NT
Andreaea frigida	7	R	NT
Andreaea mutabilis	10	R	?
Andreaea nivalis	34	R	E
Andreaea sinuosa	1	R	?
Brachythecium glaciale	7	R	NT
Brachythecium reflexum	1	R	NT
Dicranum glaciale	17	R	R
**Heterocladium dimorphum*	1	R	NT
Hygrohypnum molle	1	R	R
**Hylocomium pyrenaicum*	1	S	NT
Isopterygiopsis muelleriana	5	S	NT
**Lescuraea incurvata*	1	R	NT
Lescuraea patens	4	R	NT
**Oncophorus virens*	1	S	R
Philonotis seriata	4	S	NT
Pohlia wahlenbergii var glacialis	23	S	NT
Polytrichum sexangulare	55	S	NT
Rhizomnium magnifolium	10	R	R
Sphagnum lindbergii	1	R	V
Cephalozia ambigua	30	R	NT
Diplophyllum taxifolium	16	S	NT
Gymnomitrion apiculatum	4	R	E
Marsupella arctica	1	R	R?
Marsupella boeckii	2	R	R
Marsupella brevissima	55	S	R
Marsupella condensata	31	R	V
Marsupella sparsifolia	5	R	V
Nardia breidleri	32	R	R
Pleurocladula albescens	51	S	NT
Scapania paludosa	12	R	NT
Athyrium distentifolium	31	S	
Carex lachenalii	4	R	
Cerastium arcticum	3	S	
Cerastium cerastoides	16	S	
Luzula arcuata	11	S	
Poa flexuosa	1	R	
Saxifraga rivularis	8	R	
Veronica alpina	7	S	

Table 3.6 Rare species occurring on 58 snow-bed sites.

*=Rare calcicole species, Ben Lawers only on this survey
U.K. Status
S = scarce (recorded in 16-30 10km squares since 1950)
R = rare (recorded in 1-15 10km squares since 1950)
E.E.C. Status
NT = not threatened; R = rare; V = vulnerable; E = endangered

Table 3.6 lists the nationally rare species occurring on the sites investigated and some indication of the status of the bryophytes in the E.E.C. (Schumacker 1988). Of the mosses that will eventually be included in the Red List some 8% have most of their sites on snow-beds or related habitats and the equivalent figure for hepatics is closer to 15% and a proportion of these are also under some threat in Europe. The number of these rare species occurring on each site is shown in the second column of Table 3.6 along with the rank position according to this figure.

A number of species have all or most of their known sites in Britain, in areas where snow lies very late. The list in Table 3.7 is the one I used to compile the third column in Table 3.5; clearly there could be some debate about the inclusion or exclusion of certain species but the list is substantially accurate.

Andreaea blyttii	*Gymnomitrion apiculatum*
Andreaea nivalis	*Lophozia opacifolia*
Andreaea sinuosa	*Marsupella arctica*
Brachythecium glaciale	*Marsupella boeckii*
Conostomum tetragonum	*Marsupella brevissima*
Dicranum glaciale	*Marsupella condensata*
Isopterygiopsis muelleriana	*Marsupella sparsifolia*
Kiaeria falcata	*Marsupella stableri*
Kiaeria starkei	*Moerckia blyttii*
Pohlia ludwigii	*Nardia breidleri*
Pohlia wahlenbergii var glacialis	*Pleurocladula albescens*
Polytrichum sexangulare	*Scapania paludosa*
Cephalozia bicuspidata ssp ambigua	*Gnaphalium supinum*
Diplophyllum taxifolium	*Saxifraga rivularis*

Table 3.7 List of preferential snow-bed species.

These three statistics are used to compile the over-all ranking of sites shown in the final column of Table 3.5. While this list is interesting and does provide a tool for deciding on conservation and management priorities, several points must be taken into consideration. All three statistics use tend to favour the coire type of site over the nivation hollow as coire sites tend to be big and have a variety of habitat. A further important consideration should be the area of the snow bed communities described in Chapter 4 which tend to be larger and reach their best development on the more uniform substrates of the nivation hollow sites. This suggests that the highest ranking sites in Group 1a should be considered along with the more diverse coire sites of Group 2a. Given the small areas involved, the many rare species and the unique communities, all snow-bed sites are in need of monitoring and some level of protection.

4. The Plant Communities

4.1 Classification and Ordination

The final table of the TWINSPAN classification is shown in Table 4.1. The analysis of the 141 samples shown in the table is the outcome of several runs of the program using a variety of cut levels and weighting for the pseudo-species. The classification shown best reflects the relationships in the field but the differences between the various runs were slight, involving only the movement of a few marginal stands. A diagram of the divisions is shown in Fig 4.1 with each of the communities on the right-hand side and the indicator species used at each level of the division shown on the appropriate 'branches'; the figures in parenthesis are pseudo-species and not Domin abundance values. Each of the communities is labelled in the table and also given a symbol in the diagrams of the ordinations, Fig 4.2 and 4.3.

In the first ordination diagram (Fig 4.2,) the inclusion of the very different *Pohlia wahlenbergii var glacialis* spring and *Deschampsia cespitosa - Galium saxatile* grassland samples causes the rest of the samples to be compressed in a way that makes interpretation difficult. To overcome this problem, a second ordination was carried out omitting samples from these two communities (as classified by TWINSPAN) and the diagram of the first two axes of this is shown in Fig. 4.3. Details of all the samples are given, community by community in

	1 111	11 1 1	1 1111 1111111 1111111	1 1 111111 111	1 1	11	
	34883 4169322489257	50033407770	180 1345 566882224 1122233345555667778990000011 11233339	1366922481 112244556678911123424 912233399	81272 136	713	
	9103013943359549231	44908855892	251673205 8391926805895647914762679070278580367812 68024684	73566754644041829011267703947167 010391612	253313858	475	
41 Cera cera	-------------------	-------2---	--------- -- --------	-------------------------------- ---------	---------	1--	1
55 Phil font	-------------------	-----------	--------- -- --------	-------------------------------- ---------	-2--3----	-2-	011
11 Pohl wahl	-------------------	-----------	--------- -- --------	-------------------------------- ---------	---1-----	555	011
47 Hupe sela	11-2--1--------1---	---2----2--	1---111-1 1-11--------1---11--------2--1-------- 1----1--	-------------------------------- --------1	---------	---	010111
42 Cryp cris	-------------------	----------1	--------- ---------------------------------2------ --------	-------------------------------- ---------	---------	---	010111
20 Barb floe	212-422-12243-24523	1--1----313	----3-1-1 2111-2-2221212--12--331-4-2-44-234-33332 32332-3-	------------------1-----1-1---11 -1------2	---------	---	010111
17 Raco lanu	2-21-11----2-------	1---1----11	1---1---- -111-------------1--------1------1----11 --1--1--	--------------------------1-1--- ----1---1	---------	---	010110
14 Raco eric	-------------------	-------1---	--------- --------1------------------------------- --------	-------------------------------- ---------	---------	---	010110
44 Desc flex	--13---12--1-444---	-1---------	11-23--1- ---1-----22--1------2--1---------------- --------	------1---1-------1------------- -2-3-----	------1--	---	010101
51 Viol palu	-----------------2-	-2---------	--------- -- -1------	-------------------------------- ---------	---------	---	010101
40 Care bige	2233354343445233141	33221-1-2--	----1---1 12-----3---------1-----------2---------- --------	---------1---------------------- -----3212	---------	---	010101
12 Poly alpi	--2-211-222-33---43	11--1--1213	1-------- 1-----12-------------------------------- 2---1---	-------------------------------- --------1	---------	---	010101
3 Dicr fusc	----2334434-3-21---	1-----4----	--------- -- --------	-------------------------------- ---------	---------	---	010101
15 Raco fasc	13131-----1--------	1--12-1--22	--------- -------------11----11-----------2------2 --2--1-2	------1-------1-----------1----- ------22-	---------	---	010100
54 Rhyt lore	-------------------	-54--------	--------- -------------------------------------21- --------	-------------------------------- ---------	---------	---	010100
53 Hylo sple	-------------------	-12--------	--------- -- --------	-------------------------------- ---------	---------	---	010100
45 Gali saxa	-------------------	422--------	--------- -- --------	-------------------------------- ---------	---------	---	010100
8 Pleu schr	-------------------	--1-----1--	--------- -- --------	-------------------------------- ---------	---------	---	010100
43 Desc caes	--------1----1---2-	22355544334	--------- --------2--------23----2--1-------12-333 332-1---	---------2--------------11--1--- ---------	22--13--3	---	010100
38 Scap ulig	-------------------	-------2--1	--------- -- ----2---	-------------------------------- ---------	1---2-3--	---	010100
49 Sali herb	43114-24244---1-1--	----1------	-----322- -2--34--2---------2--------------------- --------	------11-3---1-1-----------1--- -43333234	-3-------	---	0100
48 Junc trif	-------1-1-------1-	-----------	1-------1 1----------------------------1---------- --------	------------1------------------- -1-1---12	---------	---	0100
50 Saxi stel	-------------------	--------1-2	--------- ----------------------------1----2-1-221 22------	--------------------------1----- ---------	---------	---	001111
46 Gnap supi	-4-----------------	---------31	333------ 4------------1----3----4---------1---221 --3-----	------2-2--1----2--1-----1------ ---------	---------	---	001111
35 Nard comp	-------------------	-----------	--------- -- -------4	-------------------------------- ---------	----2----	---	001110
30 Mars emar	-------------------	---------2-	---3----- -----------1--1--1-----2-1-------1------ --------	-------------------------------- ---------	-------2-	---	001110
1 Andr niva	-------------------	-----------	4-------- -------------------4-------------------- --------	-------------------------------- ---------	-------3-	---	001110
18 Anth jula	-------------------	---1-------	--2------ -------1----------11------1----1-----1-- -------4	----1--------------------------- ---------	-------1-	---	001110
6 Kiae star	--------2-------114	-------22-2	1-2522513 33-3244442341151211124-2231213-222434334 3-44443-	22222324-3-----1-412-1-1122-31-- ----1-1-2	---------	---	001110
33 Hoer blyt	1-22---------------	-----------	-2------- -1-3-2---------44--4--41--4----42-----23 ----2-2-	------------------------23------ -------11	---------	---	001110
26 Loph opac	-------------------	-----------	--------- ------------------------1--------------- -----332	-------------------------------- ---------	---------	---	001110
13 Poly sexa	111-2------32---211	---2----211	3-2223224 233423444333231453-444222424335233222333 34332-22	121-132112-1121111-11--1321313-- 2-2-2111-	22-1----1	---	001110
36 Nard scal	---11--------------	---11----2-	-2----1-- 11---12112--22-4-121--12-111-11---12-212 -42-334-	-1-2221-121-1---1----211--1-1422 -------11	3----1222	---	001101
31 Mars spha	-22----------------	-----------	------1-- 2--2--------21-1-211--------11--1------- --1-----	----3-2-----------1--2-------1-- ---------	------1-2	---	001101
23 Dipl albi	--1----------------	--11-------	--------- --1------------1--1-------22----1------- -----2--	-121---2---------------1-----1-- ---------	------1--	---	001101
22 Ceph bicu	1-1---------1-1----	--21-------	---12---- ---1---11221-112-2------1-21---11--2--11 ----132-	32-2331343----111-------12-1-21- -11--1-1-	1--------	---	001101
37 Pleu albe	--1----------------	-----------	---11-1-- -----1---22132222-----1-3-22---1---3---- ---1---2	22132-1-2212--1----1---132-111-- 2-1------	---------	---	001101
25 Loph sude	--1-2-------1-1---1	--21-------	---311--- 1-213-21--212---1212----112111--1-121211 ---2122-	2133332-2-1--1121112111122-3311- -23324121	2--------	---	001101
7 Olig herc	-------------------	----1------	-2-1----- -----11--11-------1----------1-------212 -22--311	2--1----11--1--1--1-112--21-2211 --1-21--1	--------1	---	001101
27 Mars alpi	---1---------------	-----------	---1----- ---1--------1-1------------------------- --------	1--2-1----1--------------------- ---------	---------	---	001100
16 Raco hete	31423-1---2--------	--------111	333123423 244243313------------1-1--21---122-3--22 --3---1-	1-3-1-2-23-121-2---1-22-2-221--- -32322534	-----1---	---	001100
2 Cono tetr	1-2-1--------------	-----------	1-----123 --112-22--1---1---------1-------3--3---- ------1-	2----3--1------1-1-1------22-1-- -22221111	---------	---	00101
24 Gymn conc	-------------------	-----------	-------1- -----1-12-----------------------1-----1- --------	--2---1-1------2---1-1-1--32-1-- ---3----1	---------	---	001001
34 Nard brei	-------------------	-----------	--------- -----------------------------2-----1---- --------	---------1---------2-1---3--22-- ---12----	---------	---	001001
29 Mars cond	-------------------	-----------	--------- ---------------1--1-----1-------1------- --------	11--21----11-1--1-12---1--4-11-- ---22---1	---------	---	001001
28 Mars brev	-------------------	-----------	---21---1 1--1---2--1-1-2-1-1-----1----------3--22 --1---1-	45312232-22444444344344434444-42 -1344---2	------1--	---	001001
21 Ceph ambi	-------------------	-----------	---1----- ------------------------1-2--------1---- --------	1214--------1-11---1-1-1-11-211- --1------	---------	---	001001
19 Anth jura	-------------------	-----------	--------- ------------------2----------------2---- -------1	12-1-1222221122-212312123-213112 --2332121	---------	---	001001
5 Kiae falc	-------------------	----------1	-----1--- ---1-3-----1--------11-------1------2-12 2-1-222-	-11------332--2-3--13--242232335 5--132---	---------	---	001001
39 Scap undu	-------------------	-----------	--------- -- ---1----	-------------------------------- ---------	-----1--4	---	001001
32 Mars stab	---1---------------	-----------	-1------- -------------------1------11----1------- --------	1------22------1---1---11------- --1----2-	---------	---	001001
52 Bare Grou	-------------------	----------1	12222--21 2--1-22-1-4--1----2-2--21----------22-3- --3---11	12------22423-32333-423323333-1- -2-223-2-	32-------	---	001000
10 Pohl nuta	--------1--------1-	--------11-	------1-1 --11---11---2-----1--------------1-1---- 1-------	------11-21---1--21-1--2---213-- --1-11--2	---------	---	001000
4 Ditr zona	-------------------	---1-------	2---1---- --1------------------------------------1 -------1	1---1---1----1------------2----- ---121-21	--------1	---	001000
9 Pohl ludw	-----------------1-	-----3-1-1-	--4------ -11-----------211------12-21112--12----- ----3-1-	1-11-1-----------11------------1 ---------	4455454443	1--	000
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	4	5	1	2	3	6	

Table 4.1 Final table of TWINSPAN classification of 141 snow-bed samples

Samples are columns, species are rows; figures in the matrix are pseudo-species levels not Domin values

1 = *Polytrichum sexangulare-Kiaeria starkei* snow bed
2 = *Marsupella brevissima-Anthelia juratzkana* snow bed
3 = *Pohlia ludwigii* snow bed
4 = *Carex bigelowii-Polytrichum alpinum* sedge heath
5 = *Deschampsia cespitosa-Galium saxatile* grassland
6 = *Pohlia wahlenbergii var glacialis* spring

Appendix 3 but sample numbers are omitted from the ordination diagrams as their inclusion would obscure too much.

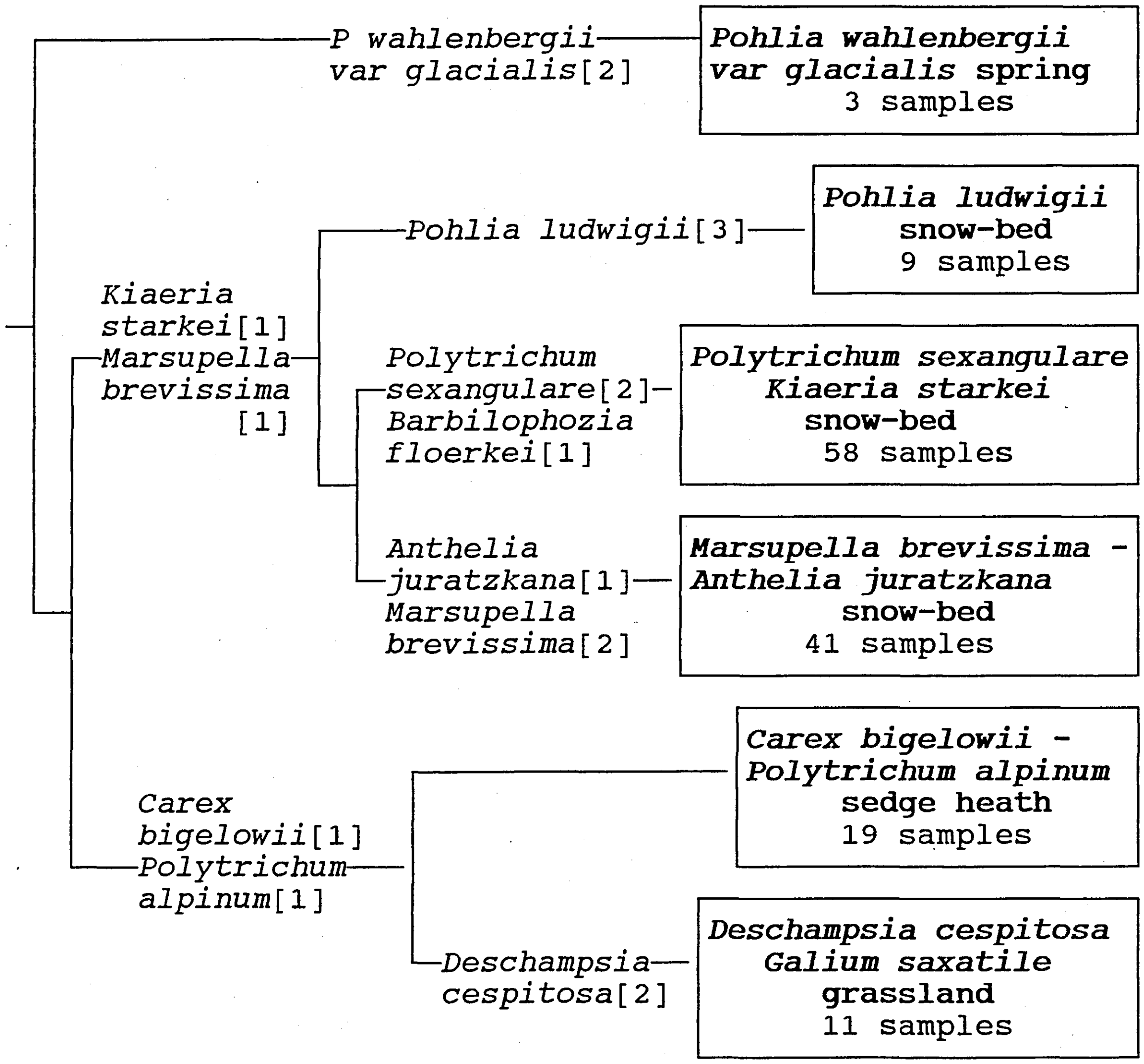

Fig.4.1 Diagram of the TWINSPAN classification of 141 samples from snow-beds.

In the community descriptions which follow 'constant' species are those with constancy values of IV or V, that is, they occur in 60% or more of the samples in that community.

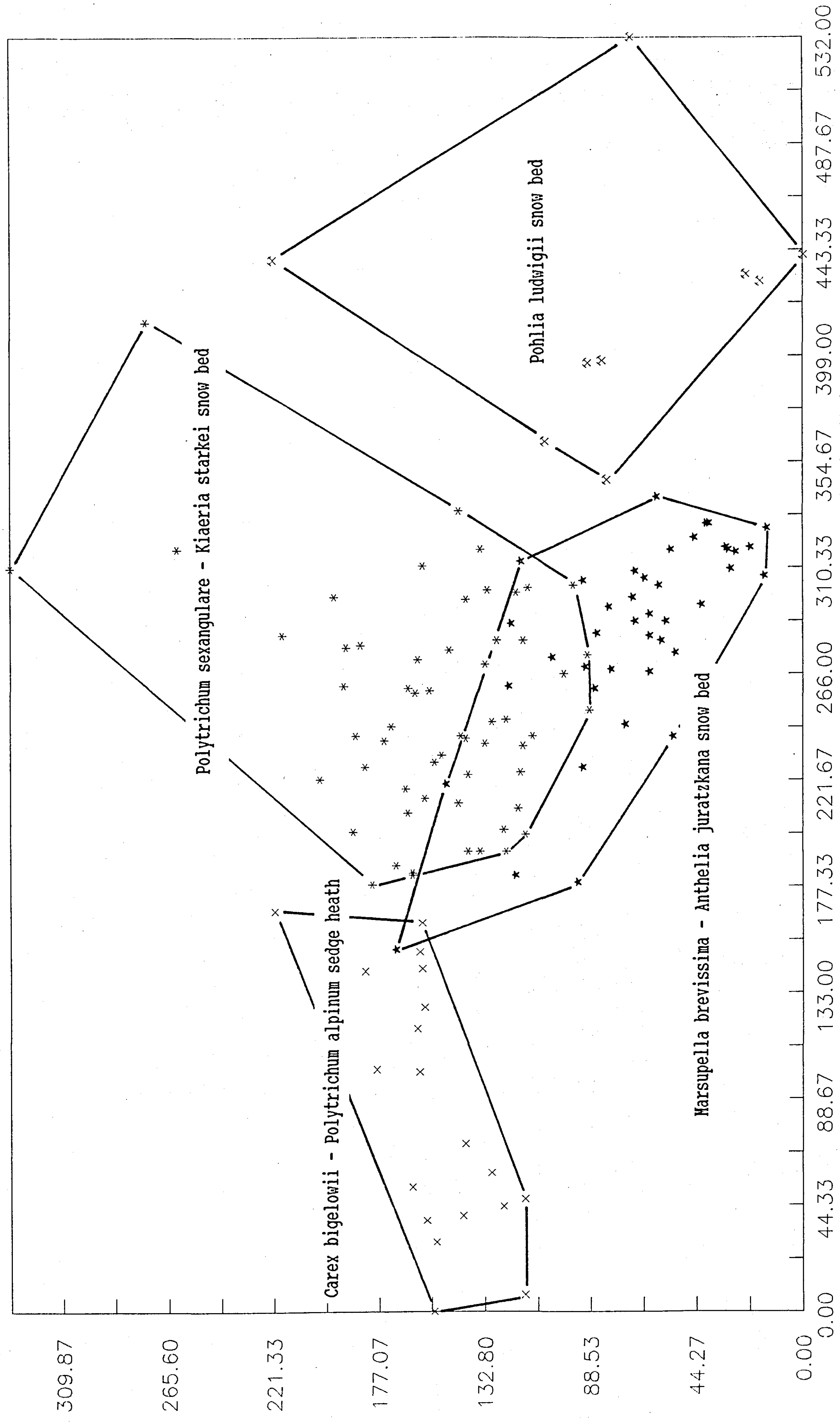

Fig. 4.3 Diagram of the first two axes of the DECORANA ordination omitting 14 samples (see text).

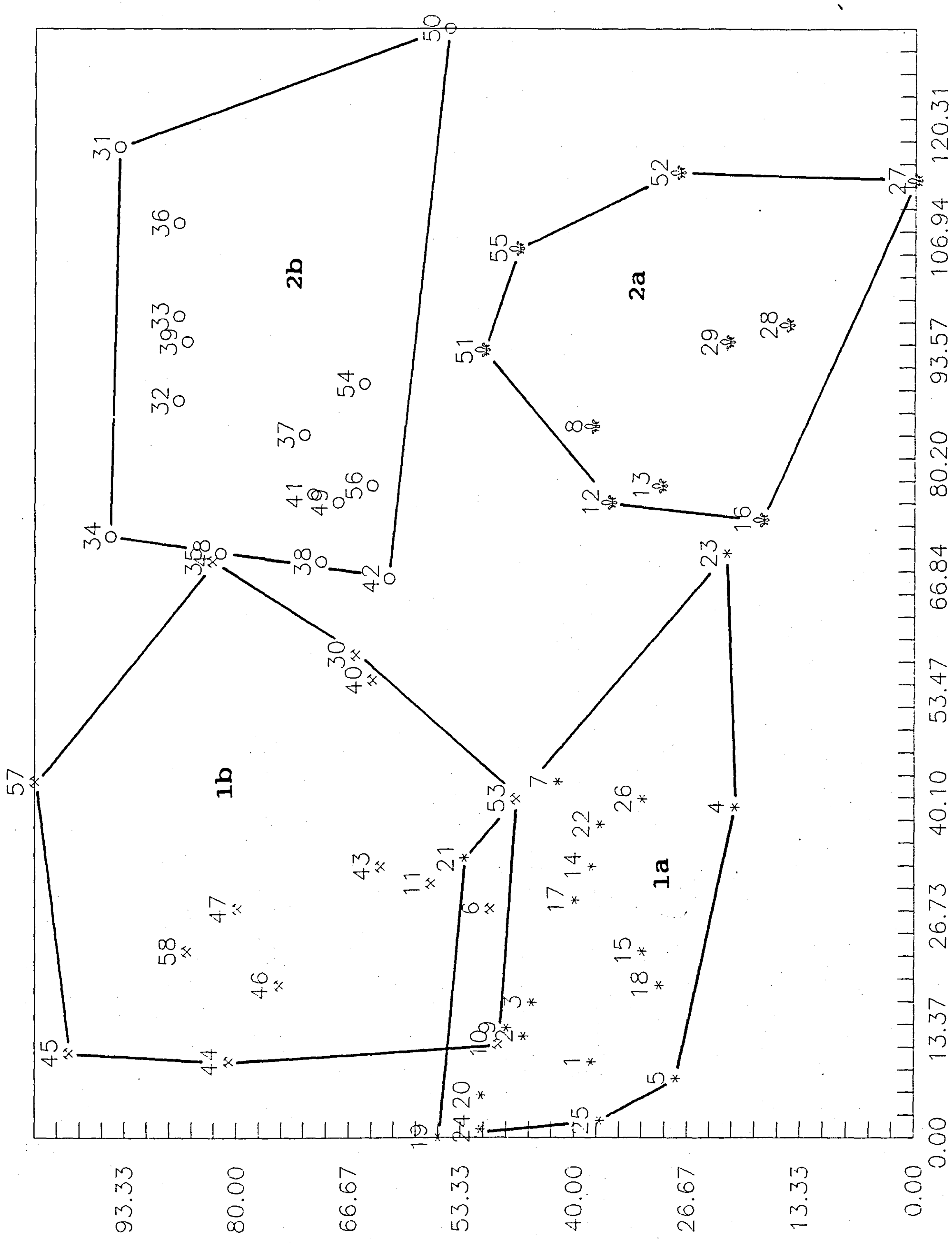

Fig. 3.3 Diagram of the first two axes of the DECORANA ordination of 58 snow-bed sites in the Scottish Highlands (See text for explanation of groups of sites.)

4.2 *Polytrichum sexangulare - Kiaeria starkei* Snow-bed

Constant Species

Kiaeria starkei, Polytrichum sexangulare, Barbilophozia floerkei.

Rare Species

Polytrichum sexangulare(b), Marsupella brevissima(b), Pleurocladula albescens(b), Andreaea nivalis(b), Ditrichum zonatum var scabrifolium(b), Cephalozia ambigua(a), Marsupella condensata(a), Nardia breidleri(b), Scapania paludosa(a)

Physiognomy

The *Polytrichum sexangulare - Kiaeria starkei* snow-bed covers a complex of bryophyte dominated vegetation in which *Polytrichum sexangulare* and *Kiaeria starkei* are the most constant species though both may vary considerably in abundance. Of the two, *Kiaeria starkei* tends to form the largest stands and on favourable sites the yellow green shoots with falcate leaves can occur in swards in excess of $100m^2$. *Polytrichum sexangulare* can also occur in moderate stands but the more open growth form of this species means that there is usually an understory of other species, usually small hepatics, under the dark green 'canopy' provided by the moss. The other constant species of this community, *Barbilophozia floerkei*, can also form large stands, either on its own, as an understory to *Polytrichum sexangulare* or as part of a complex hepatic community. Its dark green shoots and extensive mode of growth on the soil of the various snow-beds look very different to the abundant, yellow-green, cushion forming plant of open rocky sites at lower altitudes.

Blackened patches of *Racomitrium heterostichum* are a conspicuous feature of some stands, particularly soon after snow melt but this species normally has low cover values as does the even more conspicuous *Conostomum tetragonum*, the glaucous shoots of which are a more regular feature of forms of the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed. Scattered stems and small patches of *Oligotrichum hercynicum* are also common and when well grown on wetter sites can be confused with *Polytrichum sexangulare*. Often growing in close proximity to *Kiaeria starkei*, small cushions of *Kiaeria falcata* occur regularly and can be a source of confusion but the tighter growth form and the fine, regularly falcate leaves should suffice to separate the two. While never approaching the abundance levels typical of the *Pohlia ludwigii* snow-bed, that species is still a common constituent of the *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed, usually as a mixture with other bryophytes.

In addition to the mats of *Barbilophozia floerkei*, stands of other hepatics are also frequent. The two most distinctive species, and preferential for areas of late snow lie are *Pleurocladula albescens* and *Moerckia blyttii*. The whitish green shoots of the former are an obvious feature either in small swelling cushions, as procumbent shoots amongst other hepatics or occasionally as dense, erect turfs. *Moerckia blyttii* is a large thalloid hepatic but its 'crisped' habit can render it surprisingly inconspicuous when only scattered shoots are present; frequently however it forms dense pure mats, often in a bed of *Barbilophozia floerkei* when it is unmistakeable. The most constant but least conspicuous of the remaining common hepatic species is *Lophozia sudetica*; this species occurs as scattered stems and small patches in many chionophilous communities and its frequency is probably under estimated. The cosmopolitan species, *Nardia scalaris* and *Cephalozia bicuspidata ssp bicuspidata* occur both as dense stands and as part of the hepatic mat, usually with a canopy of other bryophytes but also in distinctive open patches. Both are rather nondescript species when occurring in bulk and the stands they form in snow-beds seem little different from those common on disturbed gravelly soil at lower altitudes though *Cephalozia bicuspidata ssp bicuspidata* shows considerable morphological plasticity in snow-bed sites. One form is superficially very similar to small forms of *Pleurocladula albescens*.

As is to be expected, vascular plants are very limited in extent in this community. Both the grass *Deschampsia cespitosa* and the dwarf herb *Gnaphalium supinum* occasionally have high cover values but more normally vascular plants occur as isolated stems, the most frequent being *Huperzia selago* and the most visible, *Saxifraga stellaris*.

The *Polytrichum sexangulare - Kiaeria starkei* snow-bed is a patchwork of bryophyte stands showing considerable morphological variation; however boundaries within the community are not always easy to discern and division into sub communities would suggest a sharper division than is real. To deal with this variation the snow-bed is tentatively divided into 'variants'.

Typical Variant

Most of the description above would apply to stands of this type except that in general the mat of smaller hepatics is not such a feature. In general this is the coarsest variant and the one most likely to contain a variety of isolated vascular plants, indeed the rosettes of *Saxifraga stellaris* on some sites, though well spread, are very conspicuous when in bloom. Other species of interest here include tiny dense turfs of *Ditrichum zonatum var scabrifolium*, taller and more falcate than *Ditrichum zonatum var zonatum* which also occurs in the 'drier ground variant'. Much more uncommon are flat decumbent patches of Scapania paludosa which is normally a species of springs and wet flushes fed by snow melt.

Hepatic-rich variant

When well-developed this is a very distinct facies, rather less coarse in structure, characterised by large stands of hepatics normally consisting of *Barbilophozia floerkei*, *Nardia scalaris*, *Cephalozia bicuspidata ssp bicuspidata* and *Pleurocladula albescens*, which are all constants here, but also including small quantities of *Marsupella brevissima*, *Marsupella stableri*, *Marsupella alpina*, *Nardia breidleri* and the nationally rare *Marsupella condensata* and *Cephalozia ambigua*. These latter species are all more typical of the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed but find a niche in complicated mats with the other larger hepatics in this association. In some stands of this variant *Moerckia blyttii* attains its most robust expression forming dense growths over relatively large areas ($0.25m^2$), the individual shoots appearing to burst through the smaller leafy hepatics which are its normal associates. Some stands of the *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed which contain turfs of the rare *Andreaea nivalis* fit best into this variant as this moss is usually associated with small quantities of various hepatics, particularly *Marsupella sphacelata* and *Anthelia julacea*. Because of the dense mats of hepatics which are often composed of a few species, this is the most species-poor of the variants but the differences are marginal.

The *Racomitrium* variant

This facies is characterised as much by the decrease in abundance of the hepatic species as by the occurrence of the constant *Racomitrium heterostichum*. The texture of the community is different being, in general, much more patchy, this effect being enhanced by the distinctive shoots of *Conostomum tetragonum* which are much more frequent here than in the typical community. There are also more regular occurrences of some vascular plants, notably *Salix herbacea*, *Carex bigelowii*, *Huperzia selago* and *Deschampsia flexuosa*. Both *Salix herbacea* and *Deschampsia flexuosa* can reach high cover values here but in stands which contain species typical of the association as a whole.

Habitat

This community, along with the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed and the *Pohlia ludwigii* snow-bed, are the most chionophilous communities in Britain only developing fully on sites where melting patches of snow persist into July and often for a much longer period, sometimes not melting out completely for years at a time. It normally occurs as a complex with the other snow-bed communities in the types of site described above and the ecological gradients involved in creating this pattern are not easy to discern. Given the ecological constraints that are a precondition of the existence of the community, this is the most catholic of the snow-beds, this being particularly true of the 'typical variant' with essentially similar stands occurring on a variety of substrates and under differing moisture regimes. The prolonged snow cover and the effect of meltwater and its associated leaching buffer the effect of the underlying rocks and the community is found equally on the calcareous schist of the Breadalbane range and the base poor granites of the Cairngorms. The range of pH values obtained range from 4.1 to 5.6 and the flora on all sites is markedly calcifuge.

The abundance of *Polytrichum sexangulare* in particular, appears to be related to substrate size and this species is absent from medium sized stable scree where *Kiaeria starkei* can still be very abundant. On such material, *Polytrichum sexangulare*, if it occurs, is usually associated with pockets of finer mineral material that has accumulated either within the scree or on the top of larger rocks that are flush with the scree surface. This material is presumably the result of deposition by snow melt in channels under the snow. The condition which seems to be essential for the establishment of this community is stability of substrate. On the active screes below the north east face of Ben Nevis, where the snow lies very late, the *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed is absent, even where partial stabilisation seems to be occurring and there is some build up of sand or gravel.

A few metres away, in the lee of bed-rock bands, this community develops normally on the stable material that characterises such spots. The mechanism which controls this distribution pattern will work both through the movement of the substrate and via the moisture regime.

On sites where the substrate material is predominantly sand or gravel or where the underlying scree is partially infilled by such material, it is again the stability of this soil which is the determining factor in the distribution of the community, given that snow lie is adequately late. This is well demonstrated in many places in the Cairngorms where the substrate is fairly uniform. The pattern here is for the *Polytrichum sexangulare - Kiaeria starkei* snow-bed to occur on the steeper slopes, particularly on the sides of meltwater channels, which, somewhat paradoxically, are more stable than the more open slopes which are usually covered by some form of the *Marsupella brevissima - Anthelia juratzkana* snow-bed. This preference for steeper slopes is reflected in the higher mean slope of the *Polytrichum sexangulare - Kiaeria starkei* snow-bed samples compared with those of the other extreme snow-bed communities.

The hepatic-rich variant is best developed where irrigation is a persistent feature, even when snow melt is complete, and where there is a depth of sand or gravel. Some stands show evidence of inundation by material washed down from slopes above, the stems of the liverworts trapping the sand and silt and growing on through, producing a layering effect. These silty deposits often show mottling due to gleying. Occasionally there are signs of slumping, a puckering in the hepatic mat, but these would seem to be simple gravitational effects rather than the complex heaving and slumping associated with frost action and small scale geliflucton. Even so it is sufficient to cause a local reduction in the abundance of both *Polytrichum sexangulare* and *Kiaeria starkei* and usually an increase in the cover of both *Cephalozia bicuspidata ssp bicuspidata* and *Nardia scalaris.* This variant is more frequent in the deeper coires where there is persistent irrigation and is particularly common on the fine material that builds up at an angle against the base of crags.

The *Racomitrium* variant occurs where there is a drier moisture regime and this is reflected in the decreased importance of the hepatic element in the community and the greater frequency of species like *Conostomum tetragonum* and *Gymnomitrion concinnatum* which perform better on soil that is not permanently saturated. The increased frequency of the vascular plant element also indicates that this variant is at the least chionophilous end of the spectrum covered by this snow-bed. As the mean slope figures suggest, it is usually developed on significantly less steep slopes than the other variants and is most common on the 'apron' of material below the steeper slopes of nivation hollow sites and on the top of low bluffs or large boulders in coire sites. Another difference from the other variants is the frequent development of dark organic soil layer above the grey sandy soil below.

Zonation

Large stands of any of the snow-bed communities are uncommon and so transitions from one to the other are frequent and often difficult to interpret. The gradation from *Polytrichum sexangulare - Kiaeria starkei* snow-bed to other chionophilous associations is in response to differences in length of snow lie, irrigation, substrate size and substrate stability. Where the community grows over scree, there is a rapid change along a gradient defined by both increased activity of the scree and the loss of surface drainage; vegetation becomes sparse and is either rupestral with *Andreaea* species well represented or species of *Racomitrium* in the more stable interstices. Where the scree remains stable but has a shorter snow cover then there is a change to some form of the *Cryptogramma crispa - Athyrium distentifolium* snow-bed, and this is particularly true where the scree is coarse with little infill.

Where the substrate is finer and uniform across the site, increasing wetness will lead to either a transition to the

Pohlia ludwigii snow-bed, particularly in the base of meltwater channels, or a shift towards the wetter facies of the *Marsupella brevissima - Anthelia juratzkana* snow-bed. Occasionally in the Cairngorms and on Geall Carn in the Alder Forest on sites of low angle and regular irrigation, the *Polytrichum sexangulare - Kiaeria starkei* snow-bed may give way to an attractive community with stands of *Andreaea nivalis* and *Racomitrium fasciculare* or *Racomitrium heterostichum*. On drier more unstable soil there is often a rapid transition to *Marsupella brevissima - Anthelia juratzkana* snow-bed, a change heralded by the increasing patchiness of *Polytrichum sexangulare* and *Kiaeria starkei* and the increase in frequency of the brown *Marsupellacaea* and the grey-white strands of *Anthelia juratzkana*.

On sandy or gravelly terrain where there is a gradient of decreasing snow lie and irrigation the *Polytrichum sexangulare - Kiaeria starkei* snow-bed through its *Racomitrium* variant gives way to some form of *Carex bigelowii* sedge heath. Where drainage is impeded or where precipitation is higher the change is towards *Deschampsia cespitosa - Galium saxatile* grassland but there can be large areas of transitional vegetation with a cover of *Deschampsia cespitosa* but an understory of bryophytes typical of the *Polytrichum sexangulare - Kiaeria starkei* snow-bed. This understory changes in composition along the snow melt gradient with *Rhytidiadelphus loreus* in particular becoming increasingly frequent and often abundant.

Distribution

This is the most widespread of the bryophyte dominated snow-beds with stands of vegetation assignable to it on most of the big hills in the Highlands as far north as Beinn Dearg. In the wetter north and west it is often closely linked to *Deschampsia cespitosa* - *Galium saxatile* grassland and on more marginal stands where *Polytrichum sexangulare* is infrequent the boundary is not easy to perceive. It reaches its best development on the more uniformly finer substrates derived from the Cairngorm granite and can form large stands here. There are also large areas on the plateaus of Lochnagar, Ben Alder and on neighbouring Geal-charn and a particularly fine example in a large nivation hollow to the west of the summit of Craig Megaidh. Where the snow-bed is based on coarse block scree as is often the case in the Central and Western Highlands this community is limited in extent, notably so on Ben Nevis.

	< a >	< b >	< c >	<Full Community>
Altitude (metres)	1067 (950-1230)	1109 (980-1230)	1107 (980-1230)	1094 (950-1230)
Slope (degrees)	25 (10-40)	25 (15-40)	13 (5-35)	21 (5-40)
Aspect (degrees)	(355-130)	(345-90)	(25-135)	(220-135)
pH (16 samples)	4.9 (4.1-5.6)		4.6 (4.3-4.8)	4.8 (4.1-5.6)
Soil moisture	2 (1-3)	2.3 (2-3)	1.8 (1-3)	2.1 (1-3)
Substrate size	2 (1-3)	1.8 (1-3)	1.9 (1-3)	1.9 (1-3)
Bare Ground	1 (2-5)	+ (2-7)	2 (2-4)	2 (2-7)
Number of samples	24	15	19	58
Number of species	10.5 (5-18)	9.7 (3-15)	10.25 (6-18)	10 (3-18)
Kiaeria starkei	V (2-8)	V (2-9)	V (2-9)	V (2-9)
Polytrichum sexangulare	V (4-8)	V (2-9)	V (3-7)	V (2-9)
Barbilophozia floerkii	IV (4-8)	IV (1-8)	IV (1-5)	IV (1-8)
Racomitr'm heterostichum	II (2-6)	I (2-3)	V (2-7)	III (2-7)
Lophozia sudetica	IV (1-4)	III (1-4)	III (1-5)	III (1-5)
Nardia scalaris	IV (1-8)	IV (1-7)	III (1-3)	III (1-8)
Conostomum tetragonum	I (2-5)	I (1-2)	III (1-5)	II (1-5)
Kiaeria falcata	III (1-4)	I (1-1)	I (1-5)	II (1-5)
Oligotrichum hercynicum	II (1-6)	I (1-2)	I (1-2)	II (1-6)
Pohlia ludwigii	II (1-5)	III (2-3)	I (1-7)	II (1-7)
Racomitrium lanuginosum	II (1-2)	I (1-2)	II (1-2)	II (1-2)
Cephalozia bicuspidata	II (1-5)	IV (1-4)	II (1-4)	II (1-5)
Marsupella brevissima	II (1-5)	II (1-3)	II (1-3)	II (1-5)
Marsupella sphacelata	II (1-2)	II (1-4)	I (1-3)	II (1-4)
Moerckia blyttii	II (2-5)	III (7-8)	I (2-6)	II (2-8)
Pleurocladula albescens	I (2-5)	V (1-5)	II (1-2)	II (1-5)
Deschampsia caespitosa	III (1-6)	I (1-3)	I (4-4)	II (1-6)
Gnaphalium supinum	II (2-7)	I (2-2)	I (7-7)	II (2-7)
Huperzia selago	I (1-3)	I (1-2)	III (1-1)	II (1-3)
Andreaea nivalis		I (7-7)		I (7-7)
Ditrichum zonatum	I (1-1)		I (1-2)	I (1-3)
Pohlia nutans	I (1-4)	I (2-2)	II (1-2)	I (1-4)
Polytrichum alpinum	I (2-3)		I (2-4)	I (1-4)
Racomitrium ericoides			I (2-2)	I (2-2)
Racomitrium fasciculare	II (2-4)	I (2-2)		I (2-4)
Anthelia julacea	I (1-1)	I (1-2)	I (1-2)	I (1-7)
Anthelia juratzkana	I (1-4)			I (1-4)
Cephalozia ambigua	I (1-1)	I (1-4)	I (1-1)	I (1-4)
Cephaloziella divaricata			I (1-1)	I (1-1)
Diplophyllum albicans	I (1-4)	I (1-4)	I (1-4)	I (1-4)
Gymnomitrion concinnatum	I (1-1)		II (1-3)	I (1-3)
Lophozia opacifolia	I (3-5)	I (2-2)		I (2-5)
Marsupella alpina		I (1-1)	I (1-1)	I (1-1)
Marsupella condensata	I (1-1)	I (1-1)		I (1-1)
Marsupella emarginata	I (2-3)	I (1-1)	I (5-5)	I (1-5)
Marsupella stableri	I (1-1)	I (1-1)		I (1-1)
Nardia breidleri	I (1-3)			I (1-3)
Nardia compressa				I (7-7)
Scapania paludosa	I (3-3)			I (3-3)
Scapania uliginosa	I (3-3)			I (3-3)
Scapania undulata	I (2-2)			I (2-2)
Carex bigelowii	I (1-1)	I (3-3)	II (1-5)	I (1-5)
Cryptogramma crispa	I (3-3)			I (3-3)
Deschampsia flexuosa	I (1-4)	I (1-4)	II (2-6)	I (1-6)
Juncus trifidus	I (2-2)		I (1-1)	I (1-2)
Salix herbacea	I (4-4)		III (3-8)	I (3-8)
Saxifraga stellaris	II (2-3)	I (1-1)		I (1-3)
Viola palustris	I (2-2)			I (2-2)
Rhytidiadelphus loreus	I (2-3)			I (2-3)

Table 4.2 Polytrichum sexangulare - Kiaeria starkei snow-bed

a) - Typical Community; b) - Hepatic-rich variant; c) Racomitrium variant.

4.3 *Marsupella brevissima - Anthelia juratzkana* Snow-bed

Constant Species

Anthelia juratzkana, Lophozia sudetica, Marsupella brevissima, Polytrichum sexangulare, Racomitrium heterostichum.

Rare Species

Marsupella brevissima(b), Marsupella condensata(a), Pleurocladula albescens(b), Cephalozia bicuspidata ssp. ambigua(a), Nardia breidleri(a), Polytrichum sexangulare(b).

Physiognomy

One of the first impressions gained of the vegetation in areas of very late snow lie is the pattern of browns and greens. The browns of this patchwork are largely provided by this snow-bed community in its typical form. The eye of the observer whose interest is primarily in vascular plants may be drawn to those facies in which *Salix herbacea* is a constant feature but this is an hepatic community which extends as a wrinkled uneven surface over a range of edaphic conditions and in which vascular plants are only of local importance. The three hepatic constants are all exceedingly small, typical stems being less than 10mm long and often less than 1mm wide. The whitish grey shoots of *Anthelia juratzkana* are easy to recognise (setting aside problems of confusion with *Anthelia julacea*, see page 24) as they occur in small dense patches, usually of low cover, which stand out against the predominant browns of the rest of the community. The shoots are often fertile and the distinctive perianth is visible with a good hand-lens. *Marsupella brevissima* often forms large pure stands either of procumbent arcuate stems in a complicated weft or as dense upright turfs. In either case determination is usually straightforward in the field once the observer has become familiar with the range of variation possible. Again the stands are often fertile and emergent or dehisced capsules are frequent; on more exposed sites the whitened and eroded empty perianths are often a feature, standing out against the normally shiny brown stems.

The third hepatic constant, *Lophozia sudetica*, differs from the other two in that it is far from being distinctive and is only occasionally abundant. *Lophozia sudetica* is an extremely variable plant which can form large pure cushions in the *Polytrichum sexangulare - Kiaeria starkei* snow-bed, composed of robust greenish brown stems (20-30mm long) and proportionately large leaves, but which in the present community usually has the same dimensions as *Marsupella brevissima* and usually much the same colour. The constant feature is the brown gemmae which are frequently present at the apices of the stems. Its occurrence is predominantly as scattered groups of stems in the hepatic crust.

The other two constants are the mosses *Polytrichum sexangulare* and *Racomitrium heterostichum*, the former occurring as isolated stems or groups of stems and the latter as small patches within the hepatic sward except in those stands where *Salix herbacea* is also a feature where it can reach high cover values. Four other mosses are also frequent. *Conostomum tetragonum* keeps its usual mode of growth here, the bright glaucous patches immediately attract the eye but are always widely spread and of small dimension and thus of low cover value. *Kiaeria falcata* is also a cushion former and in this community the dense cushions are often blackened until late in the season. This species is often a feature of those stands where there is much bare soil. In some facies of the typical *Marsupella brevissima - Anthelia juratzkana* snow-bed *Kiaeria falcata* can form large, dense, swelling cushions, often containing an admixture of hepatics invisible until the falcate shoots are parted. The dull yellow of *Kiaeria falcata* in this form is distinct from the brighter green of *Kiaeria starkei*, small stands of which also occur. *Oligotrichum hercynicum* occurs in much the same form as *Polytrichum sexangulare* but is generally less frequent, exploiting gaps in the bryophyte crust.

Though discreet stands of the constant species are a feature of the community, much of the interest stems from the small scale species diversity which characterises many stands of the hepatic crust. This study has produced herbarium specimens scarcely more than 10mm x 10mm which contain 13 species of bryophyte. The constituent species of these mixed stands vary somewhat but the general pattern is for the constant species to be present, *Polytrichum sexangulare* as one or two stems overtopping all else, with a liverwort complex of *Marsupella condensata, Nardia breidleri, Pleurocladula albescens, Cephalozia bicuspidata ssp bicuspidata, Nardia scalaris, Cephalozia bicuspidata ssp. ambigua, Gymnomitrion concinnatum, Marsupella stableri* and *Diplophyllum albicans* with occasional stems of *Kiaeria falcata, Pohlia nutans/drummondii* and *Ditrichum zonatum var zonatum.*

Pleurocladula albescens is not as abundant here as it is in the *Polytrichum sexangulare - Kiaeria starkei* snow-bed but it is more frequent than is at first apparent as it usually occurs in smaller stands. On some sites the nationally rare *Marsupella condensata* is as abundant as *Marsupella brevissima* but this may be masked by its superficial similarity to the more common species. It has the same range of variation as Marsupella brevissima but the lunate sinus to the leaf and the more terete shoots are constant features and should be visible to the competent field bryologist. *Cephalozia bicuspidata ssp. ambigua* (see page 24) can also be abundant in this snow-bed in pure, blackened patches of minuscule stems and it is often in company with the equally tiny *Nardia breidleri*. The texture and colour of the shiny brown patches of the latter species are distinctive and this field identification can often be confirmed by the large and distinctive perianths.

Three other nationally rare hepatics are associated with this snow-bed; they do not feature in any of the samples but occurred on several of the sites. *Gymnomitrion apiculatum* is very similar to small forms of *Gymnomitrion concinnatum* but is usually rather more brown with less white at the edge of the leaf and occurs in small dense stands within the hepatic crust. *Marsupella sparsifolia* is a larger plant than *Marsupella brevissima* and occurs in more open upright stands; it normally has yellow/brown leaves with 'scorched' edges and is paroecious. *Marsupella arctica* was first discovered in Britain as a direct result of this study and on one of its two stations occurs as flat black mats within this hepatic community (Long *et al.* 1990).

The *Marsupella brevissima* - *Anthelia juratzkana* snow-bed covers a range of different ecological conditions and two sub communities have been identified in recognition of this range, both grade into the typical community described above but are very different from each other.

The *Salix herbacea* sub community

The carpets of *Salix herbacea* with an abundance of *Racomitrium heterostichum* interspersed with the other community constants make this facies easy to recognise. Early in the season, immediately after snow melt, *Salix herbacea* may not be in leaf and is then largely invisible but investigations with a knife will soon reveal the stems if they are present. There is an increase in frequency of *Ditrichum zonatum* but while this is interesting ecologically it will not be as apparent to the observer as the more noticeable *Conostomum tetragonum* and the vascular plants, *Carex bigelowii, Juncus trifidus* and *Deschampsia flexuosa*. This mix of species makes this a very attractive community but one in which the presence of the vascular plants along with taxonomically more difficult bryophytes has led to an over-emphasis on the former at the expense of the latter in some surveys.

The *Cephalozia bicuspidata ssp bicuspidata - Nardia scalaris* sub community

The most obvious feature which sets this sub community apart is the greater preponderance of green and the lush texture. *Marsupella brevissima* is still abundant but even this species often has a greenish hue and the erect, densely packed shoots present a different appearance to the typical community.

Anthelia juratzkana is less evident here but *Polytrichum sexangulare* is rather more frequent and *Kiaeria starkei* is constant and can form moderate stands. However it is the combined effects of the three hepatics, *Cephalozia bicuspidata ssp bicuspidata, Nardia scalaris* and *Pleurocladula albescens* with the more robust patches of *Marsupella brevissima* that give the community its character; an 'hepatic mat' rather than the 'hepatic crust' of the typical community. Vascular plants are of even less importance than in the main association and *Racomitrium heterostichum* is rather patchy. Some stands of this type can have large flat mats of *Marsupella sphacelata* and more frequently distinctive rosy-red wefts of the tiny *Marsupella stableri*. *Marsupella alpina*, also a species more typical of irrigated rocks can also occur on soil in this community and on occasions can be very hard to distinguish from *Marsupella brevissima*.

Habitat

As the crude estimates of substrate size and soil moisture content indicate this is a community of medium to fine mineral soils where the soil is not permanently saturated once snow melt has taken place. Even where the immediate substrate appears stony the crust of hepatics with its integral silty soil retained by the buried stems seems independent of this and the adhesion to the stones below is often only tenuous. Small stands can occur in areas of block scree where large blocks have been stable long enough, and with their upper surface at a shallow enough angle to have accumulated a mineral soil. The remarkably uneven surface of many of the stands is due to frost heave and small scale gelifluction and the overall effect often depends on the steepness of the slope and the amount of bare soil. Where there are large areas devoid of vegetation and relatively steep slope, then the scattered stands of this snow-bed are frequently arranged in a discernible pattern of lines down the slope, as a result of soil movement. Where vegetation cover is more complete and the slope less, then patterning is not so obvious and the crust has a seemingly random pattern of small scale hummocks and hollows

This community has an extremely harsh environment to contend with. Under the snow pack, the soil, while buffered from variations in temperature, remains frozen for much of the winter but at the interface between the soil surface and the snow, meltwater may percolate during thaws, melting out the upper layers. So there may be a succession of freezing and thawing of the upper layers, a process which is repeated during the final snow melt. Even after the snow cover has gone, sharp frosts in the hills can occur early and late in the summer subjecting the soil to further disturbance. Crossing a slope that has been subjected to these processes just after snow-melt, the fragility of the surface is apparent and on the steeper slopes one is ankle deep in sand and gravel. The species of the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed cope not only with this instability but also with the dryness associated with the porous substrate once snow melt is complete; the same slope that was composed of ankle deep wet sand and gravel, can two weeks later, be very firm and dusty dry. Again, once the snow cover has gone, this community is exposed to the abrading power of the wind loaded with fine grains of sand and many stands show evidence of such erosion.

The spatial arrangement of the two snow-beds suggests that snow lies later on average over the *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed but there is no reliable data to support this. However it seems reasonable to postulate that it is the extreme conditions of instability and variability in irrigation that prevents the more robust *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed from establishing itself here although there is no information on the dynamics of these two snow-beds.

The most extreme stands of this community in environmental terms are those which occur in very open communities on the shoulders of nivation hollows where the substrate is formed from eroded granite. Here the vegetation occurs as islands in the gravel and some of the smaller stands, typically of *Marsupella brevissima* and *Kiaeria falcata* are so rounded as to be almost detached from the substrate. This extreme grades into the typical community, a gradient which will reflect both an increase in soil stability and, particularly, more regular irrigation.

For the *Salix herbacea* sub community conditions are rather different. This is an association of more easy-angled sites where instability is active but not catastrophic and where there may still be some surface drainage after snow melt. It is best developed on the lower angled apron below the steep slopes of nivation hollows or on terraces above incised burns that act as snow catchment zones. It may also occur in a more fragmented form along the 'cornice zone' which can be a feature of the edge of ridges and plateaux above steep slopes and here *Gymnomitrion concinnatum* may be much more abundant than in the typical community. These fragments provide a link with similar stands which can occur on exposed sites on summit plateaux where there is some snow holding capacity. These sites become snow free much earlier in the year and their links with the snow-bed proper is not clear.

The *Cephalozia bicuspidata ssp bicuspidata - Nardia scalaris* sub community occurs on those sites which receive regular irrigation for most of the year. These two hepatics need moisture to develop the swelling cushions that can be a feature of this association. The increased frequency of both *Kiaeria starkei* and *Polytrichum sexangulare* also suggests a more stable soil and the more regular hepatic mat here seems to bear this out although fat folds of hepatics, slumping down the slope are still apparent on the steeper sites. Although no direct observations have been made, the typical sites of this sub-community on the sides of meltwater channels and at the base of small crags, suggest a later snow lie than the main community but also a less intimate contact with the lower snow surface.

Zonation

The facies of the community with much bare granite gravel and only isolated stands of hepatics, gives way to boulder studded gravel slopes with very sparse vegetation, often only single tussocks of *Juncus trifidus* and scattered stems of the ubiquitous *Oligotrichum hercynicum*. On these slopes the snow melts earlier leaving the soil at the mercy of severe late spring frosts; this and the subsequent dry conditions appear to be sufficient to preclude even *Marsupella brevissima*. More generally, the boundaries of this community are with either the *Polytrichum sexangulare - Kiaeria starkei* snow-bed often through the *Cephalozia bicuspidata ssp bicuspidata - Nardia scalaris* sub-community or with some form of *Carex bigelowii - Polytrichum alpinum* sedge heath, sometimes through the *Salix herbacea* sub-community. Both these transitions are gradual and emphasise the continuity of these chionophilous communities as their constituent species respond to the relatively regular ecological gradients. In the Cairngorms the *Marsupella brevissima - Anthelia juratzkana* snow-bed can give way at its upper margin to *Nardus - Carex* grass heath as the slope merges into the plateau, often with an intermediate fragmentary band of *Deschampsia flexuosa*.

On hills further west where the rainfall is substantially higher this community can occur in a mosaic with flattened tussocks of *Deschampsia cespitosa* and there may be a rapid transition to some form of *Deschampsia cespitosa* grassland. Where this community, particularly its *Salix herbacea* facies, occurs along the cornice line above steep slopes it frequently grades into *Racomitrium lanuginosum* heath on the more exposed shoulders or plateaux above. Where deep gullies bite into this cornice zone large stands of *Pohlia ludwigii* snow-bed often occur in close proximity reflecting a steep ecological gradient based on both regularity of irrigation and length of snow lie

Distribution

This community occurs in most of the groups of hills with tops over 1000m but the largest stands occur in the Cairngorms. In the more oceanic hills the generally smaller sites, the patchy distribution of areas of fine to moderate sands and gravels that this community requires and the lower frequency of severe frosts (giving more stable substrates) all limit the extent of the *Marsupella brevissima - Anthelia juratzkana* snow-bed. There are many stands which are best viewed as transitional between this and *Polytrichum sexangulare - Kiaeria starkei* snow-bed. The best examples outside the Cairngorms are on Craig Megaidh, Ben Lawers and on the Alder hills with smaller areas on Aonach Beag, by Ben Nevis, and on Beinn Dearg in Wester Ross.

	< A >	< B >	< C >	< Full Community >
Number of Samples	23	8	10	41
Altitude (metres)	1112 (900-1230)	1080 (1000-1120)	1112 (1020-1230)	1105 (900-1230)
Slope (degrees)	19 (5-40)	8 (5-15)	16 (5-30)	16 (5-35)
Aspect (degrees)	(285-120)	(10-140)	(345-110)	(285-140)
pH (11 samples)	5.1 (4.5-5.8)	4.9 (4.8-5.1)	4.9 (4.4-5.4)	5 (4.4-5.8)
Soil moisture	1.5 (1-3)	1.25 (1-2)	1.9 (1-3)	1.5 (1-3)
Substrate size	1.6 (1-3)	1.75 (1-2)	1.5 (1-2)	1.6 (1-3)
Bare ground	5 (0-8)	2 (0-5)	1 (0-4)	5 (0-8)
Number of species	10.6 (3-18)	12.9 (9-18)	12.6 (8-18)	11.5 (3-18)
Anthelia juratzkana	V (1-6)	V (1-6)	IV (1-4)	V (1-6)
Lophozia sudetica	IV (1-6)	V (II-7)	IV (1-6)	V (1-7)
Marsupella brevissima	V (3-8)	IV (1-7)	V (2-9)	V (1-9)
Polytrichum sexangulare	IV (1-5)	IV (1-4)	V (1-5)	IV (1-5)
Racomitrium heterostichum	III (2-4)	V (3-9)	III (1-6)	IV (1-9)
Conostomum tetragonum	II (1-4)	V (1-4)	II (2-6)	III (1-6)
Kiaeria falcata	IV (2-9)	II (2-6)	II (1-6)	III (1-9)
Kiaeria starkei	III (1-7)	II (1-4)	V (3-7)	III (1-7)
Oligotrichum hercynicum	III (1-4)	III (1-3)	II (2-3)	III (1-4)
Cephalozia bicuspidata	II (1-4)	III (1-2)	V (1-8)	III (1-8)
Marsupella condensata	III (1-7)	II (1-4)	II (1-3)	III (1-7)
Nardia scalaris	III (1-7)	II (2-2)	IV (1-4)	III (1-7)
Pleurocladula albescens	III (1-5)	I (1-1)	IV (1-5)	III (1-5)
Ditrichum zonatum	I (1-3)	IV (1-3)	II (1-2)	II (1-3)
Pohlia nutans	II (1-5)	III (2-3)	II (1-3)	II (1-5)
Cephalozia ambigua	III (1-3)	I (1-1)	II (2-8)	II (1-8)
Gymnomitrion concinnatum	II (1-5)	II (2-5)	II (1-3)	II (1-5)
Marsupella stableri	I (1-2)	II (1-3)	II (1-4)	II (1-4)
Salix herbacea	I (1-2)	V (4-7)	II (2-5)	II (1-7)
Pohlia ludwigii	I (1-2)		II (1-2)	I (1-2)
Racomitrium fasciculare	I (1-2)	II (3-3)	I (2-2)	I (1-3)
Racomitrium lanuginosum	I (1-2)	II (1-2)		I (1-2)
Barbilophozia floerkii	II (1-2)	II (1-4)		I (1-4)
Diplophyllum albicans	I (2-2)		II (1-4)	I (1-4)
Marsupella alpina	I (1-1)		II (1-4)	I (1-4)
Marsupella sphacelata	I (1-4)		I (3-6)	I (1-6)
Moerckia blyttii	I (4-5)	II (1-2)		I (1-5)
Nardia breidleri	II (2-5)	II (2-4)	I (2-2)	I (2-5)
Carex bigelowii		III (2-5)	I (2-2)	I (2-5)
Deschampsia caespitosa	I (2-2)		I (4-4)	I (2-4)
Deschampsia flexuosa	I (2-2)	II (3-5)	I (2-2)	I (2-5)
Gnaphalium supinum	I (1-4)		I (4-4)	I (1-4)
Juncus trifidus	I (1-1)	III (2-3)		I (1-3)

Table 4.3. Marsupella brevissima - Anthelia juratzkana Snow-bed

a) - Typical sub-community; b) - Salix herbacea sub-community; c) - Cephalozia bicuspidata ssp bicuspidata - Nardia scalaris sub-community.

4.4 Pohlia ludwigii snow-bed

Constant Species

Pohlia ludwigii

Rare Species

Polytrichum sexangulare(b), Andreaea nivalis(b), Pohlia wahlenbergii var glacialis(b), Marsupella brevissima(b).

Physiognomy

This is a simple snow-bed community of low species diversity, in which *Pohlia ludwigii* is usually abundant or dominant, sometimes over large areas, occasionally in excess of $100m^2$ as on Aonach Mor in Lochaber and in Garbh Coire on Braeriach in the Cairngorms. Though the colour of this moss is not as immediately recognisable as *Pohlia wahlenbergii var glacialis* it is none the less distinctive, particularly when growing in large pure stands as is often the case and recognising this snow-bed should present no problems. The bright, mid-green colour of the erect stems with their ovate/lanceolate leaves that are longly decurrent down the stem serve make for an easy confirmation of this first impression. Where this species occurs outside of the latest snow-beds sporophytes appear to be rare (Smith, 1978) but on many of the sites visited on this study there were stands that were abundantly fertile. The long snow cover has a marked effect on the shoots of the moss and when they are first uncovered during snow melt, the flattened stems with a dull red-brown colour are initially confusing, resembling some species of *Bryum*.

Scattered stems and small patches of *Polytrichum sexangulare* are a frequent feature but much more noticeable are the isolated tussocks of *Deschampsia cespitosa,* often the viviparous form previously distinguished as *Deschampsia alpina*. *Nardia scalaris* is much less conspicuous but no less frequent, occurring both as isolated stems in the moss carpet or as small cushions. Decumbent patches of three other hepatics also grow mixed in with *Pohlia ludwigii;* *Scapania undulata* can be abundant and is often associated with the tussocks of *Deschampsia cespitosa*, the shoots are green and take on none of the red colouration that is common on more exposed montane sites. *Scapania uliginosa* is also less pigmented in this community than in the springs that are its more usual habitat but the antical lobes of the leaf are consistently small and concave here so identification presents none of the problems that can arise elsewhere. *Marsupella sphacelata* is equally frequent, the predominantly black shoots in flat mats standing out in an otherwise green vegetation. The erect, bright-green stems of *Philonotis fontana* are a feature of some sites usually forming moderate to large, discrete patches within the sward of *Pohlia* *ludwigii.*

Several other bryophytes have single occurrences in the small number of samples deemed necessary to describe this community but some of these can be abundant and are not just 'noisy data'. Some stands on bed-rock (and so not sampled) contain large patches of the rare *Andreaea nivalis* and occasionally the even more rare *Andreaea frigida*, the contrast between the dull red of the *Andreaea* and the green of the *Pohlia*, set off by the sparkle of the melt water burn, being particularly memorable. Also on bed-rock and large rocks in burns and equally distinctive, are the stands which contain *Anthelia julacea* and *Nardia compressa*, the former in dense silver-grey patches and the latter, deep red cushions.

Habitat

This is typically a snow-bed of moderately angled sites on medium to coarse substrates which receive constant irrigation either from snow melt or from spring-heads. Its relationship with the *Polytrichum sexangulare - Kiaeria starkei* community suggests that average snow lie is rather similar for both snow-beds. It often spreads from a coarse stony substrate onto bed-rock and generally seems intolerant of soil instability. This may either be a direct effect or may operate through the availability of percolating water having a buffering effect on soil instability through frost action. The constancy of irrigation appears to be the crucial factor in the occurrence of this snow-bed and in some ways it may be more instructive to regard this as a spring community with some snow-bed features.

Two types of habitat have the largest and most continuous stands; in coire snow-beds large stands can occur on a base of block scree where for some reason drainage remains at the surface. On such sites the stems of the moss retain much particulate material and the shoots grow through this - stems of 15cm can be extracted with care. Successional relationships here are open to speculation; the stands of *Pohlia ludwigii* are dependant on the impeded drainage but this in turn seems to depend on the fine material trapped by the snow-bed without which the water would percolate down into the scree. The other typical habitat is along the base of melt water channels that retain some moisture even after snow melt, and as a fringing zone along the larger burns emerging from melting snow.

On several of the large Cairngorm snow-beds, notably Garbh Uisge Beag on Ben Macdui, there are large stands in the splash zones of the burns as they cascade down the broken granite crags, and somewhat similar communities also occur on the volcanic crags in the coires of Ben Nevis. More moderate stands occur on the steep funnels of fine scree where large gullies in craggy coires emerge onto the flatter summit areas above; the tops of these gullies retain snow very late and also water draining from the ground above is channelled into them. Finally, there are fragmentary stands on ledges at the base of crags where snow banks up in the winter and remains into the summer and where there is also water draining from above. These stands are often transitional and in one or two places contain rare vascular plants like *Saxifraga rivularis* and *Cerastium cerastoides*.

Zonation

Transition from the *Pohlia ludwigii* snow-bed to other communities depends on changes in substrate size and drainage as well as snow lie. Where irrigation remains constant but snow lie is reduced then there is an increase in the frequency of *Deschampsia cespitosa* and a move towards an extreme form of the *Deschampsia cespitosa* - *Galium saxatile* grassland. In most cases however there is a gradual change to *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed reflecting a decreasing level of soil moisture during and after snow melt. On some sites this ecotone may be almost as extensive as the 'parent' communities. Where the snow-bed is bordering a burn there may be a narrow zone of transition to the more definitely aquatic species; in the Cairngorms and on Ben Alder this change may well be to large red cushions of *Nardia compressa*.

On bed-rock sites and stands based on spring-heads the *Pohlia ludwigii* snow-bed grades abruptly into spring communities. On Braeriach and in Glencoe, stands of this snow-bed surround large *Pohlia wahlenbergii var glacialis* springs but a more gradual change to some form of *Philonotis fontana Saxifraga stellaris* or *Sphagnum auriculatum* spring is more common. At the tops of gullies where there is a steep ecological gradient from wet coarse soil in the gully bed, to the drier, finer soil of the 'cornice zone', the *Pohlia ludwigii* snow-bed occurs in close proximity to the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed and one sample from such a zone contained much *Salix herbacea*.

Distribution

This snow-bed is much more limited in distribution than either the *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed or the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed. It is confined to the largest snow-beds where irrigation is constant and few convincing stands were seen outside of the Central Highlands and Cairngorm areas. As with other snow-bed communities it is best developed in the nivation hollows and coires of the Cairngorms but there are also good examples on Aonach Mor and Ben Nevis in Lochaber.

Number of samples	9	
Altitude (metres)	1108	(1050-1230)
Slope (degrees)	17	(5-35)
Aspect (degrees)		(315-100)
pH (2 samples)	4.9	(4.6-5.1)
Soil moisture	3	(3-3)
Substrate size	2.1	(1-3)
Bare Ground	1	(0-5)
Number of species	5.3	(2-8)
Pohlia ludwigii	V	(6-10)
Polytrichum sexangulare	III	(1-4)
Nardia scalaris	III	(1-5)
Deschampsia caespitosa	III	(2-5)
Marsupella sphacelata	II	(2-4)
Scapania uliginosa	II	(1-5)
Scapania undulata	II	(1-7)
Philonotis fontana	II	(4-6)
Andreaea nivalis	I	(5-5)
Ditrichum zonatum	I	(2)
Oligotrichum hercynicum	I	(2)
Pohlia wahlenbergii var glacialis	I	(1)
Racomitrium heterostichum	I	(2)
Anthelia julacea	I	(2)
Cephalozia bicuspidata	I	(2)
Diplophyllum albicans	I	(1)
Lophozia sudetica	I	(4)
Marsupella brevissima	I	(1)
Marsupella emarginata	I	(4)
Nardia compressa	I	(4)
Deschampsia flexuosa	I	(1)
Salix herbacea	I	(6)

Table 4.4. ***Pohlia ludwigii*** **snow-bed**

4.6 *Carex bigelowii - Polytrichum alpinum* sedge heath, *Barbilophozia floerkei* sub community

The typical *Carex bigelowii - Polytrichum alpinum* sedge heath (Rodwell 1987) though markedly chionophilous was considered to be outside the scope of this study because of the high cover of vascular plants. However, within the limits of the sites that were investigated, there were areas of vegetation that had strong links with this heath rather than with the bryophyte dominated snow-beds. Some of the samples in what is described here as the *Barbilophozia floerkei* sub-community of the *Carex bigelowii - Polytrichum alpinum* sedge heath would fit within the parameters of the parent community but others show a rather different structure. This is rather unsatisfactory and it is with some trepidation that this sub-community is erected.

The *Barbilophozia floerkei* sub-community

Constant Species

Carex bigelowii, Barbilophozia floerkei, Salix herbacea.

Rare Species

Polytrichum sexangulare(b).

Physiognomy

This association has a short closed sward with a patchy structure containing either large clumps or scattered stems of *Carex bigelowii* in a matrix provided by *Barbilophozia floerkei, Dicranum fuscescens* and *Polytrichum alpinum*. In many stands *Salix herbacea* grows and may be locally abundant, particularly where *Dicranum fuscescens* is also abundant. *Polytrichum sexangulare* is also common but usually has low cover values, growing as scattered small patches, and its presence is often masked by the more abundant *Polytrichum alpinum*. The only other common species is *Deschampsia flexuosa* and in some stands this species can form an open sward with the common bryophytes, *Carex bigelowii* occurring only as scattered stems. In those stands where *Polytrichum alpinum* and *Dicranum fuscescens* are infrequent the three *Racomitrium* species, *Racomitrium heterostichum, Racomitrium fasciculare* and *Racomitrium lanuginosum* become the dominant bryophytes, giving a different colour and texture to the vegetation. This facies may also have a good cover of *Salix herbacea* particularly where *Racomitrium heterostichum* is abundant. Of the less common species, *Conostomum tetragonum* and *Moerckia blyttii* catch the eye where they occur, the former because of its colour and the latter because of its morphology.

Habitat

This is a community of moderate slopes adjacent to the more extreme bryophyte dominated snow-beds and which are snow free earlier in the year, perhaps as early as mid May in some cases. It is absent where there is underlying block scree or where there is constant irrigation and is best developed where the soil is stable. There is usually a relatively deep peaty soil layer above a sandy gravel that may show evidence of gleying and this provides a major contrast with the bryophyte snow-beds where development of an organic layer is normally rudimentary. As with other chionophilous communities this association will always be very wet during the period of snow melt but once the snow has gone the stands are mostly well drained and are absent from obvious lines of drainage. The typical habitat is on the more open slopes of nivation hollows, well away from the effective snow gathering slopes and often on terraces that occur above the incised burns which flow from the longest lying snow. There may be smaller stands on the upper slopes of these hollows as they merge into the plateau above. On coire sites and in the wetter western mountains stands of this type are limited to the better drained rocky bluffs within the site and to a narrow zone where cornices form along the edges of exposed slopes above the coires.

Zonation

This sub community has strong affinities with both the drier variant of the *Polytrichum sexangulare - Kiaeria starkei* snow-bed and the *Salix herbacea* sub community of the *Marsupella brevissima - Anthelia juratzkana* snow-bed and can grade into either one. This will depend on both increasing length of snow lie and on irrigation and soil stability. Where snow lies longer and the soil is stable and well irrigated then the vegetation changes to stands that fit better within the *Polytrichum sexangulare - Kiaeria starkei* snow-bed. Where the snow lies longer but irrigation is less the soil will tend to be more prone to frost heave and the change will be towards the *Marsupella brevissima - Anthelia juratzkana* snow-bed. As length of snow cover decreases, stands become indistinguishable from the typical *Carex bigelowii - Polytrichum alpinum* sedge heath.

Distribution

This tentative sub community has a similar distribution to the typical sedge heath (Rodwell, 1987) favouring the more continental climate of the eastern hills with only isolated outposts to the west. Stands can be large in some of the Cairngorm snow-beds and on the White Mounth - Lochnagar plateau. It is absent from the plateau of Ben Alder where it might have been expected to occur but there is a good example on neighbouring Geal-carn where the drainage regime is more favourable. Isolated small stands occur in the Affric - Cannich hills but none any further north or west. On Creag Megaidh the plateau has much vegetation that seems to consist entirely of *Carex bigelowii* and *Dicranum fuscescens* (Ratcliffe 1956-9)) but this does not grade into anything that could be placed in this sub-community.

Number of samples	19	
Altitude (metres)	1125	(1030-123)0
Slope (degrees)	11	(5-25)
Aspect (degrees)		(315-140)
pH (4 samples)	4.5	(4.1-4.8)
Soil moisture	1.8	(1-3)
Substrate size	1.8	(1-3)
Bare ground	0	
Mean number of species	7.6	(4-15)
Barbilophozia floerkii	V	(2-9)
Carex bigelowii	V	(1-9)
Salix herbacea	IV	(2-8)
Dicranum fuscescens	III	(1-7)
Polytrichum alpinum	III	(1-7)
Polytrichum sexangulare	III	(1-5)
Deschampsia flexuosa	III	(2-8)
Kiaeria starkei	II	(2-7)
Racomitrium fasciculare	II	(1-5)
Racomitrium heterostichum	II	(1-7)
Racomitrium lanuginosum	II	(1-4)
Cephalozia bicuspidata	II	(1-2)
Lophozia sudetica	II	(1-3)
Huperzia selago	II	(1-3)
Conostomum tetragonum	I	(1-3)
Pohlia nutans	I	(1-2)
Diplophyllum albicans	I	(1-1)
Marsupella sphacelata	I	(3-3)
Moerckia blyttii	I	(2-3)
Nardia scalaris	I	(2-2)
Ptilidium ciliare	I	(2-2)
Deschampsia caespitosa	I	(1-4)
Gnaphalium supinum	I	(7-7)
Juncus trifidus	I	(1-2)
Viola palustris	I	(3-3)

Table 4.5. *Carex bigelowii - Polytrichum alpinum* sedge heath, *Barbilophozia floerkei* sub-community

4.6 *Deschampsia cespitosa - Galium saxatile* grassland

Within the snow-beds that were investigated there are a areas of vegetation, in some cases rather extensive, in which the abundance of *Deschampsia cespitosa* in combination with a variety of other species indicates that these stands fit better at the extreme chionophilous end of the *Deschampsia cespitosa - Galium saxatile* grassland (Rodwell, 1987), rather than with the bryophyte snow-beds.

Constant Species

Deschampsia cespitosa, Carex bigelowii, Polytrichum alpinum.

Rare Species

Polytrichum sexangulare(b), Cerastium cerastoides.

Physiognomy

The tussocks of *Deschampsia cespitosa* are normally the dominant feature although *Carex bigelowii* can also be abundant. Although bryophytes form an important part of the structure of the sward they are not as immediately apparent here except in those stands which approach the *Rhytidiadelphus loreus* sub community (Rodwell, 1987). Scattered stems and small patches of *Polytrichum alpinum* are a common feature though it never forms the dense stands that are often found in some facies of the *Carex bigelowii - Polytrichum alpinum* sedge heath.

Dark green patches of *Barbilophozia floerkei* can also be common and may form a complete understory to the tussocks of *Deschampsia cespitosa* in those stands which are transitional to the *Polytrichum sexangulare - Kiaeria starkei* snow-bed; both *Polytrichum sexangulare* and *Kiaeria starkei* have scattered stems and cushions in this understory. In a similar fashion there may also be a carpet of *Pohlia ludwigii* with the Deschampsia cespitosa giving a transition to the *Pohlia ludwigii* snow-bed. Of the three *Racomitrium* species that are also common, the yellow green, much branched weft of *Racomitrium fasciculare* is the most frequent, usually as small patches around the base of the tussocks of Deschampsia cespitosa. Both *Racomitrium heterostichum* and *Racomitrium lanuginosum* occur as scattered stems within the bryophyte sward. The only other vascular plant to occur with any degree of frequency is *Galium saxatile* but it is limited to those stands in which the preferential snow-bed bryophytes are absent.

There is a long tail of other species with less frequent occurrences. As mentioned above *Rhytidiadelphus loreus* is very abundant in some stands, its characteristically coarse springy mat, often containing a little *Hylocomium splendens* and *Pleurozium schreberi* dominating the samples. More rarely there are dense stands of *Dicranum fuscescens* providing the matrix for the *Deschampsia cespitosa*, reminiscent of types of *Carex bigelowii - Polytrichum alpinum* sedge heath. On a few widely scattered sites the tussocks of *Deschampsia cespitosa* are brightened up by the trailing stems of *Cerastium cerastoides* and less frequently this may be accompanied by *Cerastium arcticum*.

Habitat

This grassland occurs on a wide range of slopes over moderate to fine substrates or even on block scree where there has been some infilling with both organic and mineral material. Spatial relationships suggest that this grassland is snow free significantly earlier in the year than the bryophyte-dominated snow-beds. The constant feature is either regular irrigation or some impedance to drainage giving soils that are always at least moderately wet. The *Deschampsia cespitosa - Galium saxatile* grassland proper is most prominent on areas of moderately late snow lie in the north and West Highlands where the conditions that it requires are met by the high rainfall, often more than 200 wet days a year (Ratcliffe 1968) and by the humidity regime of the predominantly north and east facing slopes on which it occurs (Rodwell, 1987). The extreme facies described here, exploits similar conditions which exist near very late snow-beds over a wider area. The fragmentary nature of the stands on seemingly suitable ground on the Cairngorm granite suggests a preference for more basic soils but the pH of the limited number of soil samples does not bear this out and the community is rare on the more calcareous schists of the Breadalbane range. It would appear that the balance of conditions in the Cairngorms between a lower rainfall, very late snow lie, areas of free draining gravel and areas of impeded drainage favour a transition from bryophyte-dominated communities to either *Carex bigelowii* - *Polytrichum alpinum* sedge heath or some form of *Nardus* grassland.

Zonation

On western and northern hills this facies of the *Deschampsia cespitosa* - *Galium saxatile* grassland grades into the more typical *Rhytidiadelphus loreus* sub community to which it is most closely allied and which formed the border for many of the sites investigated. As length of snow lie increases then the preferential snow-bed species increase in abundance, leading finally to stands of *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed. On the north east slope of Sgurr Mor Fannich (Site 32) in the Northern Highlands there is an excellent example of this gradual change from typical *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed through transitional vegetation to *Rhytidiadelphus loreus*-rich *Deschampsia cespitosa* grassland and finally to the "species-rich facies" of McVean and Ratcliffe's *Deschampsietum* (McVean and Ratcliffe, 1962) on the summit ridge above.

Further east where the typical *Deschampsia cespitosa* - *Galium saxatile* grassland is largely absent these samples grade into *Carex bigelowii* - *Polytrichum alpinum* sedge heath or *Nardus Carex* grassland as drainage improves or snow lie decreases. Where snow lies longer *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed develops except where irrigation is constant when *Pohlia ludwigii* snow-bed may be the end point of this gradient.

Distribution

These transitional stands are more frequent where the 'parent community' is best developed and so they are a feature of the hills of the north and west and, on a number of hills where no bryophyte dominated snow-beds exist, these stands with their scattering of snow-bed species are the most chionophilous community. The eastern limit would appear to be the western Cairngorms and even here the stands are very small.

Number of samples	11
Altitude (metres)	1065 (970-1200)
Slope (degrees)	22 (5-35)
Aspect (degrees)	(320-140)
pH (3 samples)	4.6 (4.2-5.0)
Soil moisture	2.2 (1-3)
Substrate size	1.7 (1-3)
Bare Ground	
Number of species	8.6 (2-13)
Deschampsia caespitosa	V (3-9)
Carex bigelowii	IV (2-6)
Polytrichum alpinum	IV (1-5)
Barbilophozia floerkii	III (1-6)
Racomitrium fasciculare	III (2-4)
Galium saxatile	II (3-7)
Kiaeria starkei	II (3-3)
Nardia scalaris	II (1-3)
Pohlia ludwigii	II (1-5)
Polytrichum sexangulare	II (2-4)
Racomitrium heterostichum	II (1-2)
Racomitrium lanuginosum	II (1-2)
Agrostis capillaris	I (5-5)
Anthelia julacea	I (2-2)
Cephalozia bicuspidata	I (2-3)
Cerastium cerastoides	I (4-4)
Cryptogramma crispa	I (1-1)
Deschampsia flexuosa	I (2-2)
Dicranum fuscescens	I (2-8)
Diplophyllum albicans	I (1-1)
Ditrichum zonatum	I (1-1)
Gnaphalium supinum	I (2-5)
Huperzia selago	I (3-3)
Hylocomium splendens	I (2-3)
Kiaeria falcata	I (1-1)
Lophozia sudetica	I (2-3)
Marsupella emarginata	I (4-4)
Oligotrichum hercynicum	I (2-2)
Pleurozium schreberi	I (1-2)
Pohlia nutans	I (1-1)
Racomitrium ericoides	I (2-2)
Rhytidiadelphus loreus	I (8-9)
Salix herbacea	I (2-2)
Saxifraga stellaris	I (1-3)
Scapania uliginosa	I (2-3)
Viola palustris	I (3-3)

Table 4.6. Deschampsia cespitosa grassland

4.7 *Pohlia wahlenbergii var glacialis* spring

This striking community, though dependant upon melt water from late snow-beds, often lies outside the zone of bryophyte-dominated vegetation, forming at spring-heads where cold water from the snow melt emerges from block scree. It is a simple community and the descriptions provided by both the NVC (Rodwell, 1987) and by McVean and Ratcliffe (1962) is accurate. The small number of samples of this community (3) made during this survey are merely duplications of the slightly larger number made during the surveys mentioned above and add little extra floristic information. Observation of a range of stands of this spring community did yield more information on habitat and on some other associated species.

The *Pohlia wahlenbergii var glacialis* spring shows a similar variation in stand type to the *Philonotis fontana - Saxifraga stellaris* spring in that there can be marked differences in species diversity. In some cases there may be many square metres of *Pohlia wahlenbergii var glacialis* with no other species; one large stand ($100m^2$+) in Garbh Coire Mor (Site 13) on Braeriach in the Cairngorms has only the occasional straggling stem of *Cerastium cerastoides*, and the transition to the surrounding *Pohlia ludwigii* snow-bed is very precise with little mixing. Other stands may have a good admixture of other species, usually of low cover but occasionally abundant. Good examples of the latter exist in the coires and gullies of Bidean nam Bian (Site 50) in Glencoe, on Ben Nevis (Site 52) and on Craig Megaidh (Site 55) involving species like *Saxifraga stellaris, Chrysosplenium oppositifolium, Cochlearia* agg., *Stellaria alsine, Epilobium anagallidifolium, Philonotis fontana, Marchantia alpestris* and rarities like *Saxifraga rivularis* and *Rhizomnium magnifolium*. A further variant occurs on Beinn Dearg (Site 33) in the north where large linear stands of *Pohlia wahlenbergii var glacialis* contain beautifully contrasting pink patches of *Bryum weigelii* and, where water flow is stronger, dull green wefts of *Hygrohypnum ochraceum* and large swollen cushions of the rare hepatic, *Scapania paludosa*.

Stands of this community can occur in a range of sites that receive the required melt water irrigation. The largest stands tend to occur on the more typical spring head sites where water emerges either from scree or finer, porous sub strata and here there is a considerable build up of a very wet mix of fine mineral and organic debris held in place by the mat of *Pohlia wahlenbergii var glacialis*. Good examples of this types occur in Garbh Coire Mor (Site 13), Braeriach and in the Drumochter hills (Site 39). Other stands form on low angled crags receiving water from above where the vegetation has provided sufficient impedance to the flow of water for fine mineral material to be deposited and thus for the community to establish and expand. Catastrophic slumping or erosion must be common in such habitats and several examples were seen, so it seems likely that there may be some cyclical process of establishment and destruction involved on this type of site. In general, the latter type of *Pohlia wahlenbergii var glacialis* spring is the more widespread but forms much more fragmentary and much smaller stands. Most of the snow-beds in craggy coires had at least small examples and on Ben Nevis, Bidean nam Bian in Glencoe and in the Northern Coires of the Cairngorms (Site 26) the bright, glaucous green cascades on broken crags are identifiable from hundreds of metres away.

Transition from the *Pohlia wahlenbergii var glacialis* spring to other vegetation is normally sharp with little floristic overlap. Even where the transition is to *Pohlia ludwigii* snow-bed with which this community has some affinities the line between the two dominants is clearly defined and is presumably related to the constancy of irrigation. The exception to this general position is the transition to the more widespread *Philonotis fontana - Saxifraga stellaris* spring as the temperature of the ground water increases. Here there is often continuity in the less frequent species and zones where the two dominant mosses are equal in abundance. There is an excellent illustration of this in the incised burns in the vicinity of the upper Allt Coire Chuirn (Site 39) in the Drumochter hills where *Pohlia wahlenbergii var glacialis* springs give way to *Philonotis* *fontana* - *Saxifraga stellaris* springs, here with much *Philonotis seriata*, in a complicated sequence of mixed stands. Where this community occurs on steeper craggy ground there is also an overlap with the complex vegetation of wet ledges and with stands of *Pohlia ludwigii* which can also occur here.

Number of samples	3	
Altitude (metres)	1030	(900-1100)
Slope (degrees)	20	(5-35)
Aspect (degrees)		(320-100)
pH (2 samples)	6.2	(5.9-6.5)
Soil moisture	3	(3-3)
Substrate size	3	(3-3)
Bare Ground	0	
Number of species	4.0	(3-5)

Pohlia wahlenbergii var glacialis	V	(9-9)
Pohlia ludwigii	II	(1)
Philonotis fontana	II	(1)
Philonotis seriata	II	(1)
Marchantia alpestris	II	(1)
Cerastium cerastoides	II	(1)
Chrysosplenium oppositifolium	II	(1)
Cochlearia agg.	II	(1)
Epilobium anagallidifolium	II	(1)
Stellaria alsine	II	(1)

Table 4.7 ***Pohlia wahlenbergii var glacialis*** **spring**

4.8 Associated Snow-bed Vegetation

Stands of the communities described above and zones of transition between them cover the largest part but not all, of many of the snow-beds surveyed. Other stands occur which show clear links with vegetation types that are either not exclusively limited to late snow-bed areas or which could not be sampled in a comparable manner for reasons described above (pp 21-22).

Spring and Fluvial Vegetation

The redistribution of precipitation through snow melt means that most of the sites surveyed have areas that are exceedingly wet and many have perennial watercourses through them. Some of the vegetation on such ground is covered by forms of the bryophyte-dominated snow-beds described above, particularly the *Pohlia ludwigii* snow-bed and to a lesser extent the *Pohlia wahlenbergii var glacialis* spring. Other spring communities are very patchy but their area will certainly far exceed the area of *Pohlia wahlenbergii var glacialis* springs.

Most of these springs are related to the *Philonotis fontana* - *Saxifraga stellaris* spring of the NVC (Rodwell, 1987), particularly the *Sphagnum auriculatum* rich facies. The late snow lie means that vascular plants are reduced in importance compared with the typical *Philonotis fontana* - *Saxifraga stellaris* spring but *Saxifraga stellaris* is still common. *Drepanocladus exannulatus* and *Scapania uliginosa* are often abundant over small areas, particularly in those springs at the base of block scree. In this latter habitat two rare species may also occur, *Scapania paludosa* in green swelling cushions where the flow of water is strongest and *Rhizomnium magnifolium* around the bases of the boulders on the margins of the spring. Where this spring community is derived from water percolating through the lower, broken rocks of large crags it shows affinities with the NVC's *Montia fontana* - *Chrysosplenium oppositifolium* facies with the regular occurrence of species like *Stellaria alsine, Cochlearia* agg., *Epilobium anagallidifolium*, the diminutive form of *Caltha palustris* and, much more rarely, *Cerastium arcticum* and *Saxifraga rivularis*. This vegetation often forms a complex with stands of *Pohlia wahlenbergii var glacialis*.

Although *Anthelia julacea* occurs on most sites, only infrequently does it form stands with *Sphagnum auriculatum* which are significant enough to assign to the *Anthelia julacea* - *Sphagnum auriculatum* spring. On some of the Cairngorm snow-beds where there is a permanent trickle of water, *Anthelia julacea* can form large carpets but it is often in company with species like *Nardia compressa, Andreaea nivalis* and *Pohlia ludwigii* and so its affinities are not clear.

Where the flow of water is strong and persistent enough to be termed a burn, then a different suite of species develops. On many Cairngorm sites the sequence of vegetation by the burns is visible, with a bright green marginal band of *Pohlia ludwigii* snow-bed contrasting with the dull reds of *Nardia compressa, Scapania undulata, Scapania uliginosa* and *Andreaea nivalis* growing on the rocks in the burn itself. In the Garbh Uisge Mor and Garbh Uisge Beag of Ben Macdui and in Garbh Coire on Braeriach, the very rare *Andreaea frigida* may occur on rocks in the burns with *Andreaea nivalis*. The latter species also occurs in abundance in similar situations on Ben Nevis and on the Aonach Mor-Aonach Beag massif in the west and is locally abundant on the Ben Alder hills but is very rare elsewhere.

Where the bed of the burn is composed of schists or granulites the more mundane stands of *Scapania undulata, Marsupella emarginata* and occasionally *Racomitrium aciculare* are more typical. Where the burn is linked to a flush system there may be a greater diversity with *Scapania uliginosa* and *Hygrohypnum ochraceum* often abundant. In burns associated with three of the largest snow-bed sites the very rare *Hygrohypnum molle* occurs, both on boulders and in one case on bed-rock by a small waterfall.

Block Scree Vegetation

Scree of a variety of block size is a feature of many of the sites, particularly those in the more western hills. Where all drainage is sub-surface or where the scree is unstable vegetation is very scant in the interstices of the blocks although more strictly rupestral communities do have a limited development. Where the scree is stable and there are areas of finer mineral material the *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed occurs as described above (4.2). However, apart from the frequency of *Kiaeria starkei*, much of the vegetation is rather different from that snow-bed and is closer to the *Cryptogramma crispa* - *Athyrium distentifolium* snow-bed as described by the NVC. In the very late snow-beds of this survey there are no large stands of either of these ferns in the scree and often no more than an isolated frond. *Huperzia selago*, *Saxifraga stellaris* and the tussocks of *Deschampsia cespitosa* are the only other vascular plants that occur with any regularity and bryophytes dominate. Small stands of *Kiaeria starkei* are common amongst the blocks but equally abundant are more cosmopolitan species like *Racomitrium heterostichum, Isopterygium elegans* and *Diplophyllum albicans* often with stems of *Polytrichum alpinum* and *Oligotrichum hercynicum*. A species limited to this type of habitat in Britain is *Lophozia opacifolia*, growing on mineral soil in stable scree, its white-green shoots being particularly common on the less extreme western sites. *Lophozia sudetica* is also common in this habitat on most sites in a much more robust form than occurs in the more open, hepatic-rich snow-beds.

Large pleurocarpous mosses occur increasingly as length of snow lie decreases; typically the species involved will be *Racomitrium lanuginosum, Rhytidiadelphus loreus, Hylocomium umbratum, Hypnum callichroum, Plagiothecium denticulatum var obtusifolium* and sometimes *Plagiothecium undulatum*. On Ben Nevis (Site 52), Aonach Beag (Site 51) and to a limited extent on Coire Ardair, Creag Megaidh (Site 55) and Garbh Coire Mor, Braeriach (Site 13) mixed stands of the two rarities *Brachythecium glaciale* and *Lescuraea patens* occur in this habitat in deep gullies where snow lies very late. *Brachythecium glaciale* seems to be most abundant in less snow bound sites however, and is normally associated with fern litter that has accumulated in the scree and here it may be accompanied by the threadlike shoots of the equally rare *Brachythecium reflexum*. The mat green shoots of the rare hepatic *Diplophyllum taxifolium*, camouflaged by the common *Diplophyllum albicans*, are quite frequent in the scree on some sites.

The shelter and moisture provided by the snow and the buffering from rapid changes in humidity provided by the block scree enable some of the typical oceanic montane hepatics (Ratcliffe, 1968) to extend their range into these late snow-beds as far east as the Cairngorms. Most common are the least demanding species like *Bazzania tricrenata* and *Mylia taylori* but there are several sites for both *Scapania nimbosa* and *Scapania ornithopodioides* and for *Anastrophyllum donianum*.

Rupestral Vegetation

Virtually all of the sites investigated have large expanses of rock, either as large blocks in the scree or as crags. The two most frequent species on exposed rock surfaces are *Andreaea rupestris* and *Racomitrium heterostichum* and both can occur in small tight patches or extended carpets. *Racomitrium heterostichum* is often blackened in the latest snow-beds and is superficially easy to confuse with *Andreaea* species. Frequently mixed with the two mosses or forming pure erect stands is the tiny *Marsupella sprucei*; it is always fertile and the white empty perianths can give the patches a hoary appearance. Much less common but in the same habitat is the equally paroecious *Marsupella adusta* and these two *Marsupella* species can only be separated with difficulty in the field. *Gymnomitrion concinnatum* may also be frequent on more sheltered rocks in scree.

Where melting snow leads to a limited build up of silt on the rocks, tight cushions of *Kiaeria falcata* are frequent and, as length of snow lie decreases, they may be replaced by the untidy, dark green cushions of *Kiaeria blyttii*. Two more species of *Andreaea* occur on a number of sites; *Andreaea mutabilis* forms small red cushions on rocks that receive intermittent irrigation while the rare *Andreaea blyttii* grows in distinctive flat, black patches on the upper surface of low-angled rocks and appears to be indicative of the areas of latest snow lie.

On the steep sides of the larger blocks in scree and on steep rock on the base of crags, much of the vegetation consists of common species like *Marsupella emarginata, Nardia scalaris* and *Diplophyllum albicans* but in sheltered spots where there is some irrigation, *Marsupella stableri* can grow in profusion, its tiny stems forming large, easily detached wefts. This is also the habitat of the very rare *Marsupella boeckii* on Aonach Mor (Site 29) in Lochaber and Coire an Lochain (Site 26) in the Cairngorms. On more slabby rocks which are irrigated, large patches of *Marsupella alpina* can occur. The erect stems and leaves reflexed from a sheathing base superficially look very like *Andreaea rupestris* and are of a similar colour.

The bottom part of the crags, where snow piles up to considerable depth, can have stands of *Kiaeria starkei* and areas of *Pohlia ludwigii* snow-bed and various spring communities. In the most sheltered recesses, the narrow flat stems *Isopterygiopsis muellerianum* grow in a few of the large coire sites. Two other species are of interest here, *Arctoa fulvella* which is limited to late-snow areas in Britain and *Oedipodium griffithianum* which is certainly montane but not so reliant on lengthy snow cover. Both occur in crevices and along crack lines low down on the crags and normally only in very small amounts.

4.9 Comparison with other descriptions of snow-bed communities

Various workers have described the plant communities of areas of late snow lie in Britain. Macvicar (Macvicar, 1910) described a *Marsupella* association which, on the basis of the list of species given, is very similar to the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed described here. Smith (Smith, 1912) described a visit to Ben Lawers with a group of continental phytosociologists during which three snow-bed communities were identified as similar to Alpine associations; these are listed as an *Anthelia* association, an association with *Polytrichum sexangulare* and *Polytrichum alpinum* and a *Salix herbacea* community. There is some confusion over the relationship between the *Anthelia* snow-bed and the very different *Anthelia* community of irrigated rocks. Watson (Watson, 1925) in his study of the vegetation on Ben Lawers produced a list from snow-beds which encompassed both the hepatic communities described by Smith and Macvicar. Watson did not describe a separate *Polytrichum sexangulare* or *Kiaeria starkei* association which is perhaps not surprising as this community is not well developed on Ben Lawers. There is little in a comparison of Watson's list with mine (see Appendix 1.4) to suggest that the constituent bryophyte species of late-snow areas on Ben Lawers have changed much over the intervening 75 years.

In yet another study in the Ben Lawers area of the

Breadalbane hills, Poore (Poore, M. E. D., 1955) detailed a *Salix herbacea* 'nodum' from snow-beds with the following species in constancy class V (ie. present in more than 80% of the samples included in the table):-

Salix herbacea
Kiaeria (Dicranum) starkei
Oligotrichum hercynicum
Racomitrium heterostichum
Lophozia sudetica (alpestris)
Nardia scalaris

He divided his 11 samples into three groups; those with much *Gymnomitrion concinnatum* and *Kiaeria starkei*, those with *Lophozia sudetica* and *Kiaeria starkei* and those dominated by *Salix herbacea* and *Racomitrium heterostichum*. As noted above, the *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed is not well developed on Ben Lawers so it is not surprising that it is missing from Poore's analysis. What is slightly puzzling is the complete absence of species like *Anthelia juratzkana, Marsupella brevissima* and *Marsupella condensata*, all common in Lawers snow-beds, from the hepatic element of the nodum, when the map references and descriptions indicate that Poore visited much the same ground as I did.

A much more comprehensive treatment of snow-bed vegetation is included in McVean and Ratcliffe's monograph on the plant communities of the Scottish uplands (McVean & Ratcliffe

1962). Three 'late snow-bed heaths' are described:-

Polytricheto-Dicranetum starkei

Constant species:-	*Deschampsia cespitosa*
(Class V)	*Saxifraga stellaris*
	Kiaeria (Dicranum) starkei
	Oligotrichum hercynicum
	Polytrichum alpinum
	Polytrichum sexangulare

Rhacomitreto-Dicranetum starkei

Constant species:-	*Deschampsia cespitosa*
(Class V)	*Carex bigelowii*
	Gnaphalium supina
	Kiaeria (Dicranum) starkei
	Oligotrichum hercynicum
	Polytrichum sexangulare

Gymnomitreto-Salicetum herbaceae

Constant species:-	*Salix herbacea*
(Class V)	*Conostomum tetragonum*
	Kiaeria starkei
	Oligotrichum hercynicum
	Nardia scalaris
	Gymnomitrion concinnatum
	Marsupella brevissima

Direct comparison of these associations with the snow-beds described in this study is not straightforward as there are differences both in sample size and in the process of classification and table construction. McVean and Ratcliffe used a $4m^2$ sample plot as opposed to the $0.25m^2$ plot I used for the reasons given in Chapter 2.3. In their construction of community tables McVean and Ratcliffe used a Braun-Blanquet method whereby those samples that were deemed to have been made in 'hybrid stands' were rejected, thus producing a set of samples with a high number of constant species. I used all samples for the classification by TWINSPAN thus retaining a greater amount of information, presenting the variation that exists within the vegetation but at the expense of some clarity of definition.

Despite these differences there is a broad correspondence between these snow-bed heaths and the communities I have described. The *Polytricheto-Dicranetum starkei* is equivalent to the typical *Polytrichum sexangulare - Kiaeria starkei* snow-bed except that I have split off the distinctive patches of *Pohlia ludwigii* dominated vegetation as a separate unit. The *Rhacomitreto-Dicranetum starkei* is similar to the '*Racomitrium* variant' of the *Polytrichum sexangulare - Kiaeria starkei* snow-bed. Given the degree of inter-grading between this drier variant and the typical community, its status as a distinct association is questionable. The *Gymnomitreto-Salicetum herbaceae* is split by McVean and

Ratcliffe into three facies - 'typical', 'exposed ground' and *'Gymnomitrion varians' (Marsupella brevissima)*. These cover some of the same vegetation in the *Marsupella brevissima - Anthelia juratzkana* snow-bed but with a rather different emphasis. The exposed ground variant is outwith the scope of this work but the *Gymnomitrion varians* facies and the typical *Gymnomitreto-Salicetum herbaceae* are strongly linked with the *Marsupella brevissima - Anthelia juratzkana* snow-bed and its *Salix herbacea* sub-community respectively. There are some problems in this comparison which I find hard to resolve. *Gymnomitrion concinnatum* is a common species in snow-bed vegetation but only occasionally reaches the abundance levels described by McVean and Ratcliffe in the samples I selected. *Salix herbacea* can be abundant on some snow-bed sites and in the hepatic communities that occur there but not exclusively so (Watt, A.S & Jones, E. W.,1948); its ecological amplitude is wider than that. To use *Salix herbacea* as an indicator species for this distinctive hepatic community is too restrictive and diverts attention from the importance of the bryophyte populations and the conditions which produce them.

The problems involved in distinguishing between the bryophyte communities in snow-beds in the field is recognised by Birks and Ratcliffe (1980) in their digest of upland communities intended as an interim field guide until the National Vegetation Classification (NVC) was completed. Here all the bryophyte associations are lumped together as *Dicranum (Kiaeria) starkei* snow-bed heaths and, given the small areas involved, there is much to be said for this when vegetation mapping is the objective.

The most recent work on the classification of upland communities in Britain is the National Vegetation Classification (Rodwell, 1987). This has two bryophyte-dominated snow-beds:-

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

Constant species:-	*Deschampsia cespitosa*
(Classes IV & V)	*Kiaeria starkei*
	Oligotrichum hercynicum
	Polytrichum sexangulare

***Salix herbacea* - *Racomitrium heterostichum* snow-bed**

Constant species:-	*Salix herbacea*
	Racomitrium heterostichum

The *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed sensu NVC would appear to refer to a rather wider range of vegetation than the community of the same name that I describe, reflecting both a larger sampling area and a less restricted view of sample homogeneity. It includes a number of vascular plants that, in my narrower view, suggest transitional vegetation. Again, the distinctive *Pohlia ludwigii* snow-bed with its rather different ecological requirements is not recognised although stands where *Pohlia ludwigii* is dominant are mentioned.

The NVC unites McVean and Ratcliffe's *Rhacomitreto-Dicranetum starkei* and *Gymnomitreto-Salicetum herbaceae* to form the *Salix herbacea - Racomitrium heterostichum* snow-bed. As argued above, both floristics and ecology suggest that the *Rhacomitreto-Dicranetum starkei* is better placed as a variant of the *Polytrichum sexangulare - Kiaeria starkei* snow-bed. The *Salix herbacea - Racomitrium heterostichum* snow-bed has three sub-communities:- *Silene acaulis - Luzula spicata*, *Gymnomitrion concinnatum* and *Marsupella brevissima*. In my treatment, the first sub-community would be placed at the extreme chionophilous end of the NVC's *Carex bigelowii - Polytrichum alpinum* sedge heath (see Chapter 4.5). The difficulties posed by the *Gymnomitrion concinnatum* sub-community have already been mention with regard to McVean and Ratcliffe's *Gymnomitreto-Salicetum herbaceae*. This leaves the *Marsupella brevissima* sub-community which is described on the basis of three samples all of which fit well within the *Marsupella brevissima - Anthelia juratzkana* snow-bed described in Chapter 4.3, although the failure to include any stands with the distinctive and preferential *Anthelia juratzkana* is a puzzle.

In the Alps and Central Europe extreme snow-bed communities closely related to those in Britain are grouped under the

Salicetea herbaceae (Rübel, 1912; Braun-Blanquet, 1936; Diersson, 1984). Two of Rübel's snow-bed 'synusia' are bryophyte communities - an *Anthelietum* and a *Polytrichetum*; both have a rather wider span than the two similar communities described here but within the rather different floristics there are clear areas of overlap. Diersson (1984) points out some of the difficulties involved in the sufficient consideration of bryophytes in community analysis and emphasises their importance in the description of micropatterns in snow-bed vegetation. In the overview of the *Salicetea herbaceae* presented, my *Polytrichum sexangulare* - *Kiaeria starkei* and *Pohlia ludwigii* snow-beds would appear as facies of the *Polytrichetum sexangularis*, and the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed as a facies of the *Salicetum herbaceae*

Rather more comparable communities exist in the snow-beds of Scandinavia and these have attracted a considerable amount of attention (Nordhagen, 1928, 1943; Dahl, 1956; Gjaerevoll, 1950,1956). The much greater area of snow-bed vegetation on a variety of rocks and soils gives a wider range of plant communities in Scandinavia. These are described in detail in Gjaerevoll's classic paper (1956) and provide an insight into the affinities of some snow-bed stands in the Highlands. For instance, Gjaerevoll describes a whole range of *Deschampsia flexuosa* communities in snow-beds which aids an understanding of the fragmentary *Deschampsia flexuosa* stands in several of the Cairngorm snow-beds.

Gjaerevoll is strongly in favour of separating out those extreme snow-beds in which vascular plants are very scarce and the three communities he describes on this basis are grouped in his Alliance, *Polytrichion norvegici*. The first Association, the *Polytrichetum norvegici* has 18 of its 27 species (excluding the lichens) in common with the *Polytrichum sexangulare - Kiaeria starkei* snow-bed and when the Association is broken down into its constituent 'sociations' (see Gjaerevoll 1956 pp218-228) the correspondence is better than 75%. Of the species with higher constancy values, the only major difference is the absence of *Barbilophozia floerkei and Racomitrium heterostichum* in the Scandinavian samples The physiognomy and ecology of the two communities seem very similar. There would appear to be no equivalent in Scandinavia of the *Pohlia ludwigii* snow-bed, the stands of *Pohlia drummondii* occurring in Norwegian snow-beds being rather different.

The *Anthelia juratzkana - Gymnomitrion varians (now Marsupella brevissima*) 'sociation' of the second Association, the *Anthelietum juratzkanae* bears an even closer resemblance to the typical *Marsupella brevissima - Anthelia juratzkana* snow-bed of the Scottish Highlands. 19 of its 25 vascular plants and bryophytes also occur in the equivalent community here including all the species with high constancy values.

Gjaerevoll's description of the stands also tallies with sites here, particularly his reference to the variability of soil moisture and the prevalence of frost heaving and small scale solifluction.

In North America, Belland (1983) investigated the flora of eight bryophyte-dominated snow-beds in western Newfoundland, and suggests that the communities are equivalent to Gjaerevoll's Polytrichion Norvegici with a sharp boundary between the phanerogam-dominated vegetation and the bryophyte snow-beds. Of the 49 species recorded, 36 occur on similar sites in Scotland and of the 28 species occurring on two or more sites, 24 of these also occur in Scottish snow-beds. It would appear that the extreme conditions of the snow-bed environment lead to a convergence of floristics over a large geographic area.

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Appendix 1 Selected site descriptions

A1.1 The Cairngorms

Site I. Ciste Mhearad

Date of Survey:- 20/07/89

Grid Reference:- 38/012045

Altitude of Site:- 1100m

Aspect:- The aspect of the coire is 122o but the slope containing the existing snow has an aspect of 48o

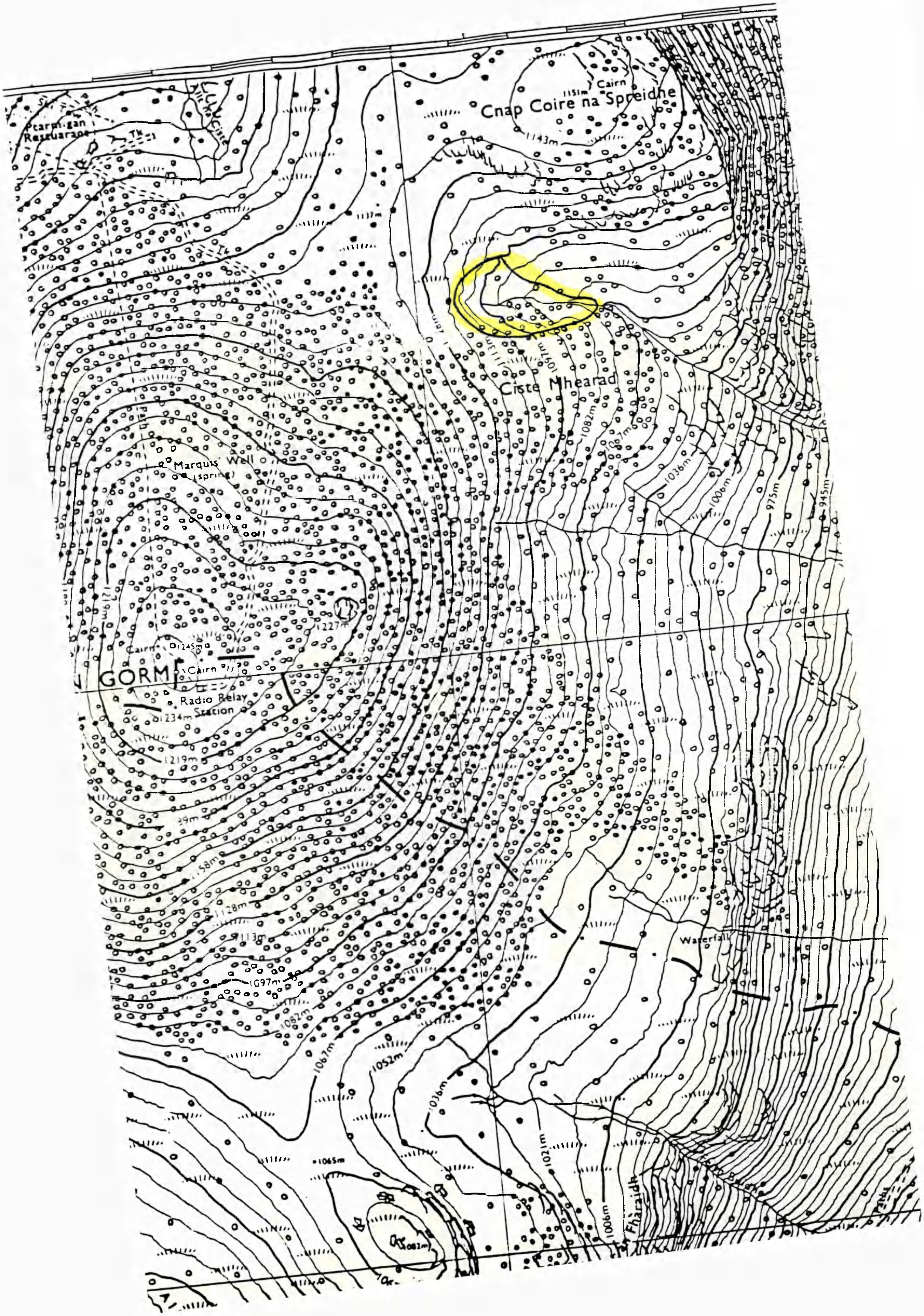
Slope:- The slope varies from 14o to the N of the main burn to 25o on the north facing slope.

Irrigation:- A substantial burn emerges from the western margin of the coire and is fed by numerous rills from the remaining snow to the south and by a seepage line to the north.

Substrate:- The rock type is granite which has weathered here to give scattered boulders to 1m in a matrix of pea-sized gravel.

Site Description

The southern and western margins of the site are given by the sharp break in slope at the upper margin of the nivation hollow where the unstable gravel slope and its *Marsupella brevissima* community merges abruptly into the *Juncus trifidus* and *Nardus stricta* vegetation of the Cairngorm Plateau. The northern margin is less definite and seeks to trace the zone where bryophytes cease to form a major part of the vegetation. The site boundaries converge eastwards to meet



Cnap Coire na Spreidhe
Cairn
1151m
1143m
Ptarmigan Restaurant
Ciste Mhearad
1082m
1067m
1036m
1006m
975m
945m
Marquis' Well
(spring)
1227m
Cairn
1245m
GORM
Radio Relay
Station
1234m
1219m
1158m
1128m
1113m
1097m
1082m
1067m
1052m
1036m
1065m
1021m
1006m
Waterfall

at the burn though patchy stands of late snow lie bryophytes persist in the incised channel for some distance down the burn. Anecdotal evidence suggests that snow persists throughout the year here for 8 years in 10 and on the date of the survey there were large patches remaining.

The Plants

Mosses:-	**25**
Hepatics:-	**23**
Vascular Plants:-	**14**
Total:-	**62**
Number of Snow-bed Species	**15**

Rare Species:-

Andreaea blyttii
A. nivalis
Dicranum glaciale
Cephalozia bicuspidata ssp ambigua
Marsupella condensata
Luzula arcuata

All the bryophyte snow-bed communities are well represented here with a zonation running from the less chionophilous *Carex bigelowii - Polytrichum alpinum* sedge heath to the north of the main burn to the *Marsupella brevissima - Anthelia juratzkana* snow-bed by the remaining snow on the scarp slope to the south, reflecting the pattern of snow melt. The gravel substrate means that the *Carex* communities and *Marsupella* snow-bed are a feature, the former in a complex on easy angled south facing slopes and the latter on the steeper, less stable north facing slope. The *Pohlia ludwigii* snow-bed and *Polytrichum sexangulare - Kiaeria starkei* snow-bed are limited to the frequent meltwater channels and their stable banks; on the steeper banks, *Moerckia blyttii* may be abundant. In the *Marsupella brevissima - Anthelia juratzkana* snow-bed, *Cephalozia bicuspidata ssp ambigua* is frequent with *Marsupella condensata* rather less common. On the most unstable ground there is an open facies of this community which illustrates well the patterning of the vegetation caused by frost heave and downslope movement durong spells of freeze-thaw. In the *Polytrichum sexangulare - Kiaeria starkei* snow-bed, *Dicranum glaciale* occasionally occurs at the base of boulders while scattered plants of *Luzula arcuata* occur in the drier facies.

Several rocks on the steep slope near the snow patches have patches of *Andreaea blyttii*, often eroded and lichen encrusted. *Andreaea nivalis* is common in the burn and on silted rocks above the burn there are tiny red cushions of *A. mutabilis* in amongst the abundant *A. rupestris*. The margins of the major burn are marked by a band of *Pohlia ludwigii* snow-bed which contrasts with the dull reds of the hepatics on the rocks in the burn, often dominated by *Nardia compressa*.

Species list for Site 1 Ciste Mhearad

Grid Ref.38/012045 Date:-20.7.89

SPECIES	SCORE
MOSSES	
Andreaea alpina	2
Andreaea blyttii	2
Andreaea mutabilis	1
Andreaea nivalis	3
Andreaea rupestris	4
Calliergon sarmentosum	2
Conostomum tetragonum	3
Dicranum fuscescens	3
Dicranum glaciale	1
Ditrichum zonatum	2
Kiaeria falcata	3
Kiaeria starkei	4
Oligotrichum hercynicum	3
Philonotis fontana	1
Plagiothecium denticulatum var obtusifolium	1
Pohlia drummondii	2
Pohlia ludwigii	4
Pohlia nutans	3
Polytrichum alpinum	2
Polytrichum sexangulare	4
Racomitrium fasciculare	3
Racomitrium heterostichum	4
Racomitrium lanuginosum	2
Sphagnum capillifolium	2
Sphagnum papillosum	2
HEPATICS	
Anthelia julacea	4
Anthelia juratzkana	3
Barbilophozia floerkii	4
Cephalozia ambigua	2
Cephalozia bicuspidata	4
Diplophyllum albicans	3
Gymnomitrion concinnatum	2
Lophozia opacifolia	1
Lophozia sudetica	3
Marsupella alpina	1
Marsupella brevissima	4
Marsupella condensata	1
Marsupella emarginata	4
Marsupella sphacelata	2
Marsupella sprucei	3
Marsupella stableri	3
Moerckia blyttii	4
Nardia compressa	4
Nardia scalaris	4
Pleurocladula albescens	3
Ptilidium ciliare	2
Scapania uliginosa	2
Scapania undulata	3
VASCULAR PLANTS	
Carex bigelowii	4
Deschampsia cespitosa	3
Deschampsia flexuosa	4
Galium saxatile	2
Gnaphalium supinum	3
Huperzia selago	2
Juncus trifidus	3
Loisleuria procumbens	2
Luzula arcuata	2
Luzula spicata	3
Nardus stricta	2
Salix herbacea	3
Saxifraga stellaris	3
Silene acaulis	2

MOSSES	25
HEPATICS	23
VASCULAR PLANTS	14
TOTAL	62

A1.2 Northern Highlands

Site 33, Beinn Dearg

Date of Survey:- 20.7.90

Grid Reference:- 28/256815-6

Altitude of Site:- 1000m

Aspect of Site:- 75^{o}

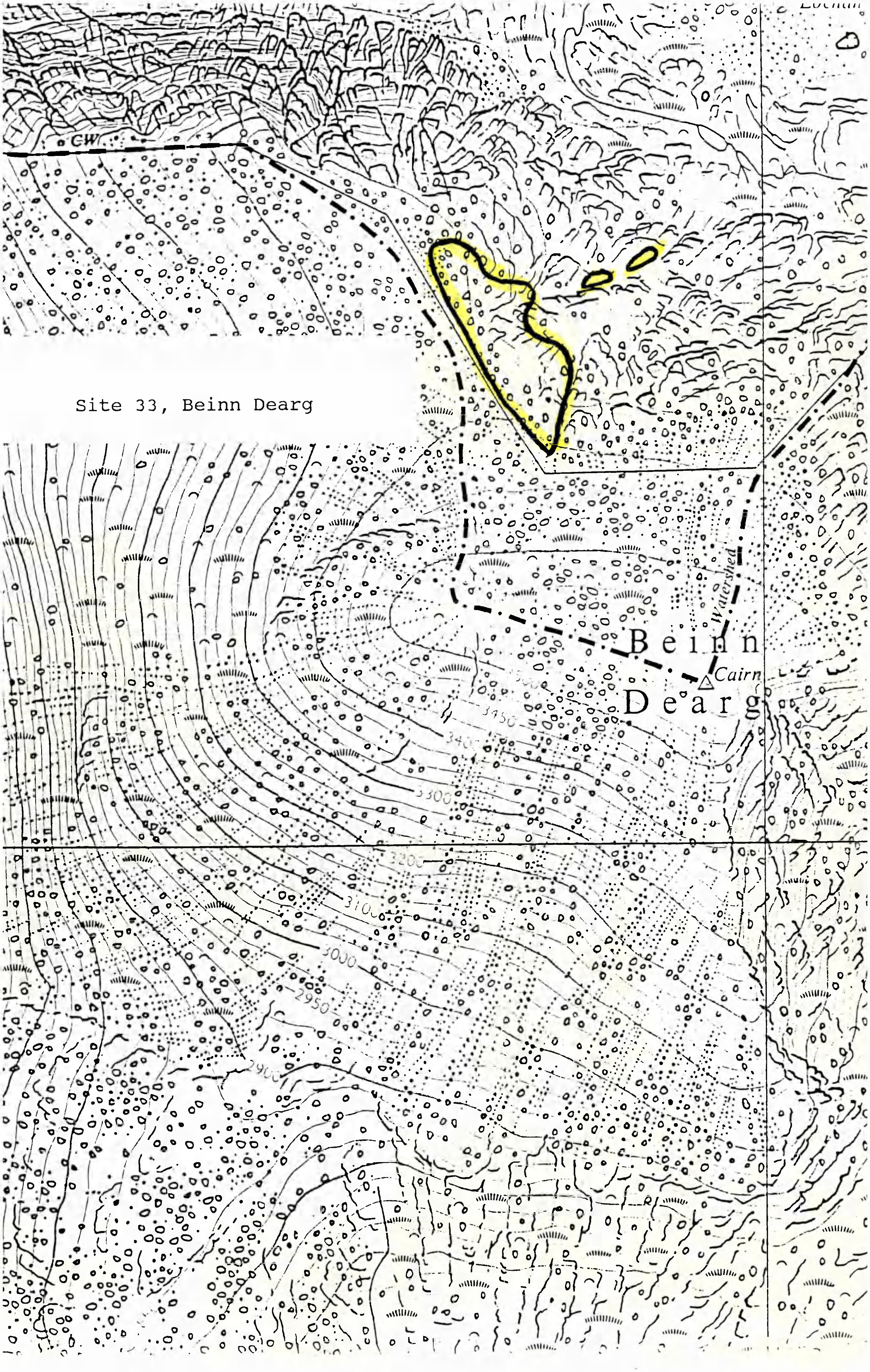
Slope:- 35^{o}

Irrigation:- there is little apparent surface drainage in the upper section of the site but water from the broad summit area above emerges as a series of springs in the lower part giving rise to two substantial burn/flush systems, one in each 'bay'.

Substrate:- The site is based on block scree, finer and with much infill at the top of the site but larger and more unstable near the base and around the flush systems. Four soil samples gave pH readings of between 5.0 and 5.8. The rock is Moine schist which in places on Beinn Dearg is quite calcareous.

Site Description

Beinn Dearg has a broad summit area which provides the source of snow for the complex of snow patches which persist late into the summer on the northern flanks of the mountain. The site surveyed is perhaps the largest single area of bryophyte dominated snow-bed communities but the sites further to the east would repay further investigation. A little west of due north from the summit cairn of Beinn Dearg is a shallow



Site 33, Beinn Dearg

coire with two bays which collect snow; this gives the site. The upper margin is the break in slope with the plateau, here conveniently marked by a stone wall. The lower margin is associated with the system of springs and is somewhat arbitrary as there is much *Deschampsia caespitosa* grassland mixed in here, but the site should include the excellent flushes which persist for some 150m below the main snow-bed. The lateral margins are given by the more open shoulders of the hollows which are snow free much earlier and have either sparsely vegetated scree or grassland. This gives a site some 200m long with a maximum downslope extent of 75m but associated flushes extending much further than this.

The Plants

Mosses:-	**36**
Hepatics:-	**27**
Vascular Plants:-	**16**
Total:-	**79**
Number of Snow-bed Species:-	**16**

Rare Species:-

Andreaea blyttii
Dicranum glaciale
Rhizomnium magnifolium
Cephalozia ambigua
Nardia breidleri
Scapania paludosa

Appendix 1 Selected site descriptions

The unusually late lie of snow again hampered the survey, with snow still covering a significant proportion of the site, with a vertical depth in excess of 5m in one spot. This is a large and important site, representing the northernmost outpost of extensive bryophyte-dominated snow-beds. On the upper part of the site where the scree is finer and has a sandy infill there is a patchwork of *Polytrichum sexangulare - Kiaeria starkei* snow-bed mixed with *Marsupella brevissima - Anthelia juratzkana* snow-bed, the former on the more stable, often steeper slopes and the latter on material that is clearly subject to much small scale disturbance by frost

As is usual with the *Polytrichum sexangulare - Kiaeria starkei* snow-bed, there is an understory of hepatics; dense pure swards of *Barbilophozia floerkei* occur on the drier more stable ground while on the wetter areas there is a tight mixture of *Nardia scalaris, Cephalozia bicuspidata* and, on this site, an abundance of *Pleurocladula albescens*, often with scattered stems of *Pohlia ludwigii*. The *Marsupella brevissima - Anthelia juratzkana* snow-bed here is marked by the distinctive stems of *Anthelia juratzkana* and tight cushions of *Kiaeria falcata* as well as by the *Marsupella* and the less noticeable shoots of *Lophozia sudetica*. On the finest material and usually on the flatter tops of slumps, there are patches of the tiny hepatic *Nardia breidleri*, with their characteristic colour and texture. Tight cushions of the glaucous green stems of *Conostomum tetragonum* also occur sporadically across this part of the site, contrasting with the abundant black, hoary patches of *Racomitrium heterostichum*.

In the scree on the lower part of the site *Kiaeria starkei* and *K. falcata* are still common and there are isolated plants of *Polytrichum sexangulare* and the rare *Dicranum glaciale*, but the transition to the *Cryptogramma crispa - Athyrium distentifolium* snow-bed is quite rapid. This community also marks the lateral margins on the west of the site with another rapid transition to the *Rhytidiadelphus* rich facies of the *Deschampsia caespitosa - Galium saxatile* grassland. On several of the large boulders scattered in the areas of latest snow lie there are isolated patches of the rare *Andreaea blyttii*, but the most common plants are *A. rupestris*, *Racomitrium heterostichum* and *Marsupella sprucei*.

In the easterly hollow the flush systems start at the base of the scree while to the west the springs emerge rather lower down. There is a mosaic of three types, the *Sphagnum auriculatum* facies of *Philonotis fontana - Saxifraga stellaris* spring, *Anthelia julacea - Sphagnum auriculatum* spring and *Pohlia wahlenbergii var glacialis* spring and much that it is pointless trying to assign. In amongst the blocks where water is percolating there are occasional large cushions of *Rhizomnium magnifolium*, while large masses of *Scapania paludosa* occur down the whole spring system mixed, and easily confused, with the abundant *S. uliginosa*. The *Pohlia wahlenbergii var glacialis* spring reaches its best development low down in the western burn, immediately before the crags above the bealach. Here the contrast between the glaucous white-green of the *Pohlia* and the pink of the occasional stand of *Bryum weigelii* is spectacular.

Appendix 1 Selected site descriptions

Species List for Site 33 Beinn Dearg

Grid Ref:- 28/256815-6 Date:- 20.7.90

SPECIES	SCORE
MOSSES	
Andreaea blyttii	1
Andreaea rupestris	3
Bryum weigelii	1
Calliergon sarmentosum	2
Calliergon straminium	1
Conostomum tetragonum	2
Dicranum glaciale	1
Dicranum scoparium	1
Ditrichum zonatum	2
Drepanocladus exannulatus	2
Drepanocladus uncinatus	2
Hygrohypnum ochraceum	2
Hylocomium splendens	1
Hylocomium umbratum	3
Hypnum callichroum	3
Isopterygium elegans	1
Kiaeria falcata	4
Kiaeria starkei	4
Oligotrichum hercynicum	3
Philonotis fontana	4
Plagiothecium undulatum	2
Pleurozium schreberi	2
Pohlia ludwigii	2
Pohlia nutans	2
Pohlia wahlenbergii var glacialis	2
Polytrichum alpinum	4
Polytrichum sexangulare	4
Racomitrium ericoides	2
Racomitrium fasciculare	1
Racomitrium heterostichum	4
Racomitrium lanuginosum	2
Rhizomnium magnifolium	1
Rhizomnium punctatum	2
Rhytidiadelphus loreus	3
Sphagnum auriculatum var auriculatum	4
Sphagnum capillifolium	2
HEPATICS	
Anastrophyllum donianum	1
Anthelia julacea	3
Anthelia juratzkana	3
Barbilophozia floerkei	4
Bazzania tricrenata	1
Cephalozia ambigua	1
Cephalozia bicuspidata	4
Diplophyllum albicans	3
Gymnomitrion concinnatum	3
Gymnomitrion obtusum	1
Lophozia opacifolia	3
Lophozia sudetica	4
Marsupella brevissima	4
Marsupella emarginata	2
Marsupella sprucei	3
Marsupella stableri	2
Moerckia blyttii	4
Mylia taylori	2
Nardia breidleri	3
Nardia scalaris	4
Pleurocladula albescens	4
Ptilidium ciliare	1
Scapania nimbosa	1
Scapania paludosa	1
Scapania uliginosa	4
Scapania undulata	2
Tritomaria quinquedentata	1
VASCULAR PLANTS	
Alchemilla alpina	2
Athyrium distentifolium	2
Blechnum spicant	1
Carex bigelowii	2
Cryptogramma crispa	2
Deschampsia caespitosa	4
Deschampsia flexuosa	2
Galium saxatile	2
Gnaphalium supinum	3
Huperzia selago	3
Juncus trifidus	1
Nardus stricta	2
Saxifraga stellaris	3
Sibbaldia procumbens	2
Silene acaulis	1
Viola palustris	2

MOSSES	36
HEPATICS	27
VASCULAR PLANTS	16
TOTAL	79

A1.3 Central Highlands
Site 51, An Aghaidh Gharbh, Aonach Beag

Date of Survey:- 17.8.90

Grid Reference:- 27/20-71-

Altitude of Site:- 900-1150m

Aspect of Site:- 50^{o}

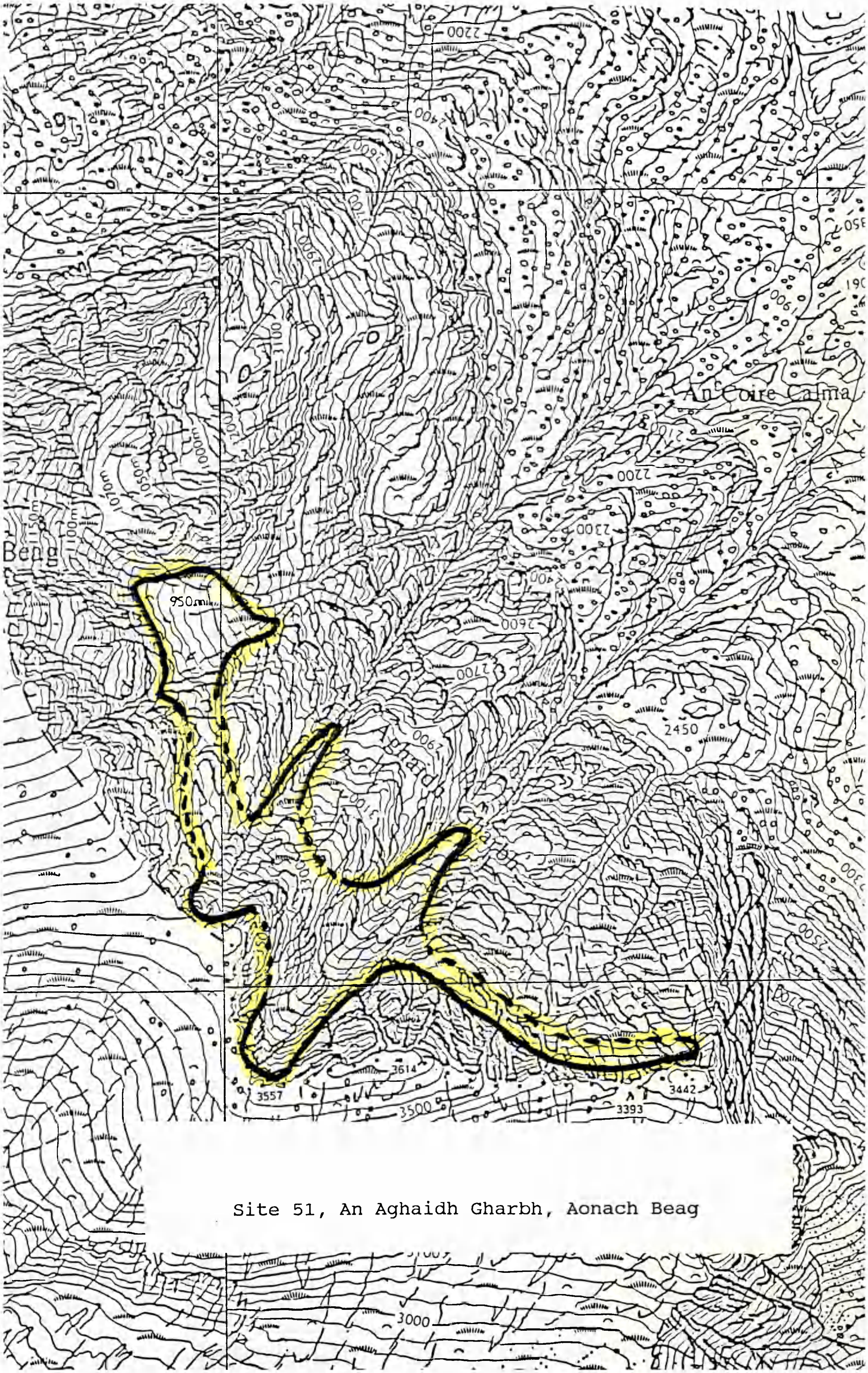
Slope:- 25^{o} (much variation)

Irrigation:- This very large site has three major gully lines and many smaller drainage channels and seepage lines. The snow often persists here throughout the year providing constant irrigation.

Substrate:- The major part of the site is scree and crag but locally there are areas of finer material, particularly in the broad bay in the northern part of the site. In this area one soil sample gave a pH reading of 5.4. The rock is Dalradian schist, locally with some calcareous facies.

Site Description

This is a very large and complex site covering the biggest part of the coire wall known as An Aghaidh Gharbh (the rough face), where snow blown from the extensive plateau area around the summit gathers in gullies and snowfields right across the face. The site is centred on the two obvious large gullies in the middle of the face and the more open area at mid height, directly below the summit, but snowbed vegetation occurs locally right round to Stob Coire Bhealach.



Site 51, An Aghaidh Gharbh, Aonach Beag

Appendix 1 Selected site descriptions

Though time and conditions did not permit verification, it is reasonable to assume that the upper limit of the site corresponds with the rim of the plateau. The bottom part of the coire wall is steep and it is the upper margin of this steep section that gives the lower margin of the site with the exception of the gullies, where the snow-beds descend much lower. This steep lower section makes the approach to the site interesting and it is recommended that routes either from the extreme north or the extreme south are chosen, rather than a frontal assault. The southern margin is a rather arbitrary line down the open slope below Stob Coire Bhealach, while the northern margin is given by the line of steeper crags above the northern snowfield.

The Plants

Mosses:-	**45**
Hepatics:-	**25**
Vascular Plants:-	**33**
Total:-	**103**
Number of Snowbed Species:-	**20**

Rare Species:-

Andreaea blyttii

Andreaea nivalis

Brachythecium glaciale

Brachythecium reflexum

Lescuraea patens

Rhizomnium magnifolium
Cephalozia ambigua
Marsupella condensata
Nardia breidleri
Cerastium cerastoides
Saxifraga rivularis

In those areas where there is a stable soil and where snow melt is rather earlier, much of the vegetation is *Deschampsia caespitosa - Galium saxatile* grassland, usually with patches of *Rhytidiadelphus loreus, Viola palustris* and the odd plant of *Cerastium cerastoides* and *Sibbaldia procumbens*. On the better drained shoulders between the gullies there are occasional stands of *Carex bigelowii* with much *Racomitrium lanuginosum*, these spots often being snow free much earlier in the year.

The gullies have large areas of block scree where the common plants are *Kiaeria starkei, K. falcata, Diplophyllum albicans, Hylocomium umbratum, Hypnum callichroum, Lophozia sudetica, L. opacifolia* and the *Racomitriums, R. heterostichum, R. fasciculare* and *R. lanuginosum*. In several places there are mats of *Brachythecium glaciale* which, in at least two places, is accompanied by the rare *Lescuraea patens* with capsules. The block scree in more open areas, particularly near the northern snowfield, is more definitely attributable to the *Cryptogramma crispa - Athyrium* *distentifolium* snow-bed, often with the odd stand of *Brachythecium glaciale* and more rarely the fine wefts of *Brachythecium reflexum*. On the boulders themselves, *Andreaea rupestris* is common and locally there are patches of *Andreaea blyttii* where snow lies later and, in one of the gullies, there are some bright red cushions of *Andreaea mutabilis*.

In places where finer material has collected, against the gully walls or in the lee of the largest boulders, there are patches of *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed with good stands of *Moerckia blyttii* and *Barbilophozia floerkei* with the usual abundance of both *Cephalozia bicuspidata* and *Nardia scalaris*. However, this community is best developed on the large area of mineral soil associated with the snow filled bay which occupies the northern part of the site. Here it occupies the more stable ground in a complex with *Marsupella brevissima* - *Anthelia juratzkana* snow-bed vegetation which has large stands on the lobes above the drainage lines, these showing signs of frost heave and slumping. *Pleurocladula albescens* is fairly common as is *Anthelia juratzkana*. Locally frequent in the hepatic community are curious stands of *Nardia breidleri*, often green and upright rather than the normal procumbent red-brown mats. Also locally frequent here is *Marsupella condensata*, occasionally with sporophytes, a very rare occurrence in Britain.

Forming a strip along the side of some of the meltwater channels are stands of *Pohlia ludwigii* snow-bed, occasionally quite extensive. On rocks in the burns the dull red cushions of *Andreaea nivalis* are locally frequent and this species also occurs on dripping rocks elsewhere on the site, usually with *Marsupella emarginata, Nardia scalaris, Scapania undulata* and *S. uliginosa*. Other rocks, with perhaps less irrigation, occasionally have distinctive upright stands of *Marsupella alpina*. Most of the springs belong to the *Anthelia julacea - Sphagnum auriculatum* spring community, particularly in the less extreme southern wing of the site, but where water trickles over low crags in the gullies then there are isolated stands of *Pohlia wahlenbergii var glacialis*. These stands are often associated with more productive flushes with *Chrysosplenium oppositifolium, Epilobium anagallidifolium, Cochlearia agg.* and more rarely *Rhizomnium magnifolium*. In one spot in the central gully there were a few plants of *Saxifraga rivularis*. Close to these flushes there were plants of *Cerastium alpinum, Polystichum lonchitis, Saxifraga oppositifolia* and *Ctenidium molluscum var condensatum*, all indicators of more basic ground.

Further to the north on Aonach Beag, there is another large snow-bed in the broad gully that runs down from the bealach between the two Aonachs and into An Chul Coire. There is much calcareous rock in the gully giving an important flora over and above the snow-bed interest; this site was visited by the British Bryological Society in 1986 (Rothero, 1987). The plateau of Aonach Beag is also interesting bryologically, with good stands of *Dicranum glaciale* and *Nardia breidleri* complementing the spikes of *Luzula arcuata*. These sites plus the areas on Aonach Mor surveyed in 1989 (Rothero, 1990) make up what is arguably the most important sequence of extreme snow-bed vegetation outside of the Cairngorms, the interest being augmented by the varied geology. The Aonachs should be managed as a unit and deserve the highest priority.

Appendix 1 Selected site descriptions

Species List for Site 51

An Aghaidh Gharbh
Aonach Beag

Grid Reference:-27/20-71-

Date:- 17.8.90

SPECIES	SCORE
MOSSES	
Amphidium mougeottii	1
Andreaea alpina	2
Andreaea blyttii	1
Andreaea mutabilis	1
Andreaea nivalis	2
Andreaea rupestris	3
Bartramia ithyphylla	1
Brachythecium glaciale	2
Brachythecium reflexum	1
Calliergon sarmentosum	2
Conostomum tetragonum	3
Ctenidium molluscum var condensatum	2
Dicranella palustris	1
Dicranoweissia crispula	1
Dicranum majus	1
Dicranum scoparium	1
Ditrichum zonatum	2
Drepanocladus exannulatus	1
Hylocomium splendens	1
Hylocomium umbratum	2
Hypnum callichroum	3
Isopterygium elegans	2
Kiaeria falcata	4
Kiaeria starkei	4
Lescuraea patens	1
Oligotrichum hercynicum	3
Philonotis fontana	2
Plagiothecium undulatum	1
Pleurozium schreberi	1
Pohlia ludwigii	4
Pohlia nutans	2
Pohlia wahlenbergii var glacialis	2
Polytrichum alpinum	3
Polytrichum juniperinum	2
Polytrichum sexangulare	4
Racomitrium aquaticum	1
Racomitrium ericoides	2
Racomitrium fasciculare	3
Racomitrium heterostichum	4
Racomitrium lanuginosum	3
Rhizomnium magnifolium	1
Rhytidiadelphus loreus	2
Sphagnum auriculatum var auriculatum	2
Sphagnum capillifolium	1

SPECIES	SCORE
Sphagnum tenellum	1
HEPATICS	
Anthelia julacea	4
Anthelia juratzkana	3
Barbilophozia floerkei	4
Cephalozia ambigua	1
Cephalozia bicuspidata	4
Diplophyllum albicans	3
Diplophyllum taxifolium	1
Gymnomitrion concinnatum	2
Lophozia opacifolia	3
Lophozia sudetica	4
Marsupella alpina	2
Marsupella brevissima	4
Marsupella condensata	1
Marsupella emarginata	4
Marsupella sphacelata	2
Marsupella sprucei	2
Marsupella stableri	3
Moerckia blyttii	4
Nardia breidleri	2
Nardia compressa	1
Nardia scalaris	4
Pellia epiphylla	1
Pleurocladula albescens	3
Scapania uliginosa	3
Scapania undulata	3
VASCULAR PLANTS	
Alchemilla alpina	2
Athyrium distentifolium	2
Blechnum spicant	1
Caltha palustris	1
Carex bigelowii	3
Cerastium alpinum	1
Cerastium cerastoides	1
Chrysosplenium oppositifolium	1
Cochlearia agg.	2
Cryptogramma crispa	3
Cystopteris fragilis	1
Deschampsia caespitosa	4
Deschampsia flexuosa	2
Diphasiatrum alpinum	1
Epilobium anagallidifolium	1
Galium saxatile	2

Appendix 1 Selected site descriptions

Species List for Site 51

SPECIES	SCORE
Gnaphalium supinum	3
Huperzia selago	2
Juncus trifidus	2
Luzula spicata	1
Nardus stricta	2
Oxyria digyna	1
Polystichum lonchitis	1
Salix herbacea	1
Saxifraga azoides	1
Saxifraga oppositifolia	1
Saxifraga rivularis	1
Saxifraga stellaris	3
Sibbaldia procumbens	2
Silene acaulis	1
Taraxacum agg.	1
Veronica serpyllifolia ssp humifusa	1
Viola palustris	2
MOSSES	45
HEPATICS	25
VASCULAR PLANTS	33
TOTAL	103

Appendix 1 Selected site descriptions

Site 58, Ben Lawers

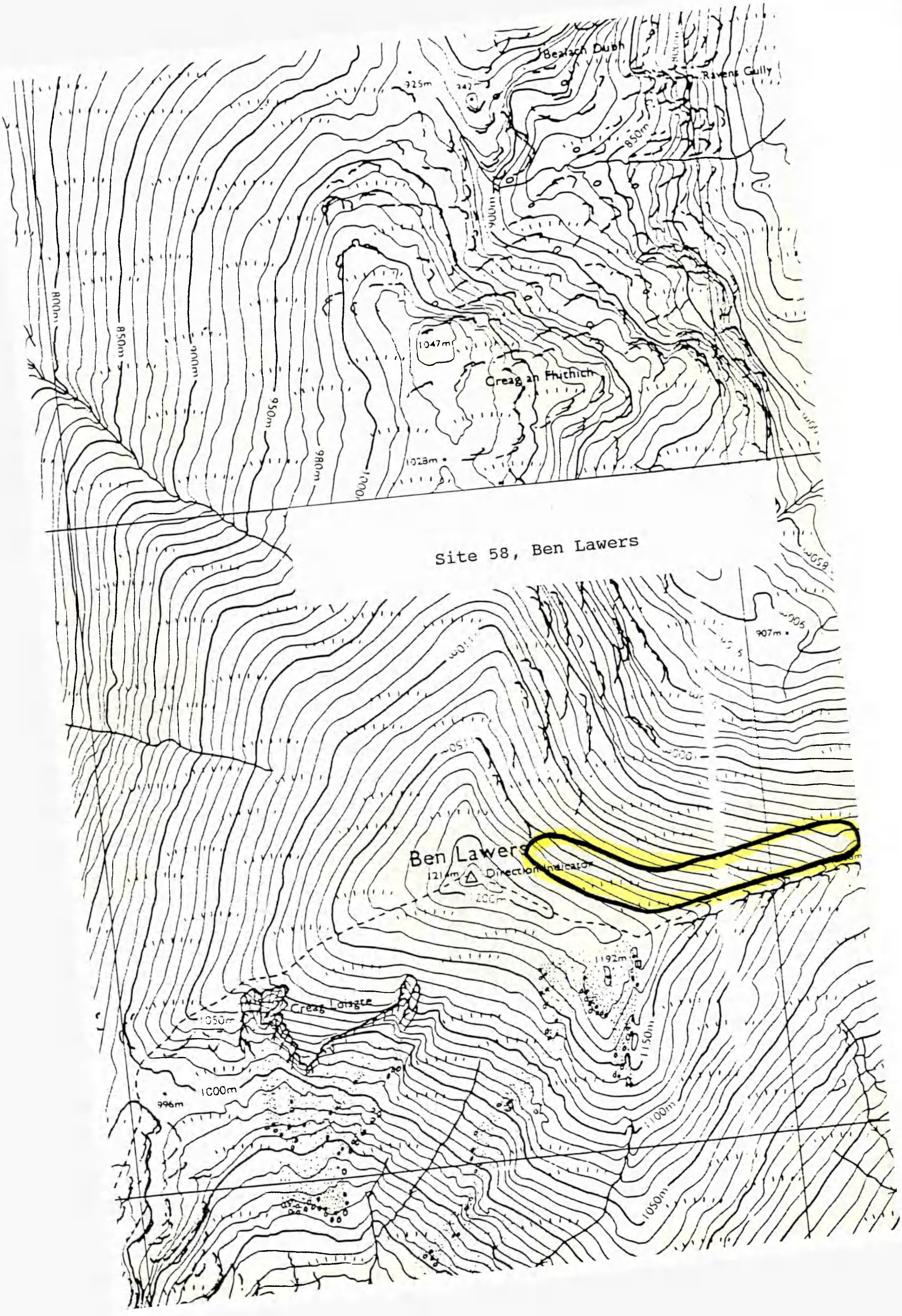
Date of Survey:-	**10.9.90**
Grid Reference:-	**27/636-640413**
Altitude of Site:-	**1050-1200m**
Aspect of Site:-	**0-20^{o}**
Slope:-	**20-25^{o}**

Irrigation:- There are no drainage lines on the site apart from some vague seepage lines the most defined of which is on the eastern margin of the site. This must be rather a dry site after the snow has melted.

Substrate:- The site is based on a moderate block scree that has been infilled by finer mineral material which is vegetation covered. The effect of the calcareous nature of much of the rock on Ben Lawers is not immediately apparent and one soil sample gave a pH value of only 4.5. The rock is Dalradian schist.

Site Description

Snow blown from the south and east ridges and the summit area of Ben Lawers forms a long snow slope on the face that stretches down from the eastern ridge towards Lochan nan Cat. This snow lies deepest and longest under the edge of the ridge and it is here that the communities exist which form the basis for this site. All the boundaries are rather arbitrary but the zones in which they occur are clear. The upper margin follows the line of, but is rather lower than,



Site 58, Ben Lawers

the ridge, and the line of the eastern margin is given by the shallow bealach at 1068m. The western margin is some way short of the broad northern ridge while the lower boundary is defined by the increase in the cover of vascular plants and is very imprecise. This gives a long narrow site, approximately 500m long but with a maximum width only rarely exceeding 50m.

The Plants

Mosses:-	20
Hepatics:-	18
Vascular Plants:-	12
Total:-	50
Number of Snowbed Species:-	12

Rare Species:-

Heterocladium dimorphum
Lescuraea incurvata
Cephalozia ambigua
Marsupella condensata
Nardia breidleri

This is a very uniform site which therefore has a surprisingly low species count given the reputation of the hill. There is a mosaic of chionophilous communities across the site with no really large continuous stands of bryophyte dominated vegetation. The vascular plant 'matrix' is provided by combinations of *Alchemilla alpina* - *Sibbaldia procumbens* and *Festuca* - *Alchemilla* - *Silene* dwarf herb communities and this is developed on the more stable soil. Where solifluction movement is more in evidence then hepatic vegetation tends to dominate, most broadly fitting into the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed. The *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed is not well developed though *Kiaeria starkei* is abundant across the site; *Polytrichum sexangulare* is much less frequent and is usually associated with stable patches in amongst the *Marsupella brevissima* - *Anthelia juratzkana* snow-bed. The site is rather dry and this probably limits the possibilities for the *Polytrichum sexangulare* - *Kiaeria starkei* snow-bed and some of its more moisture demanding hepatics are only occasional, eg. *Barbilophozia floerkei*, or absent, eg. *Moerckia blyttii*. It is best developed in the drainage channel that runs down from the bealach on the eastern margin of the site and it is here also that the only stands of *Pohlia ludwigii* occur.

The hepatic community is excellent, often forming significant patches and with plants like *Salix herbacea, Conostomum tetragonum, Anthelia juratzkana* and *Gymnomitrion concinnatum* catching the eye and there is a general abundance of *Racomitrium heterostichum*. The rare *Marsupella condensata* is almost as abundant as *Marsupella brevissima* here, and its sporophytes are locally common. There are also good stands of *Nardia breidleri* scattered across the slope but, again, the moisture demanding species are absent.

Only the vascular plant communities indicate the more calcareous nature of the substrate here, with occurrences of *Silene acaulis, Minuartia sedoides* and Agrostis spp. but there are scattered cushions of the calcicole moss *Oncophorus virens* in the more stony soil. On low crags near the top of the site two of the Lawers 'specialities' occur in mixed wefts of *Lescuraea incurvata* and *Heterocladium dimorphum*.

All around the summit of Ben Lawers there are scattered patches of late snow-bed bryophytes, particularly hepatic communities in which *Marsupella condensata* and *Nardia breidleri* are still frequent.

Appendix 1 Selected site descriptions

Species list for Site 58 Ben Lawers

Grid Ref:-27/636-640413 Date:- 10.9.90

SPECIES	SCORE
MOSSES	
Andreaea rupestris	2
Arctoa fulvella	1
Conostomum tetragonum	3
Dicranum fuscescens	3
Ditrichum zonatum	3
Heterocladium dimorphum	1
Kiaeria blyttii	2
Kiaeria falcata	3
Kiaeria starkei	4
Lescuraea incurvata	1
Oncophorus virens	1
Oligotrichum hercynicum	3
Pohlia ludwigii	2
Pohlia nutans	3
Polytrichum alpinum	3
Polytrichum sexangulare	3
Racomitrium fasciculare	2
Racomitrium heterostichum	4
Racomitrium lanuginosum	2
Sphagnum auriculatum var auriculatum	2
HEPATICS	
Anthelia julacea	2
Anthelia juratzkana	3
Barbilophozia floerkei	2
Cephalozia ambigua	2
Cephalozia bicuspidata	4
Diplophyllum albicans	2
Gymnocolea inflata	1
Gymnomitrion concinnatum	4
Jungermannia atrovirens	1
Lophozia opacifolia	2
Lophozia sudetica	3
Marsupella brevissima	4
Marsupella condensata	3
Marsupella emarginata	2
Marsupella sprucei	2
Nardia breidleri	2
Nardia scalaris	4
Pleurocladula albescens	3

SPECIES	SCORE
VASCULAR PLANTS	
Agrostis capillaris	2
Alchemilla alpina	2
Carex bigelowii	2
Minuartia sedoides	1
Deschampsia caespitosa	2
Festuca ovina/vivipara	2
Gnaphalium supinum	3
Huperzia selago	2
Nardus stricta	2
Salix herbacea	3
Saxifraga stellaris	2
Silene acaulis	2
MOSSES	20
HEPATICS	18
VASCULAR PLANTS	12
TOTAL	50

Appendix 2. Full list of species occurring on the 58 sites and the number of sites on which they occur

Mosses

Amphidium mougeottii	6
Andreaea alpestris	1
Andreaea alpina	30
Andreaea blyttii	27
Andreaea frigida	7
Andreaea mutabilis	10
Andreaea nivalis	34
Andreaea rothii	1
Andreaea rupestris	57
Arctoa fulvella	17
Bartramia ithyphylla	2
Bartramia pomiformis	3
Blindia acuta	6
Brachythecium glaciale	7
Brachythecium plumulosum	5
Brachythecium reflexum	1
Brachythecium rivulare	3
Bryum pseudotriquetrum	3
Bryum weigelii	4
Calliergon sarmentosum	26
Calliergon straminium	11
Conostomum tetragonum	58
Cratoneuron commutatum var falcatum	1
Ctenidium molluscum var condensatum	10
Dichodontium pellucidum	1
Dicranella heteromalla	3
Dicranella palustris	11
Dicranella subulata	1
Dicranoweissia crispula	1
Dicranum fuscescens	51
Dicranum glaciale	17
Dicranum majus	4
Dicranum scoparium	19
Ditrichum zonatum	49
Drepanocladus exannulatus	31
Drepanocladus uncinatus	8
Dryptodon patens	1
Heterocladium dimorphum	1
Heterocladium heteropterum	7
Hookeria lucens	5
Hygrohypnum molle	1
Hygrohypnum ochraceum	22
Hylocomium pyrenaicum	1
Hylocomium splendens	8
Hylocomium umbratum	20
Hypnum callichroum	20
Hypnum cupressiforme var cupressiforme	4
Hypnum jutlandicum	1
Isopterygiopsis muelleriana	5
Isopterygium elegans	35
Kiaeria blyttii	37
Kiaeria falcata	57
Kiaeria starkei	58
Lescuraea incurvata	1
Lescuraea patens	4
Oedipodium griffithianum	6
Oncophorus virens	1
Oligotrichum hercynicum	57
Philonotis fontana	43
Philonotis seriata	4
Philonotis tomentella	1
Plagiothecium denticulatum var obtusifolium	14
Plagiothecium undulatum	22
Pleurozium schreberi	16
Pogonatum urnigerum	2
Pohlia drummondii	13
Pohlia ludwigii	57
Pohlia nutans	53
Pohlia wahlenbergii var glacialis	23
Polytrichum alpestre	1
Polytrichum alpinum	54
Polytrichum juniperinum	5
Polytrichum sexangulare	55
Racomitrium aciculare	3
Racomitrium aquaticum	17
Racomitrium elongatum	1
Racomitrium ericoides	15
Racomitrium fasciculare	50
Racomitrium heterostichum	58
Racomitrium lanuginosum	51
Rhizomnium magnifolium	10
Rhizomnium punctatum	10
Rhytidiadelphus loreus	32
Rhytidiadelphus squarrosus	9
Sphagnum auriculatum var auriculatum	39
Sphagnum capillifolium	20
Sphagnum fuscum	2
Sphagnum girgensohnii	1
Sphagnum lindbergii	1
Sphagnum papillosum	14
Sphagnum recurvum	1
Sphagnum russowii	1
Sphagnum squarrosum	1
Sphagnum tenellum	12
Sphagnum teres	1

Appendix 2 Full list of species from the 58 sites

Tortella tortuosa	1
Hepatics	
Anastrophyllum donianum	12
Anthelia julacea	57
Anthelia juratzkana	51
Barbilophozia floerkii	57
Barbilophozia hatcheri	1
Barbilophozia lycopodioides	3
Bazzania tricrenata	10
Blepharostoma trichoclados	1
Calypogeia azurea	1
Calypogeia muelleriana	3
Cephalozia ambigua	30
Cephalozia bicuspidata	57
Cephaloziella divaricata	5
Chiloscyphus polyanthos	1
Diplophyllum albicans	54
Diplophyllum taxifolium	16
Gymnocolea inflata	6
Gymnomitrion apiculatum	4
Gymnomitrion concinnatum	51
Gymnomitrion crenulatum	2
Gymnomitrion obtusum	13
Harpanthus flotowianus	1
Hygrobiella laxifolia	5
Jungermannia atrovirens	1
Jungermannia exsertifolia ssp cordifolia	5
Jungermannia hyalina	3
Jungermannia obovata	1
Lophozia opacifolia	52
Lophozia sudetica	57
Lophozia ventricosa	2
Marchantia alpestris	2
Marsupella adusta	13
Marsupella alpina	22
Marsupella arctica	1
Marsupella boeckii	2
Marsupella brevissima	55
Marsupella condensata	31
Marsupella emarginata	50
Marsupella sparsifolia	5
Marsupella sphacelata	43
Marsupella sprucei	56
Marsupella stableri	49
Moerkia blyttii	49
Mylia taylori	12
Nardia breidleri	32
Nardia compressa	31
Nardia scalaris	58
Pellia epiphylla	7
Pellia neesiana	2
Pleurocladula albescens	51
Ptilidium ciliare	6
Scapania nimbosa	8
Scapania ornithopodioides	2
Scapania paludosa	12
Scapania scandica	3
Scapania subalpina	1
Scapania uliginosa	52
Scapania umbrosa	1
Scapania undulata	51
Tritomaria quinquedentata	5
Vascular plants	
Achillea millefolia	1
Agrostis capillaris	7
Alchemilla alpina	35
Alchemilla glabra	3
Armeria maritima	2
Athyrium distentifolium	31
Blechnum spicant	16
Caltha palustris	9
Carex bigelowii	56
Carex lachenalii	4
Carex saxatilis	1
Cerastium alpinum	2
Cerastium arcticum	3
Cerastium cerastoides	16
Cherleria sedoides	1
Chrysosplenium oppositifolium	8
Cochlearia agg.	12
Cryptogramma crispa	20
Cystopteris fragilis	3
Deschampsia caespitosa	56
Deschampsia flexuosa	52
Diphasiatrum alpinum	17
Dryopteris affine	1
Dryopteris dilatata	5
Empetrum sp	1
Epilobium anagallidifolium	13
Eriophorum angustifolium	10
Festuca ovina/vivipara	12
Galium saxatile	34
Gnaphalium supinum	53
Huperzia selago	52
Juncus trifidus	42
Loisleuria procumbens	1
Luzula arcuata	11
Luzula spicata	29
Nardus stricta	32
Oxyria digyna	9
Poa alpina	4

Appendix 2 Full list of species from the 58 sites

Poa annua	1
Poa flexuosa	1
Polystichum lonchitis	2
Ranunculus acris	3
Rumex acetosa	4
Salix herbacea	40
Saxifraga azoides	1
Saxifraga oppositifolia	2
Saxifraga rivularis	8
Saxifraga stellaris	53
Scirpus caespitosa	4
Sedum rosea	3
Selaginella selaginoides	1
Sibbaldia procumbens	20
Silene acaulis	24
Stellaria alsine	7
Taraxacum agg.	8
Thalictrum alpinum	2
Trollius europaeus	1
Vaccinium myrtillus	2
Veronica alpina	7
Veronica serpyllifolia ssp humifusa	6
Viola palustris	26

Appendix 3 Full sample data by community

The following pages contain the full data collected for all samples on the snow-bed sites in 1989 and 1990. The samples are grouped into the various communities described in Chapter 4 above. The figures in the matrix are Domin scale scale values and the species are listed in order of constancy value with species of the same constancy then being listed alphabetically. Grid references are given in three parts; first comes the numeric reference for the 100km square followed by the easting and then the northing. The explanation of the figures for soil moisture and substrate are given on page 21: the figure for bare ground, including rock surfaces, is a Domin scale value.

Polytrichum sexangulare - Kiaeria starkei snow bed

Typical facies

Sample number	9	34	46	52	57	60	72	77	98	100	103	106	107	108	111	112	116	118	120	132	134	136	138	2	12	85	94
Site number	1	4	6	7	8	9	13	14	19	27	27	30	30	32	33	33	35	40	40	45	48	50	54	1	1	17	19
Grid reference	38	28	28	37	37	38	27	27	28	27	27	28	28	28	28	28	28	27	27	37	28	27	27	38	38	27	28
Grid reference, easting	012	990	990	093	092	095	941	943	986	193	193	466	466	205	256	256	165	490	490	241	016	142	404	012	012	990	986
Grid reference, northing	045	000	001	980	992	010	980	983	010	738	736	686	686	718	815	815	262	720	720	846	194	543	872	045	045	990	010
Altitude (metres)	1100	1100	1200	1100	980	1150	1090	1220	1120	1120	1130	980	980	970	1000	1000	1050	1080	1080	1030	1000	1100	950	1100	1100	1230	1120
Slope (degrees)	20	20	20	35	30	10	30	40	20	30	35	20	20	35	30	30	30	25	10	15	25	25	20	5	15	15	10
Aspect (degrees)	50	90	70	220	70	355	100	130	45	110	50	65	65	75	70	70	75	100	90	60	15	15	20	120	120	90	110
pH												4.6	4.4	4.9	5.3	5	5.1	4.7	4.8	4.1	5.3	5.6	4.8				
Soil moisture	2	1	2	2	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	1	2	3
Substrate size	2	2	2	2	2	2	3	2	1	3	2	2	3	1	2	2	1	2	2	2	2	3	2	2	2	2	3
Bare Ground		4	3		4							4	4		5				5				2		2	3	2
Number of species	8	16	5	5	10	5	7	11	15	11	7	16	5	10	18	17	9	7	13	6	13	11	16	5	9	8	6
Kiaeria starkei	7	2	4	7	4	5	2	5	3	3	8	5	8	6	6	7	6		8	8	8	8	6		2		
Polytrichum sexangulare	6		7	7	4	8	5	5	6	5	4	4	4	6	6	5	5	7	5	6	4		4		5		3
Barbilophozia floerkii	4		6	5			8	7	5	8		5	6	6	6	4	5	4	5	6	4		5				
Racomitrium heterostichum				2	2				4	3		6			3	4			5				2	5	5	6	
Lophozia sudetica	1	1				2	1	2	2		1	3	2	3	2	2				4	2	3	3				
Nardia scalaris		3			4	2		2			1	3		3	2	3		8	4		5	6	7			3	
Conostomum tetragonum									5			5											2		1		
Kiaeria falcata			2	1				1					3		2	4	4		2		3	3	4				
Oligotrichum hercynicum		1						2						3	2	3		4	3			6	1			3	2
Pohlia ludwigii					2		1	2		2	4										5		2				
Racomitrium lanuginosum										1					2	1			1			2			2		
Cephalozia bicuspidata	1								2			3			2	2					2	5	3				
Marsupella brevissima		2										5			3	3			2				1				
Marsupella sphacelata		1					1	1	1										2								
Moerkia blyttii					2				4						4	5					4		4			4	
Pleuroclada albescens	2											5								2			3				
Deschampsia caespitosa		5			4						1	4		6	5	5	6	5	4		2						
Gnaphalium supinum		6			7					2				4	3	2			5					5	5	5	
Huperzia selago		1					3										1					1			1		
Andreaea nivalis																								8			
Ditrichum zonatum																1								3			2
Pohlia nutans	4									1		2					1										
Polytrichum alpinum																	3				2			1			
Racomitrium ericoides																											
Racomitrium fasciculare		2							4							3			3			2					3
Anthelia julacea		1							1						1											4	7
Anthelia juratzkana		3										4											1				
Cephalozia ambigua												1															
Cephaloziella divaricata																											
Diplophyllum albicans		1							1													4					
Gymnomitrium concinnatum									1						1												
Lophozia opacifolia																					5	5	3				
Marsupella alpina																											
Marsupella condensata		1							1																		
Marsupella emarginata	2				3	2				2																	
Marsupella stableri									1																	1	
Nardia breidleri								3				1															
Nardia compressa																											7
Scapania paludosa											3																
Scapania uliginosa																					3						
Scapania undulata																				2							
Carex bigelowii		1																									
Cryptogramma crispa										3																	
Deschampsia flexuosa			4		1																				2	1	
Juncus trifidus								2																	1		
Salix herbacea		4																									
Saxifraga stellaris										3		2		3	3	2	3	3									
Viola palustris																		2									
Rhytidiadelphus loreus														3	2												

Hepatic rich facies

Sample number	5	8	15	16	24	27	29	31	37	56	59	67	70	88	95
Site number	1	1	1	1	3	3	3	4	4	8	9	10	12	17	19
Grid reference	38	38	38	38	28	28	28	28	28	37	38	38	27	27	28
Grid reference, easting	012	012	012	012	991	991	991	990	990	092	095	104	960	990	986
Grid reference, northing	045	045	045	045	023	023	023	000	000	992	010	016	970	990	010
Altitude (metres)	1100	1100	1100	1100	1100	1100	1100	1100	1100	980	1150	1120	1140	1230	1120
Slope (degrees)	20	20	30	25	20	25	20	20	15	40	15	35	35	20	30
Aspect (degrees)	50	50	50	50	360	355	35	85	20	20	355	350	345	90	70
pH															
Soil moisture	2	2	2	2	2	3	3	2	2	3	2	2	3	3	2
Substrate size	2	2	2	2	2	2	1	1	2	1	2	2	3	2	1
Bare Ground		7		2							2				
Number of species	8	10	12	12	9	9	7	13	9	5	12	15	12	3	9
Kiaeria starkei	3	5	2	2	9	2	3	2	2		2	2	3		3
Polytrichum sexangulare	6	5	4	5	2	7	9	5	7	3	2	4	7	9	3
Barbilophozia floerkii	3	2	1	4			2	3		2	8	3			4
Racomitrium heterostichum												3	2		2
Lophozia sudetica		4	4				2	3	4		1	4	2		
Nardia scalaris	4		4	3		7		2	1	2		2	1	2	
Conostomum tetragonum		2			1						2				
Kiaeria falcata			1												
Oligotrichum hercynicum	2	1													
Pohlia ludwigii					3	2	2				2	3	2	3	
Racomitrium lanuginosum								2				1			
Cephalozia bicuspidata	3	4		2	1	4		3			1	4	2		1
Marsupella brevissima		2	2		3		1				2				
Marsupella sphacelata			3	1		2		4	1						
Moerkia blyttii			8	7				7		8		8			8
Pleuroclada albescens	4	3	5	3	4	3	3			2	5	4	4		1
Deschampsia caespitosa								3				1			
Gnaphalium supinum				2											
Huperzia selago				1				2							1
Andreaea nivalis									7						
Ditrichum zonatum															
Pohlia nutans								2							
Polytrichum alpinum															
Racomitrium ericoides															
Racomitrium fasciculare			2	2					2						
Anthelia julacea									2				1		
Anthelia juratzkana															
Cephalozia ambigua											1	4			
Cephaloziella divaricata															
Diplophyllum albicans						1						4	3		
Gymnomitrium concinnatum															
Lophozia opacifolia											2				
Marsupella alpina			1		1										
Marsupella condensata						1					1				
Marsupella emarginata					1			1							
Marsupella stableri									1			1	1		
Nardia breidleri															
Nardia compressa															
Scapania paludosa															
Scapania uliginosa															
Scapania undulata															
Carex bigelowii															3
Cryptogramma crispa															
Deschampsia flexuosa	4	4		1											
Juncus trifidus															
Salix herbacea															
Saxifraga stellaris													1		
Viola palustris															
Rhytidiadelphus loreus															

Racomitrium facies

Sample number	6	7	13	32	40	55	58	63	69	81	89	122	126	128	140	101
Site number	1	1	1	4	5	8	9	9	12	17	17	42	44	44	57	27
Grid reference	38	38	38	28	28	37	38	38	27	27	27	27	37	37	27	27
Grid reference, easting	012	012	012	990	980	092	095	095	960	990	990	480	233	233	637	193
Grid reference, northing	045	045	045	000	000	992	010	010	970	990	990	749	845	845	433	738
Altitude (metres)	1100	1100	1100	1100	1160	980	1150	1150	1140	1230	1230	1050	1050	1050	1000	1120
Slope (degrees)	20	20	15	15	5	5	35	5	5	10	20	5	5	5	5	30
Aspect (degrees)	50	50	120	70	80	45	135	30	35	60	75	60	30	120	25	110
pH												4.7	4.3	4.8	4.4	
Soil moisture	2	1	1	2	2	2	1	2	2	3	1	2	2	1	2	3
Substrate size	2	2	1	2	2	2	1	2	2	2	2	2	2	1	2	3
Bare Ground	4	3			4	2	3			2		4	4		2	3
Number of species	13	11	6	11	7	9	13	10	10	18	6	11	9	14	10	6
Kiaeria starkei	9	3	3	9	2	5	5	5		5	4	7	8	8	7	4
Polytrichum sexangulare	3	3	6	4	4	7	4	5	5	7	4	5	7	7	7	4
Barbilophozia floerkii		5		1		2	4	2	2	2		4		4	4	
Racomitrium heterostichum	4	5	7	3	6		3	7	7	3	7	5	5	2	5	2
Lophozia sudetica	1	2					2		3	2	5		3	2		5
Nardia scalaris				2			2	2				2	3	1	2	
Conostomum tetragonum				2	4	5			1	1	4		3	4		
Kiaeria falcata			1							2		5				
Oligotrichum hercynicum	1											2	1			
Pohlia ludwigii								2	1							7
Racomitrium lanuginosum		1						2	2	2						
Cephalozia bicuspidata	1	4								1				2	2	
Marsupella brevissima	3	1				1	2			1				3		
Marsupella sphacelata				1			3			3						
Moerkia blyttii								2		6		4				
Pleuroclada albescens	1	1		1								2				
Deschampsia caespitosa															4	
Gnaphalium supinum							7									
Huperzia selago		1	1	1		1	1		1	1						
Andreaea nivalis																
Ditrichum zonatum	1									2						
Pohlia nutans				1		1			1	2			2	2		
Polytrichum alpinum							2						2	4		
Racomitrium ericoides															2	
Racomitrium fasciculare																
Anthelia julacea														1		
Anthelia juratzkana																
Cephalozia ambigua	1															
Cephaloziella divaricata										1						
Diplophyllum albicans									2							
Gymnomitrium concinnatum					1							2		2	3	
Lophozia opacifolia																
Marsupella alpina	1									1						
Marsupella condensata																
Marsupella emarginata																
Marsupella stableri																
Nardia breidleri																
Nardia compressa																
Scapania paludosa																
Scapania uliginosa																
Scapania undulata																
Carex bigelowii	1					1	1	4						5		
Cryptogramma crispa																
Deschampsia flexuosa	4	6			2					2						
Juncus trifidus						1	1									
Salix herbacea			5	4	3			4			5	8			4	
Saxifraga stellaris																
Viola palustris																
Rhytidiadelphus loreus																

Marsupella brevissima - Anthelia juratzkana Snowbed

Marsupella brevissima - Anthelia juratzkana Snowbed

A

Sample Number	26	47	90	4	10	14	21	28	42	49	50	51	61	62	76	87	97	110	113	119	124	137	141
Site number	3	6	18	1	1	1	3	3	5	6	7	7	9	9	14	17	19	33	33	40	43	51	58
Grid reference (100km)	28	28	27	38	38	38	28	28	28	28	37	37	38	38	27	27	28	28	28	27	27	27	27
Grid reference, easting	991	990	998	012	012	012	991	991	980	990	093	093	095	095	943	990	986	256	256	490	476	201	640
Grid reference, northing	023	001	988	045	045	045	023	023	000	001	980	980	010	010	983	990	010	815	815	720	745	715	413
Altitude (metres)	1100	1200	1220	1100	1100	1100	1100	1100	1160	1200	1100	1100	1150	1150	1220	1230	1120	1000	1000	1080	1090	900	1050
Slope (degrees)	20	15	25	20	20	15	15	10	5	15	25	25	35	25	40	20	15	20	20	5	5	15	20
Aspect (degrees)	100	50	355	50	50	120	55	55	90	45	120	50	355	285	115	100	60	70	70	70	10	95	360
pH																		5.2	5.8	5	4.6	5.4	4.5
Soil moisture	2	1	1	1	1	1	1	2	2	1	2	1	3	1	1	2	1	2	2	2	1	1	2
Substrate size	1	1	2	1	1	1	1	2	2	2	3	3	3	2	1	1	2	1	1	1	1	2	1
Bare ground	2			7	4	6		6	4	5	5	5		8	3	5	6	4	5	5	5	5	
Number of species	11	7	3	9	8	9	8	10	12	8	8	12	14	7	12	6	13	13	12	17	10	18	16
Anthelia juratzkana	2	3		4	1	1	3	3		3	1	3	5	2	3	2	4	5		3	2	6	2
Lophozia sudetica	2			2			1	1	3	1	1	2	3	1	2	1	1	4	4		6	5	2
Marsupella brevissima	8	3		4	8	8	8	8	8	8	6	8	7	5	8	8	8	6	7	7	7	7	
Polytrichum sexangulare			3		2	2	3	1	1	2	2		2	2			2	5	3	2	5	2	5
Racomitrium heterostichum					2	4	2		4				2		4	3		3		3	3	2	
Conostomum tetragonum									2		1		2							4	4		1
Kiaeria falcata	6	9	9	5	4			3		5			2	5			3	7	4	4	5	4	6
Kiaeria starkei									1		7	2	4		2		1	2	3	3		6	2
Oligotrichum hercynicum	1	2				1			1			1		2	1	3			3	2		4	4
Cephalozia bicuspidata	1							2	2	1								2	4		2		3
Marsupella condensata				1	2		1			2		1	3				2			7		2	2
Nardia scalaris	4	4		1		1				1					3	2	2			2		2	7
Pleuroclada albescens	1		3	1	3			2					1					2	5	3		2	2
Ditrichum zonatum							1													3			
Pohlia nutans				1				2			3	1		2			3				3	2	5
Cephalozia ambigua	1					1		1	1				1		1		1		1	2		3	2
Gymnomitrium concinnatum									4				1		1		1			5	4		1
Marsupella stableri									1				1				1	2					
Salix herbacea							2		2													1	
Pohlia ludwigii		1									1	2											
Racomitrium fasciculare								2												1			
Racomitrium lanuginosum																				2		1	
Barbilophozia floerkii	1	2										1						2		2			
Diplophyllum albicans																	2						2
Marsupella alpina					1																		
Marsupella sphacelata	1											1			4								
Moerkia blyttii																		4	5				
Nardia breidleri													4		2				5			3	3
Carex bigelowii																							
Deschampsia caespitosa																		2	2			2	
Deschampsia flexuosa				2								2											
Gnaphalium supinum						2						4			2							1	
Juncus trifidus						1																	

B

Sample Number	36	91	92	131	11	20	123	139
Site number	4	19	19	45	1	3	42	57
Grid reference (100km)	28	28	28	37	38	28	27	27
Grid reference, easting	990	986	986	241	012	991	480	637
Grid reference, northing	000	010	010	846	045	023	749	433
Altitude (metres)	1100	1120	1120	1030	1100	1100	1050	1000
Slope (degrees)	5	5	15	10	10	10	5	5
Aspect (degrees)	25	75	140	10	120	55	30	25
pH				4.8			4.9	5.1
Soil moisture	1	2	2	1	1	1	1	1
Substrate size	2	2	2	2	2	1	1	2
Bare ground		4		5	4		4	4
Number of species	9	14	18	12	9	13	13	15
Anthelia juratzkana	1	3	2	4		3	6	5
Lophozia sudetica	2	4	2	7	4	5	5	3
Marsupella brevissima			3		1	6	7	7
Polytrichum sexangulare	2	1		2		3		4
Racomitrium heterostichum	9	6	7	3	5	3	5	3
Conostomum tetragonum	1	1	2	2	3	4	3	3
Kiaeria falcata				3			2	6
Kiaeria starkei	1		4					2
Oligotrichum hercynicum			2	2		1		3
Cephalozia bicuspidata		2		2	2	1		
Marsupella condensata			1				3	4
Nardia scalaris		2	2					
Pleuroclada albescens						1		
Ditrichum zonatum		3	1	2			2	3
Pohlia nutans			3	2		2		2
Cephalozia ambigua						1		
Gymnomitrium concinnatum			2				5	
Marsupella stableri		3				1		
Salix herbacea	4	5	7	5	7	5	6	5
Pohlia ludwigii								
Racomitrium fasciculare	3	3						
Racomitrium lanuginosum			2					1
Barbilophozia floerkii			4		1			
Diplophyllum albicans								
Marsupella alpina								
Marsupella sphacelata								
Moerkia blyttii		1	2					
Nardia breidleri							2	4
Carex bigelowii	4	2	3	5				
Deschampsia caespitosa								
Deschampsia flexuosa					3		5	
Gnaphalium supinum								
Juncus trifidus		2	3		2		2	

C

Sample Number	25	44	86	114	17	33	65	66	96	127
Site number	3	5	17	34	1	4	10	10	19	44
Grid reference (100km)	28	28	27	28	38	28	38	38	28	37
Grid reference, easting	991	980	990	120	012	990	104	104	986	233
Grid reference, northing	023	000	990	255	045	000	016	016	010	845
Altitude (metres)	1100	1160	1230	1020	1100	1100	1120	1120	1120	1050
Slope (degrees)	15	10	15	25	20	20	10	5	30	10
Aspect (degrees)	110	345	95	40	50	50	90	110	85	95
pH				5.4						4.4
Soil moisture	1	3	2	2	1	1	2	3	2	2
Substrate size	1	1	2	2	1	2	2	1	2	1
Bare ground			3	4	2	4				
Number of species	18	8	14	15	13	14	10	11	13	10
Anthelia juratzkana	4	4	4	4	2	4		1		2
Lophozia sudetica	3		3		4	1	6	5	5	6
Marsupella brevissima	5	3		3	7	9	5	2	3	4
Polytrichum sexangulare	4	1	1	3	2	3	2		1	5
Racomitrium heterostichum	4		4	5	2		6		1	
Conostomum tetragonum			2		4					6
Kiaeria falcata				6		1	2			
Kiaeria starkei	4	7		5	3	3	4	3	4	6
Oligotrichum hercynicum			2	2	3			2		
Cephalozia bicuspidata	1	6	8	5	5	3		3	5	5
Marsupella condensata					1	1			3	1
Nardia scalaris	1		2	3		1		3	4	3
Pleuroclada albescens	2		4	4	4	4	1	5	4	
Ditrichum zonatum			1			1				2
Pohlia nutans	1	1		3						
Cephalozia ambigua					2	3	2	8		
Gymnomitrium concinnatum	2		1				3			
Marsupella stableri		3	4		1					
Salix herbacea	2	2		5						
Pohlia ludwigii	2					1		2	1	
Racomitrium fasciculare	2									
Racomitrium lanuginosum										
Barbilophozia floerkii										
Diplophyllum albicans			3				1	4	1	
Marsupella alpina	1					1			4	
Marsupella sphacelata	3								6	
Moerkia blyttii										
Nardia breidleri				2						
Carex bigelowii				2						
Deschampsia caespitosa				4						
Deschampsia flexuosa	2									
Gnaphalium supinum	4		4							
Juncus trifidus										

A - Typical community, B - Salix herbacea sub-community, C - Cephalozia sub-community

Pohlia ludwigii snowbed

Sample number	82	115	23	73	121	3	18	35	68
Site number	17	35	3	13	40	1	1	4	10
Grid reference, 100km square	27	28	28	27	27	38	38	28	38
Grid reference, easting	990	165	991	941	490	012	012	990	104
Grid reference, northing	990	262	023	980	720	045	045	000	016
Altitude (metres)	1230	1050	1100	1090	1080	1100	1100	1100	1120
Slope (degrees)	10	15	25	35	5	20	5	30	5
Aspect (degrees)	85	75	315	100	90	20	120	340	30
pH		4.6			5.1				
Soil moisture	3	3	3	3	3	3	3	3	3
Substrate size	1	2	2	3	2	2	2	3	2
Bare Ground		5	4						
Number of species per sample	7	5	1	3	5	5	7	5	8
Pohlia ludwigii	8	8	10	10	8	9	8	8	6
Polytrichum sexangulare	4	4		2					1
Nardia scalaris	5					1	3	4	3
Deschampsia caespitosa	4	4			2	5			5
Marsupella sphacelata							2		4
Scapania uliginosa	1				4		5		
Scapania undulata						1			7
Philonotis fontana		4			6				
Andreaea nivalis								5	
Ditrichum zonatum									2
Oligotrichum hercynicum									2
Pohlia wahlenbergii var glacialis				1					
Racomitrium heterostichum						2			
Anthelia julacea								2	
Cephalozia bicuspidata	2								
Diplophyllum albicans							1		
Lophozia sudetica	4								
Marsupella brevissima							1		
Marsupella emarginata								4	
Nardia compressa					4				
Deschampsia flexuosa							1		
Salix herbacea		6							

Carex bigelowii - Polytrichum alpinum Sedge Heath

Sample number	39	41	80	83	130	1	43	19	64	93	133	125	129	45	84	99	22	53	71
Site number	4	5	17	17	44	1	5	3	9	19	45	43	44	5	17	19	3	7	13
Grid reference	28	28	27	27	37	38	28	28	38	28	37	27	37	28	27	28	28	37	27
Grid reference, easting	990	980	990	990	233	012	980	991	095	986	241	476	233	980	990	986	991	093	941
Grid reference, northing	000	000	990	990	845	045	000	023	010	010	846	745	845	000	990	010	023	980	980
Altitude (metres)	1100	1160	1230	1230	1050	1100	1160	1100	1150	1120	1030	1090	1050	1160	1230	1120	1100	1100	1090
Slope (degrees)	15	5	5	15	5	15	5	10	15	10	15	10	5	5	10	10	10	25	25
Aspect (degrees)	50	105	80	60	140	120	95	55	60	80	60	20	140	50	130	350	315	110	90
pH					4.6						4.1	4.6	4.8						
Soil moisture	1	3	2	2	1	1	2	1	2	2	2	2	2	2	2	2	2	2	1
Substrate size	3	1	1	2	1	2	2	2	1	2	1	1	2	2	2	2	2	2	3
Bare ground																			
Number of species	11	9	15	9	11	5	8	6	8	7	7	5	7	4	7	5	5	8	7
Barbilophozia floerkii	4	2	4		8	4	4		2	4	4	8	5		3	7	9	4	5
Carex bigelowii	4	4	5	5	5	9	7	6	7	5	7	7	9	4	6	5	1	7	1
Salix herbacea	7	5	2	2	7		4	7	4	8	7				2		2		
Dicranum fuscescens					3	6	6	7	7	5	7		6		4	1			
Polytrichum alpinum			4		4	1	2		4	3	4		5	5				7	5
Polytrichum sexangulare	2	2	1		4							5	3				4	1	2
Deschampsia flexuosa			2	5				2	3			2		8	8	8			
Kiaeria starkei									3								2	2	7
Racomitrium fasciculare	1	5	1	5	2						1								
Racomitrium heterostichum	6	2	7	4	5		1				4								
Racomitrium lanuginosum	4		4	2		1	2					3							
Cephalozia bicuspidata	2		1										1		1				
Lophozia sudetica			1		3								2		1				1
Huperzia selago	2	1		3			2									1			
Conostomum tetragonum	1		3		2														
Pohlia nutans										2									1
Diplophyllum albicans			1																
Marsupella sphacelata		3	3																
Moerkia blyttii	2		3	3															
Nardia scalaris				2	2														
Ptilidium ciliare								2											
Deschampsia caespitosa									1					2				4	
Gnaphalium supinum		7																	
Juncus trifidus								1		2								2	
Viola palustris																		3	

Deschampsia caespitosa - Galium saxatile Grassland

Sample number	54	104	109	30	38	48	105	75	78	79	102
Site number	7	30	32	4	4	6	30	13	16	16	27
Grid reference	37	28	28	28	28	28	28	27	27	27	27
Grid reference, easting	093	466	205	990	990	990	466	941	944	944	193
Grid reference, northing	980	686	718	000	000	001	686	980	988	988	738
Altitude (metres)	1100	980	970	1100	1100	1200	980	1090	1040	1040	1120
Slope (degrees)	20	20	35	15	15	5	25	35	5	30	35
Aspect (degrees)	120	20	75	85	330	320	110	100	140	90	110
pH		4.2	5				4.7				
Soil moisture	2	1	2	3	3	2	2	3	2	2	2
Substrate size	2	1	1	3	2	2	1	2	1	2	2
Bare Ground											2
Number of species	9	7	7	12	11	2	4	8	11	13	11
Deschampsia caespitosa	4	3	6	9	9	9	7	8	5	6	7
Carex bigelowii	6	5	4	4	2		2		3		
Polytrichum alpinum	1	2			1			1	3	1	5
Barbilophozia floerkii	1			2					6	1	5
Racomitrium fasciculare	2			2	3		2			4	4
Galium saxatile	7	3	3								
Kiaeria starkei								3	3		3
Nardia scalaris				1	2					3	
Pohlia ludwigii						5		2		1	
Polytrichum sexangulare				4					4	2	2
Racomitrium heterostichum								1	1	2	
Racomitrium lanuginosum	1				2					1	1
Agrostis capillaris	5										
Anthelia julacea				2							
Cephalozia bicuspidata				3	2						
Cerastium cerastoides								4			
Cryptogramma crispa											1
Deschampsia flexuosa		2									
Dicranum fuscescens	2						8				
Diplophyllum albicans				1	1						
Ditrichum zonatum				1							
Gnaphalium supinum										5	2
Huperzia selago				3					3		
Hylocomium splendens		2	3								
Kiaeria falcata										1	
Lophozia sudetica				3	2						
Marsupella emarginata										4	
Oligotrichum hercynicum					2						
Pleurozium schreberi			2						1		
Pohlia nutans									1	1	
Racomitrium ericoides								2			
Rhytidiadelphus loreus		9	8								
Salix herbacea					2						
Saxifraga stellaris									1		3
Scapania uliginosa								3			2
Viola palustris			3								

Pohlia wahlenbergii var glacialis Spring

Sample Number	74	117	135
Site number	13	39	50
Grid reference (100km)	27	27	27
Grid reference (easting)	941	650	142
Grid reference (northing)	980	780	543
Altitude (metres)	1090	900	1100
Slope (degrees)	35	5	20
Aspect (degrees)	100	20	320
pH	-	5.9	6.5
Soil moisture	3	3	3
Substrate size	3	3	3
Bare Ground	-	-	-
Number of species	3	5	4
Pohlia wahlenbergii var glacialis	9	9	9
Cerastium cerastoides	1		
Chrysosplenium oppositifolium			5
Cochlearia agg.			3
Epilobium anagallidifolium		2	
Marchantia alpestris		5	
Philonotis fontana		4	
Philonotis seriata		4	
Pohlia ludwigii	1		
Stellaria alsine			2