LAND USE AND VEGETATION CHANGE ON THE LONG MYND.

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This work or any part thereof has not previously been presented in any form to the University or to any other body whether for the purposes of assessment, publication or for any other purpose (unless otherwise indicated). Save for any express acknowledgments, references and/or bibliographies cited in the work, I confirm that the intellectual content of the work is the result of my own efforts and of no other person.

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Abstract

The plant communities of the Long Mynd plateau are the culmination of over 3000 years of human intervention that largely deforested the uplands, and subsequently maintained the generally treeless heath and grassland communities now extant. The capacity of these communities to respond to directional change is well known, indeed the traditional mode of heathland management, burning, depends on the regenerative capacity of the target species, generally heather (*Calluna vulgaris*), for its success.

However, changes in post WW2 stocking practice; the loss of ponies followed by an increase in the numbers of sheep and a change to them being overwintered on the hill, led to excessive grazing and damage to the heath. This coincided with the spread over the hill by bracken (*Pteridium aquilinum*) and other changes in the distribution and nature of the vegetation.

A sequence of vegetation surveys made by various individuals and organisations over the past 75 years or so has been analysed in an attempt to delineate spatial and temporal changes in the vegetation. This demonstrated the need for a standardised survey methodology to allow consistent monitoring. The analysis showed that bracken had been infiltrating most of the communities from its origins outside the lower limits of the Common as well as from some of the valley sides. Within the last decade, this expansion has apparently been contained in line with the current management plan for control.

A survey of 730 quadrats in some 30 stands was made to characterise the variation of the vegetation on the plateau, and to relate it to some of the associated environmental factors. Classification, unconstrained ordination and ordination constrained by the abiotic environmental variables, showed that, a) the strongest trend in the vegetation distinguished water-flushed communities, b) non-wetland communities differentiate between heathland and grassland, c) this trend can be only partly be attributed to the measured abiotic environmental variables, d) the amount of pure Pteridietum [U20] is limited, although much of the heathland and grassland has bracken within it. There are indications that invasion by bracken often correlates with a loss of dominance of *Calluna* in favour of *Deschampsia flexuosa* and *Vaccinium myrtillus.* Difficulties in associating these trends with measured abiotic variables suggests, other factors probably management processes, are critical in driving this trend.

Distribution of ‘heathland’ bryophytes was found to be associated more with the structure of their ‘host’ vascular communities rather than with abiotic factors.

Finally, this investigation considers the practical implications with regard to the future encouragement of heather and the control of bracken. Cutting rather than burning appears to be the ecologically most suitable method for heather regeneration and bracken control.

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1 Introduction

1.1 Background to the study

This study aims to investigate the current status and distribution of plant communities on the upland plateau of the Long Mynd, Shropshire, and also to assess the influence of historical and contemporary land management on their development. This involves the assessment of published and unpublished reports on its vegetation extending back for almost a century as well as those detailing current practices.

The information gained will provide a baseline concerning the distribution, structure, and dynamics of these communities, and should assist in the long term conservation planning and management of the upland parts of the Long Mynd Common.

1.2 Structure and Topography of the Long Mynd

The Long Mynd, a dissected upland plateau in the South Shropshire Hills, rises to a height of 516 m OD and covers an area of *c*.45 km^2. It has distinct boundaries on three sides, being delimited by the Church Stretton Fault to the east, the River Onny to the south, and by the Long Mynd Scarp Fault to the west. On the fourth side are the headwaters of the River East Onny, but the northern limits are less distinct and merge into the Bletchcott Hills. Figure 1.2.1 shows the Long Mynd, its environs and the extent of the area owned by the National Trust.

The Long Mynd massif is formed of Pre-Cambrian rocks of the Longmyndian succession (Greig *et al.*, 1968) which consists of two principal series, the Wentnor and the Stretton. Figure 1.2.2 shows the distribution and structure of these formations on the Long Mynd and adjacent areas.

Packham and Sinker (1985) point out that, important as this solid geology may be, some of the most significant influences on soil and vegetation derive from the last Pleistocene Ice Age. Although there seems to be little to indicate the summit of the Long Mynd was covered in ice, there is some evidence (Wright, 1968) that ice was present in the High Park and Jinlye area at around 325 metres O.D.

Figure 1.2.1. The Long Mynd and its environs showing the National Trust Property Boundary (blue boundary line). Taken from Landranger 1:25000 Sheet No 137 (Grid lines are 1 km squares) © Crown copyright Ordnance Survey. All rights reserved.

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Figure 1.2.2. Diagrammatic cross section from Stiperstones to Church Stretton showing Long Mynd fold structure and associated faults. Thickness of beds not to scale (Toghill, 1990).

Toghill (1990, 2006) suggests that ground above 300 metres protruded above the level of the ice as nunataks which were subjected to frost action and which produced the head deposits, the 'thick mantle of angular stony debris' of Greig *et al.* (1968) which lies on the summit plateau, but is generally absent from the steep sides of the Long Mynd batches.

1.3 Drainage Patterns and Soils

The drainage pattern of the Long Mynd is relatively simple with the principal watershed situated near the western edge of the plateau. Streams flowing south-eastwards have deeply dissected the terrain producing the steep sided valleys or 'batches' such as Carding Mill Valley. The less dissected north and north-west flanks have an irregular stream pattern (Arnold and Macan, 1969). Figure 1.3.1 shows the principal drainage pattern of the area.

Streams from Carding Mill Valley, Batch and Gogbatch drain into the Cound Brook which runs NNE. Those emanating from the Townbrook Valley, Ashes Hollow, Callow Hollow and Minton Batch, turn south into the Quinney Brook. The principal watercourse of the northern western flank is Colliersford Gutter, where a stream drains from the

Wildmoor Pool which is fed by the Wildmoor catchment and progresses down the Gutter until joining the Darnford Brook at Lower Darnford.

Bilbatch Brook, the other major watercourse on the western flank, rises as a series of springs to the south of the Shooting Box and from the catchment on the north-western flanks of Pole Bank before flowing into the Darnford Brook south of Ratlinghope. Other minor streams e.g. Catbatch Brook and Burnhalls Brook rise low on the western flank and flow directly into the Darnford Brook.

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Figure 1.3.1. Map of the Long Mynd and its drainage pattern (Arnold and Macan, 1969) Dotted line represents land above 1000 feet (*circa* 305 metres) and shaded area that above 1400 feet (*circa* 426 metres) OD.

The plateau has a number of ponds, notably behind Pole Cottage, on Round Hill and on Wild Moor area. Many, if not all, were constructed by excavation or damming, to provide drinking places for livestock. In addition, springs arise on many of the hills and there are flushes and mires generally associated with the spring line or with streams.

Variations in topography and lithology have produced a lateral variation in soil parent material and subsequent soil development. Figure 1.3.2 shows the soils of the Long Mynd plateau and slopes. Observation suggests that the soil depth generally varies with the slope: the deeper organic soils tending to be on the flatter areas while the shallower mineral soils are usually associated with the steeper slopes. Figure 1.3.2 shows the co-incidence of the peaty gleyed podzols [Portway Complex] with the plateau areas.

Figure 1.3.2. Soils of the Long Mynd Plateau and Slopes. after Mackney and Burnham (1966).

1.4 The Developing Landscape

The Devensian glaciers retreated from their maxima some 18,000 years ago (Toghill, 1990) and deglaciation was complete in the UK by *c* 10,000 years BP. A general amelioration in climate followed, although there is a divergence of views over when the uplands were at their warmest. Ratcliffe and Thompson (1988) discount the widely held view that this was during the early Atlantic Period (7,800-5,700 BP) in favour of the view held by Birks (1988) that it was in the period 8,000-9,000 BP.

Birks (*ibid*), suggests that maximum woodland cover in the Uplands was around 8,000-7,000 BP, and while he acknowledges there were extensive areas above the tree line in North Wales, the Lake District and Scotland during this period, he points out that the Pennines, North York Moors and much of Dartmoor were forested. It is reasonable to assume that the Long Mynd, geographically between Wales and the Pennine and North York Moors and at a generally lower altitude, was similarly forested during this period.

There has been a long held view that from around 5000 BP woodland management often led to clearances. Mighall and Chambers (1995), for example, found that Neolithic and early Bronze age cultures at Bryn y Castell in Snowdonia were producing temporary clearings for arable and pastoral agriculture from this time. Birks (1988) considers the period of major deforestation (defined as when tree pollen values fall below 50% of their Holocene maxima) for all upland areas of Wales and England (except the Lake District) to be 2,100-2,600 BP.

There is other evidence of forest clearance during the Neolithic, [e.g. Atherden (1976), Simmons (1990) and Walker (1993)] and Fyfe *et al.* (2008) found Neolithic groups ‘implicated in the first establishment of heathland’ in their Dartmoor study area.

Whilst there were further clearances in some areas during the later Bronze Age and Iron age [e.g. Mighall and Chambers (1995)], in other areas there is evidence of a decline in use e.g. Dartmoor (Fyfe *et al.*, 2008), and a drift away from the uplands in Wales (Dark, 2006)

Evidence of Neolithic man's occupation of the Long Mynd is sparse and consists primarily of flint knives, axes and scrapers found at various locations: traces of Bronze Age occupation are more extensive and are generally still extant. Tumuli can be seen on many of the upper ridges or on the summit plateau, e.g. at Duckley Nap (SO 430965), at Pole Cottage (SO 411939), near Boiling Well (SO 421946) and near the car park at Shooting Box (SO 421954). Whilst providing evidence of a Bronze Age culture within the area, they do not necessarily indicate occupation of the Long Mynd plateau itself. Other structures, for example, the Devils Mouth Cross Dyke (SO 438943) have been dated to this period, *circa* 1300 BC (Dinn *et al.*, 2000) but their purpose is not known for certain although it has been suggested they may be land boundaries.

The principal evidence for the vegetation cover of the plateau at this period has emerged from analyses of soil samples taken from the original terrain surface below the Shooting Box Barrow (Dinn *et al.*, 2006). The assemblage of pollen and macrofossils found there suggests the Long Mynd was grassland at the time of the barrow construction, with bracken a minor constituent of the community. *Calluna* pollen was found in the top of the profile next to the barrow which Dinn *et al.* (2006) suggest points to the development of heather moorland at a later date though probably with a less extensive cover than that which exists now.

The charred fragments of *Rubus* sp. thorns and fragments of *Corylus avellana* nuts found beneath the barrow may indicate the use of burning to clear the site of scrub although, given the barrow is a burial site, they may represent fuel used in cremations (Dinn *et al. ibid*).

Traces of Iron Age occupation of the Long Mynd can be seen principally at the Bodbury Ring promontory fort and Black Knoll. Bodbury Ring (SO 406973) occupies an area of some 100 m by 95 m on the headland of Bodbury Hill (Eaton, 1997). This is the focus of an enclosed area of what have been considered contemporary riggs and lynchets and terraces which suggests that, despite its obvious defensive attributes, it could support some form of permanent occupation and was not merely a refuge.

The Black Knoll settlement, a nucleated settlement surrounded by its associated field systems and track ways, lies on the modern route, Jack Mytton's Way, on the western edge of the southern end of the ridge (SO389878). Whilst there is barrow evidence pointing to its Bronze Age occupation, Ainsworth and Donachie (1995) consider it to be Iron Age/Roman with subsequent Medieval and later use. However, there is a suggestion (Baugh, 1998) that some of these could be 7th or 8th century Mercian or even later medieval structures.

There is no evidence of the vegetation types extant on the plateau at the period; Barr (1997) notes that all large moors currently existing would have been created by the end of the Iron Age which suggests the plateau, at least, was probably deforested and holding the vegetation suggested by the Shooting Box barrow pollen analysis. However

Beales and Birks (1973), quoted by Sinker (1985), noted a ‘brief forest regeneration phase’ in Shropshire at the end of the middle Bronze Age with another occurring at the start of the Iron Age which may explain later references to woodlands on the Long Mynd.

There appears to be little evidence of Roman influence on the Long Mynd proper. However, given the presence of their major road in the Church Stretton valley and mines in the Shelve area, it is likely they crossed the hill although the routes used are still unknown (Thorne, 1994). Knowledge of the post-Roman/pre-Norman occupation is fragmentary, but there appears to be a change in settlement patterns with small nuclear hamlets replacing isolated settlements.

Apart from earthworks such as the nearby Offa’s Dyke and a few late Saxon Churches, evidence of the occupation of Shropshire in this period, other than place names, is rare. However the Saxon Land tenure system provided the framework of the landscape recorded in the Domesday Survey of 1086 (Rowley, 1972). Most of the land held by the manors of Stretton and Minton fell within the Long Mynd, itself part of the Long Forest (which included the woodlands of Ragleth Hill and Wenlock Edge) and also woods to the west of the Long Mynd proper.

Baugh (1998) notes that when the Long Forest was surveyed in 1235 the oak and underwood of the Long Mynd and Ragleth were well kept. This situation was not maintained and Baugh records that by 1309 Ragleth had no high timber and that parts of the Long Mynd were disafforested; the common pasture of the Stretton Hills extended *c*. 10 leagues[1] in circumference. Sheep were now becoming increasingly important to the local economy; Baugh (1998) records that a flock of 120 sheep belonging to Haughmond Abbey were driven to the Long Mynd in 1280-1 and that the right of the Lord of the Manor (recorded in 1596) to sell *agistments*[2] is taken to indicate ' the Long Mynd's plentiful summer grazing'.

Later, in the 1790s, Edward Harries[3] considered the Long Mynd as being ' so elevated and well calculated for sheep pastures that perhaps they cannot better be applied'. Whilst cattle may have been turned out on the common, as the name Bullocks Moor could indicate, traditionally sheep shared the Mynd with horses (Baugh, 1998).

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[1] The modern (19th century) league is 3 statute miles or approx 4.83 km.

[2] Opening a forest for a specified time for grazing.

Cultivation was then generally confined to the lower lands. However during the Napoleonic Wars wheat prices increased to such levels that planting was extended to part of the Long Mynd itself. Baugh (*ibid*) cites a suggestion that the ridge and furrow on the Church Stretton golf course (adjacent to Bodbury Ring) may originate from this period and de Rouffignac (1998) notes that field systems possibly dating from this period were found on the southern and northern end of the Long Mynd. Dinn *et al* (2006) also refer to an area of 'undated but probably post medieval' narrow ridge and furrow to the east of the High Park Cross Dyke [SO 444968]. Current surveys suggest the areas of ridge and furrow extant on the Long Mynd may be more extensive than previously thought (C. Uff, *pers.comm.*).

In the latter part of the 19th century the increase in the sheep population reliant on the common grazing continued, and in 1869 a committee was formed to supervise the agreement concluded between the Lord of the Manor and the Commoners Association. The influence of sheep and ponies on the vegetation of the common was maintained over the centuries, but became more and more intense with increasingly larger numbers of ponies turned out in the late 19th and early 20th centuries, paralleled by a steady increase in numbers[4] of sheep.

The Long Mynd Hill Pony Association, formed in 1890 to improve the breed, worked closely with the Long Mynd Hills Committee established in the aftermath of the 1908 Commons Act to improve the standards of both stallions and rams on the common. By the mid-1930s interest in ponies was declining, and after the Second World War the demand for pit-ponies ceased and the common became, in essence, a sheep common.

The common grazing practices of the late 19th early 20th centuries continued in the post war period under the added impetus of agricultural subsidy. Greenall (1975) noted that the Commons Registrations Act of 1965 saw claims from 106 commoners for rights to graze 24,299 sheep on the Long Mynd common but she also notes figures from ADAS which record there were only 25,000 breeding ewes in the whole county at that time. Four commoners claimed the right to graze a total of 148 cattle and 96 claims were submitted covering a total of 1,146 ponies. Other rights registered included; four rights to take fern [bracken], one to take gorse and two to take whinberries (Eaton, 1997).

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[3] Quoted by Baugh (1998).

[4] Baugh (1988) quotes 19C average of just under 7600 and gives figures for six relatively recent years 1938-9500, 1945-10,106, 1957-13,396 and 1965-16,410 with an estimate of *c.*18,000 for 1990.

The Long Mynd was classified as a 'Less Favoured Area', and since 1973 commoners have been eligible to receive a Hill Livestock Compensatory Allowance (HLCA) based on a *per capita* sum for livestock held.

The principal ecological disadvantage of such a *per capita* subsidy was to encourage overstocking and overgrazing, a situation exacerbated by a change from the traditional practice of reducing the numbers of sheep on the hill to its natural carrying capacity in winter, to one of leaving sheep on the hill all year with supplementary rations given in the winter months.

Fortunately the effects of the HLCA scheme in encouraging overgrazing and unsustainable production were recognised and there was a change to the Hill Farm Allowance Scheme [HFA] (M.A.F.F., 2001) where the emphasis changed from simple livestock numbers support to a strategy of ‘areal’ payments linked to the use of sustainable farming practices as part of a wider framework of rural developments.

Additional support for hill farmers on the Mynd was available under the 1994 Shropshire Hills Environmentally Sensitive Areas (ESA) scheme which aimed to protect and enhance the traditional and historic interest of the area by encouraging beneficial agriculture and land management practices. Graziers were invited to enter ten-year management agreements to manage their holdings in line with a set of management prescriptions; in return they were entitled to an annual payment and were also eligible to apply for a Conservation Plan which provided grant aid for capital works to protect or enhance environmental features (ADAS, 1998).

The 'specific objectives'[5] of the ESA applicable to the Long Mynd are to maintain and enhance the landscape quality and nature conservation interest of open moorland and permanent grassland, to enhance the nature conservation interest of heather moorland vegetation and to protect archaeological and historic features. A further degree of formal protection is provided to the Long Mynd through its status as a Site of Special Scientific Interest (SSSI) through its conservation interest and the importance of its ground nesting birds and its wetlands.

Notwithstanding the registered commoners’ rights, over which the National Trust has little control, its ownership of much of the Long Mynd has provided a high degree of

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[5] These will be considered in greater detail in Chapter 2.

protection since 1965. Visitor pressure, however, is increasingly becoming a problem both in terms of sheer weight of numbers -an estimated 450,000 visits[6] in 2006 (P. Carty *pers. comm*.) - and also in terms of some of the uses made of the landscape.

The Trust has various strategies in place to try to alleviate this pressure: using Carding Mill Valley as a ‘honey pot’ to cater for those visitors who merely want a ‘ride out and a picnic’ in attractive surroundings, while the Long Mynd shuttle bus picks up from the Church Stretton station and Carding Mill Valley car parks and circuits the Long Mynd and the Stiperstones area, allowing passengers to embark and disembark at various points on way-marked walks. The closure of many of the upland car parking areas, particularly those adjacent to features at risk from erosion etc, is also an important part of the strategy.

1.5 Heath and Moorland Communities; the International Context

The Western Atlantic heathland zone lies on the Atlantic seaboard and extends from Norway in the north to Portugal in the south and eastwards into Germany; Figure 1.5.1 shows Gimingham’s (1975) distribution.

Heathlands within this area have declined considerably over the past century or so, and Farrell (1989) highlighted the decline of European heaths reported by Noirfalsie and Vanesse (1976) who estimated the area remaining at around 280,000 ha, with an estimate for Britain [dated 1980] given as 60,000 ha. Webb (1998) gives an overall figure of about 350,000 ha. However, the variation in the two figures probably represents differences in estimation approaches rather than a ‘real’ difference in area.

Gimingham (1994) states that apart from direct habitat destruction, the widespread loss of heathland is largely due to the abandonment of traditional forms of management. Osterman (1998), refers to the ‘polarisation’ of agriculture where traditional low-intensity areas such as heathland are lost either through ‘intensification’ and high material inputs, or through the ‘abandonment via marginalisation’ of Baldock *et al.* (1996).

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[6] A visit is the presence of a single individual on a single occasion.

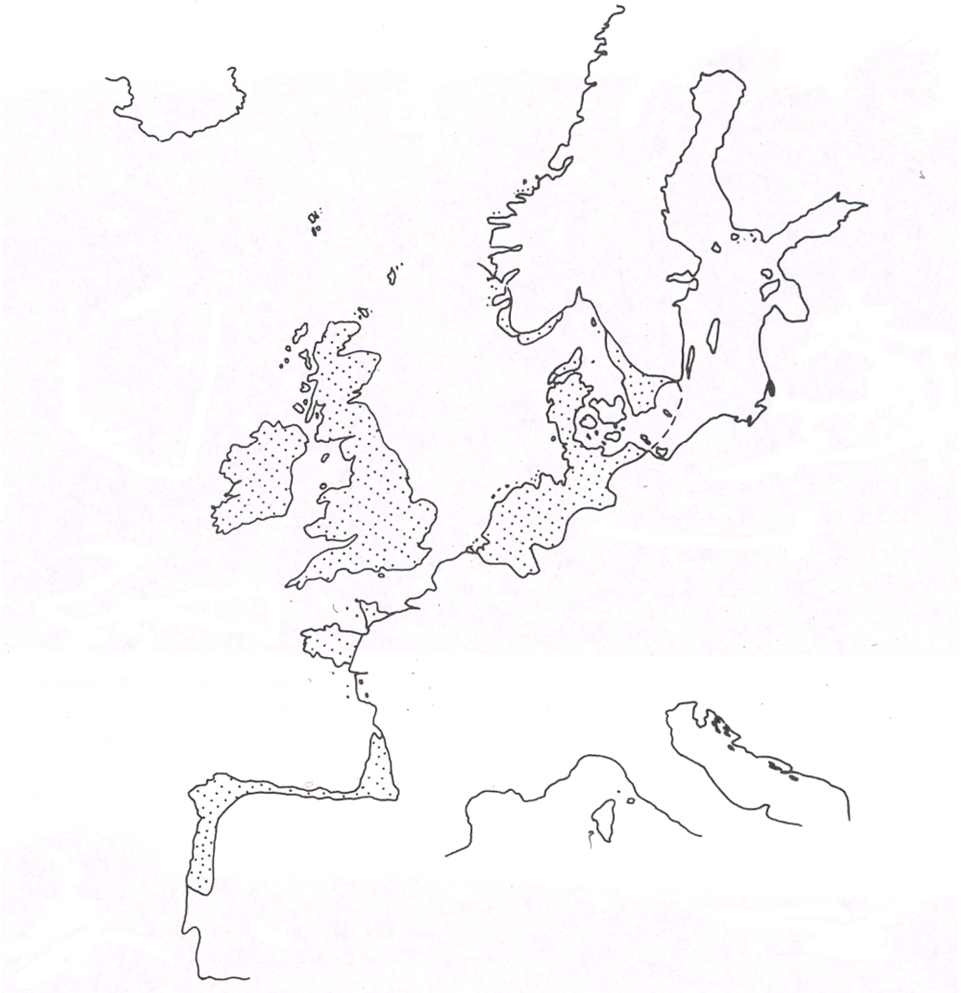

Figure 1.5.1. Western Atlantic lowland heath zone (Gimingham, 1975).

However, the increasing input of atmospheric nitrogen can also affect heathlands in a number of ways. Bobbink *et al.* (1998) suggest that apart from changes in competitive interactions, processes which open the canopy, such as heather beetle outbreaks or nitrogen-induced frost or drought damage, as well as increased rates of nitrogen accumulation in the soil, are probably important factors in changing lowland heaths. Moorlands also appear to be sensitive to low nitrogen loads (*ibid*), with bryophyte and lichens species particularly affected. Lageard *et al.* (2005) found that increased nitrogen inputs appeared to 'speed ageing *vis* the Calluna cycle.'

Within this Atlantic heathland zone, Britain has unique habitats of international conservation importance: these have been included in Annex 1 of the Habitats Directive 92/42/EEC as "a natural habitat type of community interest whose conservation requires the designation of special conservation areas". As Ratcliffe and Thompson (1988) point out " the hyper-oceanic climate… combined with historically widespread anthropogenic influences, has produced a distinctive landscape and ecosystems which are not duplicated anywhere in the World". Thompson *et al.* (1995) summarise the importance of heather and associated moorland communities and show [in Table 1.5.1] that **"**six of the heath and mire communities" [H4, H8, H21, M16, M17 and U6] "are virtually confined to the UK and that another seven" [H9, H10, H12, M15, M18, M19 and M20] " are better developed here [UK] than elsewhere**"**.

1.6 Heath and Moorland Communities; the National Context

Thompson *et al.* (1995) adopt Ratcliffe's (1977) and Thompson and Brown's (1992) view that the uplands in the UK fall within two zones: the montane zone, generally above 600-700 m (but lower towards the north and west) and the sub-montane zone below this, with its lower level defined by the limits of enclosed agricultural land around 300-400 m (although this can also be lower towards the north west).The latter holds virtually all the heather moorland in the UK with areas below this level with *Calluna* communities generally considered to be 'lowland heath'

The majority of these fall in two categories, H4010 and H4030, within the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/42/EEC).

H4010: Northern Atlantic wet heaths with *Erica tetralix,* corresponds to NVC types; H15 *Erica vagans-Schoenus nigricans* heath, M14 *Schoenus nigricans-Narthecium ossifragum* mire M15 *Scirpus cespitosus-Erica tetralix* wet heath and M16 *Erica tetralix-Sphagnum compactum* wet heath.

H4030: European dry heaths, has twelve NVC types within this definition although not all forms of these communities are within the 4030 group. H1 *Calluna vulgaris-Festuca ovina* heath, H2 *Calluna vulgaris-Ulex minor* heath, H3 *Ulex minor-Agrostis curtesii* heath, H4 *Ulex gallii-Agrostis curtesii* heath, H7 *Calluna vulgaris-Scilla verna heath,* H8 *Calluna vulgaris-Ulex gallii* heath, H9 *Calluna vulgaris-Deschampsia flexuosa* heath, H10 *Calluna vulgaris-Erica cinerea* heath, H12 *Calluna vulgaris-Vaccinium myrtillus* heath, H16 *Calluna vulgaris-Arctostaphylos uva-ursi* heath, H18 *Vaccinium myrtillus-Deschampsia flexuosa* heath and H21 *Calluna vulgaris-Vaccinium myrtillus-Sphagnum capillifolium* heath.

NVC[a]	Community name	International importance EC Habitats Directive[b]	Number of plant species			
			Rare	Mean	Range	Total
H12	*Calluna vulgaris - Vaccinium myrtillus*	I / EC	O	17	(4-42)	69
M19	*Calluna vulgaris - Eriophorum vaginatum* blanket mire	I / EC	4	19	(7-33)	84
H10	*Calluna vulgaris - Erica cinerea* heath	I / EC	1	20	(5-51)	70
H9	*Calluna vulgaris - Deschampsia flexuosa* heath	I / EC	0	8	(2-15)	41
H8	*Calluna vulgaris - Ulex gallii*	UK / EC	0	13	(4-32)	60
H4	*Ulex gallii- Agrostis curtisii*	UK / EC	1	11	(5-19)	64
H16	*Calluna vulgaris - Arctostaphylos uva-ursi* heath	- / EC	2	19	(8-31)	68
H21	*Calluna vulgaris – Vaccinium myrtillus – Sphagnum capillifolium* heath	UK / EC	9	29	(10-46)	83
M18	*Erica tetralix – Sphagnum papillosum* raised / blanket mire	I / EC	2	17	(8-30)	54
M17	*Scirpus cespitosus – Eriophorum vaginatum* blanket mire	UK / EC	5	20	(8-38)	79
M16	*Erica tetralix – Sphagnum compactum* wet heath	UK / EC	2	16	(8-28)	75
M15	*Scirpus cespitosus - E. tetralix* wet heath	I / EC	2	18	(6-57)	97
M20	*Eriophorum. vaginatum* blanket / raised mire	I / EC	0	11	(5-20)	44
U2	*Deschampsia flexuosa* grassland	- / -	0	9	(3-16)	42
U4	*Festuca ovina – Agrostis capillaris - Galium saxatile* grassland	- / -	0	22	(7-62)	83
U5	*Nardus stricta – Galium saxatile* grassland	- / -	0	21	(6-42)	79
U6	*Juncus squarrosus - Festuca ovina* grassland	UK / -	1	15	(7-36)	52

Table 1.6.1 Importance of UK Upland Communities. Adapted from Thompson *et al.* (1995).

[a] Plant Community Codes according to National Vegetation Classification (Rodwell, 1991; 1992).

[b] Three categories of community: **UK** ~no, or rare, close affinities outside the UK; **I** very localised globally, but especially well developed in UK; **EC** Listed under EC directive 92.43/EEC (species-rich communities U4 and U5 are listed under the Directive). Numbers of plant species taken from Rodwell (1991, 1992). Numbers are as counted in 2 or 4 m^2 quadrats. The rare species are those occurring in <100 10 km grid squares in GB.

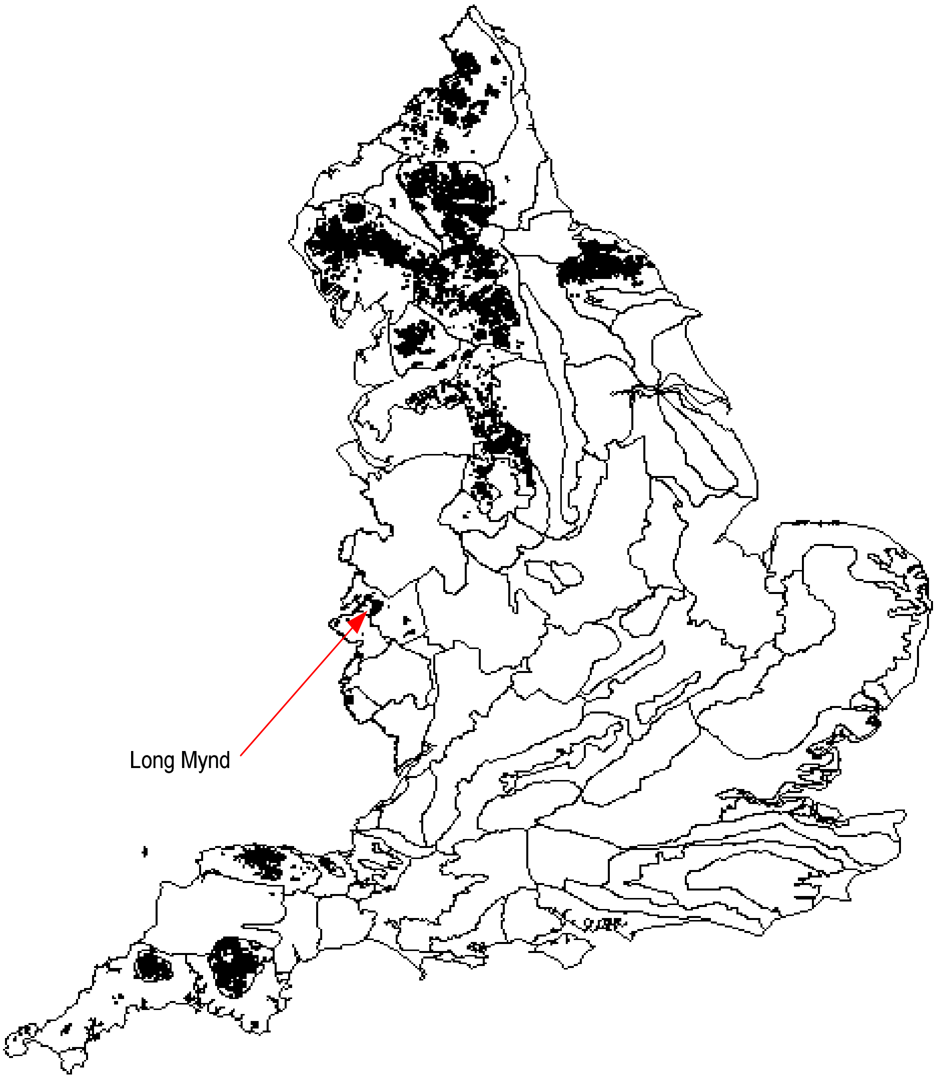

Figure 1.6.2. Location of upland heath [shaded black] sites in England shown within English Nature 'Natural Areas.' www.englishnature.org.uk/pubs/gis/gis_register.asp accessed 03-04-07.

The principal areas of upland heath in the Marches lie within the Shropshire Hills Natural Area, although small remnants also remain in the Clun and North-West Herefordshire Hills Natural Area (Johnson, 2002).

The Stiperstones and The Hollies SSSI [601 ha] together form one of the best heathland sites in the EU , one which has been designated a Special Area of Conservation [SAC] as a 4030 European dry heath site (JNCC, 2007). It contains features transitional between lowland heathland and upland heather moorland; the major vegetation type is H12 *Calluna vulgaris-Vaccininium myrtillus* heath, characteristic of the uplands whereas its south facing slopes hold stands of H8 *Calluna* *vulgaris-Ulex gallii* heath, a predominantly lowland community typical in south-west Britain (Natural England, 2008e).

The Long Mynd SSSI has some 43 ‘Dwarf shrub heath - upland’ sites totalling c. 2615 hectares and 10 ‘Acid grassland-upland’ sites covering c.174 ha (Natural England, 2008c). The Long Mynd also lies in this south-north transition zone and consequently includes a mix of both typically southern and northern species (Natural England, 2008a).

The neighbouring Welsh counties hold extensive areas of moorland communities with dry heath occurring across the steeper mountain and hill slopes in the West and on the isolated volcanic hills of the extreme east of the vice-county of Montgomeryshire (Mackintosh, 1995).

Cannock Chase, lying to the east, is the most extensive area of lowland heathland in the Midlands (Natural England, 2008d), with an area of some 1021 ha of ‘Dwarf shrub heath-lowland’ (Natural England, 2008b) although as elsewhere, there have been losses due to fragmentation and scrub and woodland encroachment as well as to forestry. Its vegetation is intermediate between that of the upland or northern heaths of England and Wales and those of the southern counties (*ibid*).

1.7 Plant Communities of the Shropshire upland heaths

Backshall *et al.* (2001) list five heath communities [H9, H10, H12, H18 and H21] as occurring in the Shropshire Hills Natural Area, together with associated acid grassland [U1, U4, U5, U6],fern [U20] and mire communities [M6, M10, M11, M19 and M20]. These communities are the base communities established by Rodwell (1991; 1992) and described in the National Vegetation Classification.

One of the most significant features of the Shropshire Hills is the presence of heaths transitional between lowland heath and upland heather moorland. These have species which would normally be considered typical of lowland, as well as others characteristic of upland (English Nature, ND). This feature is well represented on the Stiperstones NNR, which, in addition to its status as an SSSI and also as a Special Area of Conservation, is a participating site within the English Nature Validation Network Project (Bealey and Cox, 2004) and where its principal communities, H12 *Calluna* *vulgaris-Vaccinium myrtillus* dry heath and H8 *Calluna vulgaris-Ulex gallii* heath, are being monitored within the project.

The plateau area of the Long Mynd is, in the main, dominated by a community which is considered to be H12 *Calluna vulgaris-Vaccinium myrtillus* dry heath (Lockton and Whild, 1999). In some locations however, a transient community, H9 *Calluna vulgaris-Deschampsia flexuosa* heath*,* has developed, possibly as a result of overgrazing on areas recovering from management or vandalism burns. Trueman (2007), in contrast, refers to Rodwell's (1991) view that H9 is associated with atmospheric pollution and draws attention to the close proximity of Ironbridge and the Black Country with their industrial past.

Some species found on nearby heaths are not recorded on the Long Mynd, e.g. Trueman (2007) notes that *Vaccinium vitis-idaea,* is not present on the Mynd although it can be found on both the nearby Stiperstones and in the lower altitude heathlands of Cannock Chase. Similarly, *Erica cinerea,* is missing from the Long Mynd, or at best, infrequently recorded, but is present on both the Stiperstones and Cannock Chase. The lack of *Erica tetralix*, is perhaps less surprising, since it is a species usually associated with blanket bogs and wet heath which are themselves absent from the Long Mynd. *E. tetralix* is however, not uncommon at Chasewater in Staffordshire.

Whilst western gorse (*Ulex gallii*) is frequently seen on the Long Mynd, the *Calluna vulgaris–Ulex gallii* heath community was not found by Lockton and Whild (1999), although they suggest 'it may be present as the species poor H8a community which has yet to be located but is most likely to be present in Carding Mill Valley.'

Where heath has been overgrazed and/or burnt the U2b community *Deschampsia flexuosa* grassland - *Vaccinium myrtillus* sub community may develop (Lockton and Whild, 1999). If the *Vaccinium myrtillus* component is further reduced or lost (for example through further excessive grazing), the species poor U4 *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland may develop. Both the U2 and U4 communities are prone to invasion by bracken which, when established, can result in a U20 *Pteridium aquilinum* community.

Thorne (2002) reported surveys which showed patches of U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland occurring on the south facing slopes of many of the batches of the Long Mynd. A later paper (Thorne, 2007) notes that whilst their thin soils generally preclude invasion by *Pteridium,* shading from nearby bracken stands may become a problem for these U1 grasslands. A greater threat to U1 communities comes from the gorse; where patches are isolated by a perimeter of *U. galii* grazing by sheep is prevented, though that by rabbits continues. The ability of *U. galii* to enrich soil through nitrogen fixation does not appear to be a problem on the Long Mynd (Thorne, 2007).

The eastern slopes of the Long Mynd below the plateau are dissected by a series of steep sloping valleys, the batches, which carry a variety of mires and flushes with their diverse flora (Natural England, 2008a).

Lockton and Whild's (1999) review discounted some records but confirmed the presence of five 'wetland' communities. M10 *Carex dioica-Pinguicula vugaris* mire; M23 *Juncus effusus/acutiflorus-Galium palustre* rush-pasture and M35 *Ranunculus omiophyllus-Montia fontana* rill are present at the 10 ha level[7] with M29 *Hypericum elodes-Potomagetum poligonifolius* soakaway and S6 *Carex rostrata* swamp at the 1 ha level.

1.8 The species of the uplands

Upland and lowland heaths are, perhaps, the ultimate in plagioclimax communities being the culmination of generations (if not centuries) of management and exploitation, principally as a grazing resource for sheep although in the uplands their value was often as a sporting resource – 'grouse moor' or 'deer forest.'

The dominant species, *Calluna vulgaris,* has been subject to much investigation, ranging from Rayner's early work (Rayner and Jones, 1911; Rayner, 1913) through Beijerinck's (1940) monograph, to its place in Watts elucidation of '*Pattern and Process in the Plant Community*' (1947b) and, arguably, culminating in Gimingham's (1960) account in the Biological Flora Series.

A dwarf woody shrub, *Calluna* can exhibit many forms depending on its environment but also varying according to the age of the stand. Watt (1955) illustrated the four growth or structure phases in a *Callunetum*: pioneer, building, mature and degenerate.

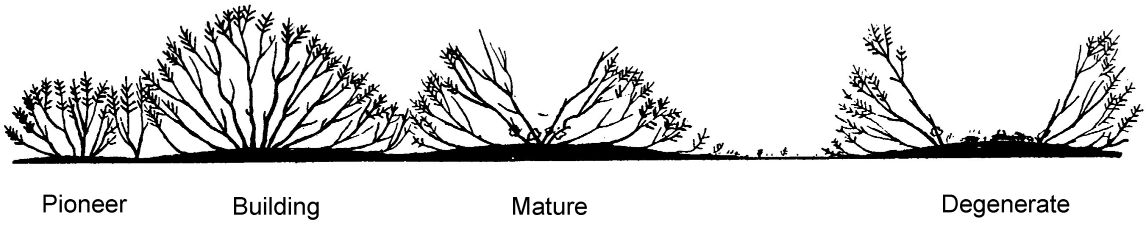

Figure 1.8.1. *Calluna* regeneration cycle. Modified from Watt (1955).

However, some subsequent work, e.g. Gimingham (1988) has cast doubts as to the validity of the Watt model in some large *Calluna* stands on upland moors. Marrs (1986) noted the effects of adverse weather and attacks of the heather beetle (*Lochmaea suturalis)* as a mechanism for producing either gaps or for killing contiguous areas of *Calluna*.

Whilst regeneration of *Calluna* across small gaps may be possible through layering (Macdonald *et al.*, 1995) in larger areas, there may be layers of pleurocarpous mosses which provide a poor seed-bed for seedling establishment and subsequent survival.

However initiated, it is the pioneer and building stages, with their abundance of young shoots, which are the forms desired by graziers and thus the focus of most management.

Vaccinium myrtillus is a common associate in upland Calluneta, occurring both as disparate areas within the mosaic and in the understorey below the *Calluna* canopy. Richie (1956) notes that it competes successfully with *Calluna* where either improved drainage 'or biotic factors' confer a competitive advantage. Moor burning is the principal biotic factor favouring *V. myrtillus* (Ritchie, *ibid*) where its ability to spread via rhizomes allows it to colonise newly burnt, open and unstable habitats.

Another constant, *Deschampsia flexuosa,* can also occur as disparate areas or 'lawns' in the mosaic as well as within the understorey. It will spread in response to preferential grazing of *Calluna* [and presumably *V. myrtillus*] by sheep. Scurfield (1954) considers it to have a preference for well drained, drier (steep and often exposed) sites of low base status.

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[7] These areas are effectively orders of magnitude as opposed to accurate estimations.

Formerly, *Pteridium aquilinum* was not generally considered a species of upland heaths although it had long been recognised as a component of lowland heaths (Watt, 1955). This situation has changed in recent decades and bracken is increasingly seen as an 'invader' of upland heaths, particularly where the *Calluna* is degraded e.g. where its re-colonisation following burning is inhibited by heavy grazing (Marrs and Watt, 2006).

1.9 Aims and Objectives

To:

- Describe the vegetation of the Long Mynd plateau at different scales.
- Investigate the relationship between the different vegetation types both in terms of environment and community development.
- To use the above to inform management on the Long Mynd in order to:
  a) Conserve the plateau heathland,
  b) Maintain and encourage biological diversity,
  c) Ameliorate the spread of bracken.

This will be achieved by:

1. Listing and evaluating previous vegetation and ecological surveys relevant to the Long Mynd plateau, paying particular attention to the areas covered by bracken, heather moorland and grassland.
2. Making detailed assessments of a representative number of stands of vegetation, each of which will be sub sampled by means of quadrats of standard size.
3. Subjecting records to various methods of computer analysis to demonstrate the role of environmental factors in influencing species distribution.

2 Management of Upland Heaths

2.1 European Practice in heathland management

As stated earlier most upland heath and moorland lies below the natural tree line and is the result of Neolithic or later clearances that were maintained by active management, principally burning and grazing, in subsequent centuries. Webb (1998) summarised national variations in heathland use and their traditional modes of management throughout Europe.

In western Norway sheep and horses were grazed outside all year but cattle were moved indoors in winter. Heather was cut on a 3-5 year cycle to provide winter fodder for the cattle, while other areas were burnt from time to time to enable regeneration of the vegetation.

In the lowlands of north-western Europe [Flanders, Netherlands and North Germany] a similar system prevailed: sheep were grazed on the heath during the day then moved to barns overnight; cattle were kept in barns all year round. Turves were cut from the heath and laid in the barns to provide fodder and as ‘bedding;’ this removal of the turves depleted nutrients in the heathland soils and also arrested succession to scrub.

In Jutland (Denmark) an analogous approach was taken with sheep grazed outdoors all year around while cattle were grazed tethered and returned overnight to the barns. Winter fodder was provided through cutting young heather shoots which were mixed with lichen and hay. Permanent arable plots were supplemented by burning and ploughing areas of heathland for short term cultivation, these generally returned to heathland when they were subsequently abandoned.

The heathlands of Brittany, Spain and Portugal were subject to what might be considered a more intense management regime; areas were sown with gorse (*Ulex* sp.) which was allowed to grow for 10-12 years before being cut for use as fodder or as fuel. The remaining vegetation was burnt so the ash could serve as fertiliser when the area was subsequently ploughed and used for cereal production for a year or two. Following this cereal interlude *Ulex* was re-sown and the cycle repeated.

Webb (1986) noted that whilst British lowland heaths were grazed and peat, turf and the vegetation cut for fodder and fuel, there was little evidence of burning being part of traditional management of lowland heaths and that it was possible that regular burning was introduced as late as the 19th century following the example set in the uplands.

Yallop *et al.* (2005) note that burning for management on the uplands can be traced back for many centuries, at first in areas such as Dartmoor, with parts of Scotland coming under regular management much later with the rise of large scale sheep farming in the eighteenth century. Nineteenth century increases in sheep grazing and grouse shooting led to ‘an intensification of moorland management by fire’ but as grouse shooting declined in the twentieth century so did burning.

Burning, *swaling* on Dartmoor and *muirburn* in Scotland, is still the principal tool for managing upland heath and moorland but is subject to statutory controls[8] and licensing. Burning can only be undertaken in the uplands during the period 1st October to 15th April, although licences may be obtained to burn outside this period in exceptional circumstances.

Burning is undertaken for two principal ends. In areas of *Calluna* in its earlier stages, up to about 15 years, the pioneer and building phases of Watt (1947b), it promotes regeneration of young shoots vegetatively from the underground stem bases. In the later mature and degenerate growth phases [*sensu* Watt (1947b)], it removes the older, woody growth allowing regeneration via the seed bank. These new shoots or the emerging seedlings provide food for grouse as well as livestock.

However, work by Macdonald *et al.* (1995) suggests that the importance of ‘layering’, the production of adventitious roots and ramets from prostrate stems as a regeneration mechanism, has been underestimated and that regular burning may not be necessary for the maintenance of *Calluna* cover, particularly in the cold moist uplands of northern Britain.

In areas of grassland its purpose is to remove litter and promote fresh growth for livestock forage. The effects of burning are linked to those of grazing; any variations in the intensity of grazing and the frequency of burning can drive or allow change (Miles, 1988). Burning favours young growth for grazing but when grazing is excessive it can prevent regeneration.

The effects of heather burning are well known. However Allen (1964) established that the layer of raw humus which accumulates beneath *Calluna* had the ability to retain nutrients which would otherwise be lost after burning.

Mallick *et al.* (1984) found that infiltration of the soil was decreased on burned plots and water retention in the top soil of burned plots was increased considerably. This increased water retention could serve to reduce leaching. However, if the protective layer of raw humus was lost through severe burning, increased losses through leaching would ensue; in addition, Imeson's (1971) work showed erosion and gulleying were a result of water seepage in the wetter soil conditions attendant on moor burning.

In contrast to the above, the accumulation of nutrients under communities which have developed on nutrient-poor substrates is becoming a particular problem given the increasing eutrophication of natural communities through air-borne nitrogen pollutants. Bobbink *et al.* (1998) refer to the effects of nitrogen deposition in enhancing the availability of nitrate or ammonium, in the acidification of soils and in its ability to increase susceptibility to secondary stress factors – drought, frost or pathogens.

Power *et al.* (1998a) found that the growth rates, survival rates and fecundity of heather beetle (*Lochmaea suturalis* L. Thompson) increased when the larvae were feeding on nitrogen rich shoots. Increased survival and fecundity can increase the incidence of heather beetle attacks and the 'catastrophic death' of *Calluna* (Marrs, 1986).

Kristensen and McCarty (1999) suggest that the loss of cover attendant on heather beetle attacks so changed the balance of N cycling that it increased the ability of grasses to gain dominance in heathland. Hester *et al.* (1991) found that *Deschampsia flexuosa* and *Agrostis capillaris* showed positive growth responses to increased nutrients [fertiliser].

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[8] Heather and Grass etc. (Burning) Regulations 1986 (SI 1986 N0 428) as amended by the Heather and Grass etc.(Burning) (Amendment) Regulations 1987 (SI 1987 No 1208) in England and Wales with equivalent Regulations in Scotland.

Davis *et al.* (2000) noted any increase in macro-nutrients can have an impact on the species composition of semi-natural habitats, where specialist species may be replaced by others better equipped to capitalise on the increased nutrient levels, while Smart *et al. (2003)* established that increases in mean Ellenberg fertility values were occurring in infertile grasslands, moorlands, upland woodlands and heath and bog.

In recent years various investigations have been undertaken to determine ways of managing heathlands to minimise the effects of nutrient accumulation; all approaches should be presaged by the need to export a significant proportion of the organic nitrogen store (Barker *et al.*, 2004).

Work by Neimeyer *et al.* (2005) showed that the loss of N from 10-15 year old stands on German heath when burning was carried out was only equivalent to *ca.* five years of atmospheric input. Thus burning on a 10 year cycle would not prevent N accumulation in the long term.

Hardtle *et al.* (2006) compared mowing [cutting], prescribed burning and sod cutting as measures to reduce nutrient loads. Their work supported the findings of Neimeyer *et al.* (2005) and showed that both mowing and burning only removed the equivalent of 5 years of atmospheric input. The most effective method was the ‘high intensity’ sod cutting which removed the equivalent of 89 years atmospheric N input. Later work by Hardtle *et al.* (2007) showed that wetland heaths managed only by prescribed burning would also accumulate nutrients in the long term.

Neimeyer *et al*. (2005), Hardtle *et al.* (2006) and Hardtle *et al.* (2007) advocate the combination of low intensity methods – prescribed burning or cutting – with high intensity measures such as sod cutting or repeated mowing.

Grazing can be used to augment these practices. Fottner *et al.* (2007) note that as sheep generally feed on the current season’s shoots which have high-nitrogen tissue, a greater amount of N is removed per unit biomass than by cutting which also removes low N woody stems. However, they point out sheep will preferentially graze on grasses which have high nutrient stores in the above ground biomass so this may contribute to the nutrient output; nutrient output rates may increase with greater proportions of grasses in the vegetation.

The effect of sheep faeces on the heathland nutrient pool will vary according to the shepherding practices of the area. Defecation rates in sheep are highest during the night so where the flock is taken off the heath overnight, the majority of the daily output of faeces [some 70%] will be produced in the fold area. Where the flock stays on the heath overnight this output will tend to concentrate in the favoured, probably more sheltered 'lawn' areas. Work carried out by Shand and Coutts (2006) suggests sheep faeces enhance fertility by increasing the concentrations of phosphorus, nitrogen, dissolved organic carbon (DOC), calcium, magnesium and potassium in the soil solution. Rooney *et al.* (2006) suggested that high levels of sheep urine and an associated increase in soil pH may place *Agrostis capillaris,* a species of nutrient poor acidic soils, at a competitive disadvantage compared to mesotrophic species such as *Lolium perrene,* and may contribute to changes in the community.

Although bracken has been gathered in many areas for various purposes: for example, the *vern* or cutting as bedding for stock carried out on Dartmoor, its use as a source of potash for the medieval glass industry (Smedley and Jackson, 2006), burning to provide a potash rich ash for use as fertiliser or in soap manufacture (Rymer, 1976), many of these traditional uses have ceased and bracken is increasingly seen as a weed species causing problems for a wide range of land management options (Marrs *et al.*, 2000). Its expansion into heathland or moorland causes competition with heathland and grassland species resulting in a reduction in species diversity (Pakeman and Marrs, 1992).

There seems to be confusion over the abundance of *Pteridium* in the latter years of the last century. Lawton (1988) notes that Taylor's (1986) estimate of 6720 km^2 as the area covered, is at variance with other estimates citing Lawson *et al.* (1986) at about half this. In any event, Pakeman *et al.* (2000) suggest that the current abundance of *Pteridium* is 'less than or at worst equivalent to maximum historical records.'

Pakeman *et al.* (2000) refer to the results reported by Barr *et al.* (1993) which showed bracken-dominated communities tended to be concentrated in the west of Britain particularly in areas of extensive grazing at altitudes between 200 and 400 m. Of a total area reported of some 3700 km^2, around 1600 km^2 lay on marginal upland agricultural areas with a further 1200 km^2 on upland areas.

The principal factor driving this distribution is agricultural practice; in the hills and uplands bracken tends to be found on sloping ground on land of low farming potential which is either impossible or uneconomic to plough or to create improved or more intensive grazing. Miles (1988) found that bracken expanded in areas with low grazing pressure although it could also expand into poorly managed heather or even where other vegetation was subject to higher grazing pressure and was consequently less competitive than *Pteridium.*

Bracken is sensitive to trampling, which can lead to destruction of the emerging crosiers and crushing and fragmentation of the rhizomes (Lawton, 1988); the reduction, and in some areas, removal of cattle and their replacement by sheep has tended to favour bracken, as the smaller hooves and lighter weight of sheep do less damage.

Bracken control is often undertaken as a component of habitat restoration programmes to meet agricultural or conservation objectives. There are two general types of control in use, mechanical damage or using herbicides, the method adopted is generally controlled by the topography of the target areas. On smaller or more accessible sites mechanical methods, typically cutting but some times rolling, can be used, whereas on more extensive and topographically diverse upland areas aerial spraying with herbicide is often the method of choice.

Timing of the cutting is important; the fronds are cut during early summer, before or up to the period of maximum frond expansion (Lowday and Marrs, 1992a). The aim is to cut following the period of maximum withdrawal of carbohydrates and nutrients from the rhizomes but before new assimilates are translocated from the fronds to the rhizomes. To this end some authorities, e.g. Le Duc *et al.* (2000) favour two cuts; one in June and the second in August. Cutting in June also ensures that the above ground biomass is at its peak which is an advantage if the cut bracken is to be collected and further processed for mulch or compost as is undertaken on the Long Mynd.

On suitable sites cutting is an effective control technique. Lowday and Marrs (1992a) reported that yearly cutting reduced bracken fronds by 70% and twice yearly cutting by >90%. However, continuity is important; when cutting ceases the bracken will recover rapidly on single cut sites albeit more slowly on twice yearly cut sites (Lowday and Marrs, 1992a).

The other principal method of control is the application of the systemic herbicide Asulam (methyl [4-aminophenyl sulfonyl] carbamate). It is generally applied as the water-soluble sodium salt Asulox using helicopters, ground based vehicles or hand operated ‘knap-sack’ sprayers.

Asluman is marketed specifically for the control of docks (*Rumex* species) and bracken although other pteridophytes may be affected (Keary *et al.*, 2000), and there is some evidence that bryophytes are effected (Rowntree *et al.*, 2003). It is general practice to use ‘buffer zones’ to prevent spray drift into sensitive areas and into watercourses, Marrs *et al.* (1992a) recommend minimum buffer zones of >160 m for aerial application although subsequent work by Robinson *et al.* (2000) led to Environment Agency approval of 50 m buffer zones when ‘Delavan RD Raindrop’ spray nozzles are used.

There is some evidence that other vascular species are sensitive to Asulam, Måren *et al.* (2008) found *Agrostis capillaris, Anthoxanthum odoratum, Holcus lanatus, Juncus squarrosus, Veronica officinalis, Galium saxatile, Lotus corniculatus and Potentilla erecta* were ‘negatively affected’. Their suggestion that *Vaccinium myrtillus* and *Calluna vulgaris* may be sensitive to Asulam could have important implications for its continued use to control bracken incursions particularly for those, for example, H12 *Calluna vulgaris*-*Vaccinium myrtillus* heath, H18 *Vaccinium myrtillus-Deschampsia flexuosa* heath and H21 C*alluna vulgaris*-*Vaccinium myrtillus-Sphagnum capillifolium* heath, where they are major components (Rodwell, 1991).

Asulam is a systemic herbicide which acts by entering the rhizome, subsequently accumulating in both active and dormant buds causing death [Måren *et al.* (2008) citing Veerasekaran *et al.* (1976)]. Frond biomass declines sharply during the two years following treatment but without further management some of the dormant buds and parts of the rhizome may survive and expand again.

Bracken adds to its litter layer through the annual fall of dead fronds and stems (Watt, 1947a) as will cutting or spraying unless appropriate litter management systems, e.g. burning or litter collection, are also used. This litter layer can have two important influences on other plant species: the layer of ‘thatch’ is thought to inhibit colonisation (Lowday and Marrs, 1992b) and even if the litter is removed the fertility which may have built up in the soil can favour species such as *Deschampsia flexuosa* (Marrs and Lowday, 1992) or other ‘weedy species’ (Pakeman and Marrs, 1992).

Consequently, bracken control measures implemented as part of heathland restoration may need to incorporate some method impoverishing the soil formerly under *Pteridium* (Marrs *et al.*, 1992b). Recent work by Smart *et al.* (2007) which found bracken had an influence on leaching organic nitrogen as well as influencing pH and base saturation, suggest this is a more complex problem than previously thought.

The disparate approaches to bracken control, cutting, spraying or, in some cases combinations of the two, adopted at various sites, and the variability of their success has been highlighted as a major issue in the UK. Marrs *et al.* (1998) showed that vegetation development during bracken control was unpredictable, especially in upland areas and Le Duc *et al.* (2000) noted that the results of control attempts were highly variable and gave conflicting results.

Cox *et al.* (2008) updated the series of experiments started in 1993 and 1994 at four different sites [reported in Le Duc *et al.(2000)*] which had been designed to test the efficacy of five treatments in controlling *Pteridium* relative to untreated comparisons in a range of ecological situations. These treatments were combined with site specific treatments designed to restore local heathland or grassland vegetation. Their major conclusion was that the isolated control treatments had relatively little influence on the subsequent long-term development of target vegetation, with a few already abundant species increasing their cover.

Stewart *et al.* (2008) used meta-analysis techniques to further explore the data from these experiments. The principal findings suggested the judgement as to the effectiveness of treatments between sites was dependent on the measure used to assess bracken performance. In general cutting twice per year was the most successful treatment although on some sites other less expensive methods were as effective, and that effective treatment was also associated with high species richness.

Notwithstanding the lack of any realistic prospect of totally clearing *Pteridium* from many areas, careful consideration should be given to the need to retain some bracken since it has its own conservation value, generally as habitat for other plant and animal species.

Allen (1995) drew attention to the importance of bracken to the whinchat (*Saxicola rubetra*) and Gribble (1983) found that bracken stands were important habitat for the nightjar (*Caprimlgus europaeus*). Fuller *et al.* (2006) found bracken dominated habitats were used by a wide range of bird species. However, as with whinchat and nightjar, the nature and structure of the mosaic was an important feature which required further investigation.

Bracken also has importance for invertebrates; Lawton (1976) refers to some 40 or so species of arthropods, principally in the Diptera, Hymenoptera and Lepidoptera, which are associated with bracken.

2.2 Management of the Long Mynd Heaths

2.2.1 Strategies

Coleshaw (1989) notes that the Long Mynd Common was managed as grouse moor for at least 150 years and as a grazing resource for considerably longer. In 1965 the National Trust acquired the lordship of the manor of Stretton-en-le-Dale and the common of the Long Mynd; subsequent acquisitions increased the area under its control, both of common and 'in hand[9]' land. Coleshaw (1989) noted that evidence from aerial photography suggested that the Plateau was burned on a rotational basis prior to its acquisition by the Trust.

After 1965 less burning was carried out, the management treatment being changed to cutting with a tractor-mounted 'swipe'. In the late 1960s and early 1970s the 'swiped' plots were in the form of large rectangular panels, *circa* 0.6 ha but later practice reduced the size of the plots, sometimes to less than 0.1 ha.

Coleshaw (1989) stated the 'ideal' management objectives for the heath were:
a) To retain, and where necessary improve, the vigour of the existing heather by managing approximately 60% of the *Calluna* heath on a 16-20 year cycle to create a series of even aged stands with a good range of age classes.

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[9] Land, frequently enclosed, and not subject to Commoners Rights.

b) To identify areas totalling 40% of the *Calluna* heath where no management would take place to encourage both the development of uneven-aged stands and the incursion of other heathland flowering plants, bryophytes and lichens.
c) To restore heather in areas where cover and vigour has decreased over the last 10-20 years.
d) To gradually eliminate bracken from the plateau, but allow scattered bracken patches to remain on the valley slopes in equilibrium with shrubby and herbaceous species.

Coleshaw added an important caveat to these objectives: “high grazing levels on the Long Mynd are severely restricting rates of heather regeneration. Until such time as grazing levels can be reduced, management should proceed with caution and results carefully monitored.”

Sheep stocking levels increased steadily from the 1970s, peaking in the 1980s when it was thought the stocking rate was in excess of 8.1 ewes/ha (Jenkins and Anderson, 2000). Subsequently voluntary reductions were made by the graziers to levels of 5.5 ewes/ha in summer and 4.24 ewes/ha in winter until 1995. Surveys by the FRCA [Farming and Rural Conservation Agency] (1994, 1995a) showed the hill was still overgrazed and more reductions were made to achieve levels of 3.5 ewes/ha in summer and 2.5 ewes/ha in winter. Subsequent FRCA Surveys (1996, 1997) showed the hill was still overgrazed and MAFF obtained agreement[10] with the graziers for further reductions to 2.5 ewes/ha in summer and 2 ewes/ha in winter.

In 1996 the Sustainable Moorland Management Project (Jenkins, 1997) was instituted. One of its principal aims was to determine the then current moorland management and sheep husbandry practices on the Long Mynd, and to assess the impact of these practices on the condition of moorland vegetation. The subsequent report (Jenkins, 1998) noted that past burns were being targeted by sheep in the area behind Pole Cottage (SO 411939): the surrounding heather was too thick for the sheep to penetrate so they concentrated on grazing the ‘burns’ which produced short, sparse and deformed heather. The Heather Consumption Survey showed that certain areas, Wildmoor, Duckley Nap and opposite Pole Bank, had places where consumption was low as a consequence of low grazing levels. These areas were almost completely surrounded by stands of tall dense heather which provided a potential barrier to sheep

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[10] Under the Hill Livestock (Compensatory Allowances) Regulations, 1994.

incursions. Areas of high consumption tended to focus on sites which were, or had in the past, been winter feed sites.

The next report (Jenkins and Anderson, 1999) noted that overall heather consumption levels had not been reduced between 1996/7 and 1997/8. Differences in consumption across the Long Mynd were, not surprisingly, related to shepherding practice on the different hefts[11] and the consequent sheep densities. Current feeding sites, and also those which had not been used for some years, continued to attract sheep to the concentration of grass species there.

In a plan commissioned by the National Trust, Penny Anderson Associates (1999) pointed out that whilst grazing levels had been reduced, the decline in heather condition had not stopped, though the rate of deterioration had declined. They envisaged grazing levels being changed to those suggested by Backshall *et al.* (2001) for 'restoration management'[12] which would become the first stage in allowing the heathland vegetation of the Long Mynd to recover from a long period of suppression. Higher grazing levels would eventually be supportable on recovered areas. Other aspects of the plan included removing stock from the moor in winter, restoration to dwarf heath of the grassy and bare areas surrounding former feed sites, and the continued control of bracken by spraying and cutting.

Jenkins and Anderson's (2000) report showed that despite the reduction in stocking levels the moor was still being grazed at unsustainable levels. Commoners were encouraged to join the ESA (Environmentally Sensitive Area) Scheme; under this scheme farmers had the option to join one of two support levels, Tier 1d and Tier 2, whereby they are paid on an areal basis for reducing sheep numbers[13] on heather moorland.

The current plan, *The National Trust Shropshire Hills ESA Long Mynd Conservation Plan 2000–2009* (Carty and Jenkins, 2000)[14] encapsulates the direction of the management strategies in the vision statement: "In the year 2020 we aim to see the

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[11] The home ranges, or grazing areas of individual flocks of sheep.

[12] Dry heath and dwarf shrub 0.5 ewes/ha, acid grassland and bracken over acid grassland 1.5/2.5 ewes/ha modified to take account of age of heather on the Long Mynd and the contiguous [unfenced] nature of the hefts.

[13] Tier 1d with additional 50% off wintering; i.e. summer level 1.5 ewes/ha with 0.75 ewes/ha in winter. Natural England paid a supplement to extend 'winter' period up to the end of April.
Tier 2: max summer level 0.66 ewes/ha and total removal of stock in winter.

Long Mynd restored to a favourable condition for native wildlife similar to that present about 1950 when it was managed as a grouse moor as well as a grazing common. We envisage a hill rich in wildlife enjoyed and understood by its neighbours and visitors and grazed sustainably as a common."

The specific objectives are:

a) To increase the area of heather at the expense of improved grassland, old car parks, bracken and valley bottoms, and to improve the condition of the heather from approximately 50% overgrazed to less than 10%, through a reduction in grazing pressure and by carrying out controlled burning.

b) Decrease bracken to zero within the heath area of the plateau and to create a more open structure on selected slopes and on High Park in order to increase butterfly and botanical interest and to provide extra grazing in the dry summer months.

c) Increase the grouse population from 25 breeding pairs to over 50 pairs through a return to traditional patchwork burning of the heather.

d) Improve the condition of native upland grassland by reducing grazing pressure to allow an increase in grasses and other plants and to permit some tussocks to develop to provide nesting sites for birds such as skylark and meadow pipit.

The reduction in grazing attendant on the Foot and Mouth Disease [FMD] cull of sheep on the northern part of the Long Mynd and the associated fencing and restriction in stock movements, resulted in increases both in growth of grasses and in tussocking which appeared to be supporting the expansion of the grayling butterfly (*Hipparchia semele*) (Uff, 2005).

One lasting effect of FMD is the element of 'noise' which removal of sheep introduced into the effects of the ESA Scheme grazing restrictions; it may take some years to establish whether vegetation and habitat changes truly reflect the new ESA stocking levels or can be related to the FMD restrictions (Uff, 2002).

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[14] Published as Chapter 10 in Jenkins and Anderson (2000)..

2.2.2 Heathland Conservation; grazing, burning, cutting and herbicides

Leach (1931) provides a convenient starting point from which to review management practices. He described *Pteridium* as the usual dominant, particularly on the western slopes, above 270 m (900 ft) and below 375 m (1250 ft), and considered that below 270 m its spread was checked by farming operations, whilst above 375m it suffered from its competition with *Calluna*. He commented that the western slopes were heavily grazed by sheep and that rabbits were also numerous. This grazing tended to produce a ‘transition’ zone where *Calluna* was suppressed and was admixed with, or replaced by, *Agrostis-Festuca* turf at the lower levels (Leach, 1931) grading to a sward dominated by close cropped *Vaccinium myrtillus* at higher levels. The summit plateau was “a rather monotonous rolling landscape over which *Calluna* is the chief dominant although repeated firing by gamekeepers causes the vegetation to have a patchwork appearance.”

The two principal strands of management on the Long Mynd since Coleshaw (1989) have been aimed at restoring and regenerating the Callunetum and controlling the current spread of *Pteridium* and ultimately reducing the area of established Pteridietum.

Heather management is of necessity cyclic; the lengths of time between control measures vary in response to local management practice. Watt (1955) reported that well managed lowland moors, i.e. below *c.*610 metres (2000 ft) were burned on a fifteen years rotation. The current practice on the Long Mynd assumes a cycle of around eighteen years (Peter Carty, *pers. comm.*) This is based on the recovery rates of a small number of fixed plots reported by Uff (2006b) which indicated it took at least 15 years for the height of the heather to reach 15 cm and that the 15-30 cm height range, the preferred burning height, was not generally found until the burns were some 15-20 years old.

Figure 2.2.1 shows the areas managed by burning during the period 1994-2006. While the timing of burning was generally within this 18 years plan, it is not impossible that areas adjacent to, or within earlier burns, may be ‘reburned’ through accidental or other fires at intervals which are less than the normal practice. Figure 2.2.2 shows the areas managed by cutting. Figure 2.2.3, an amalgamation of these two figures, shows that some areas burned during the period 1994-98 were subsequently cut during 2003, 2004 and 2005.

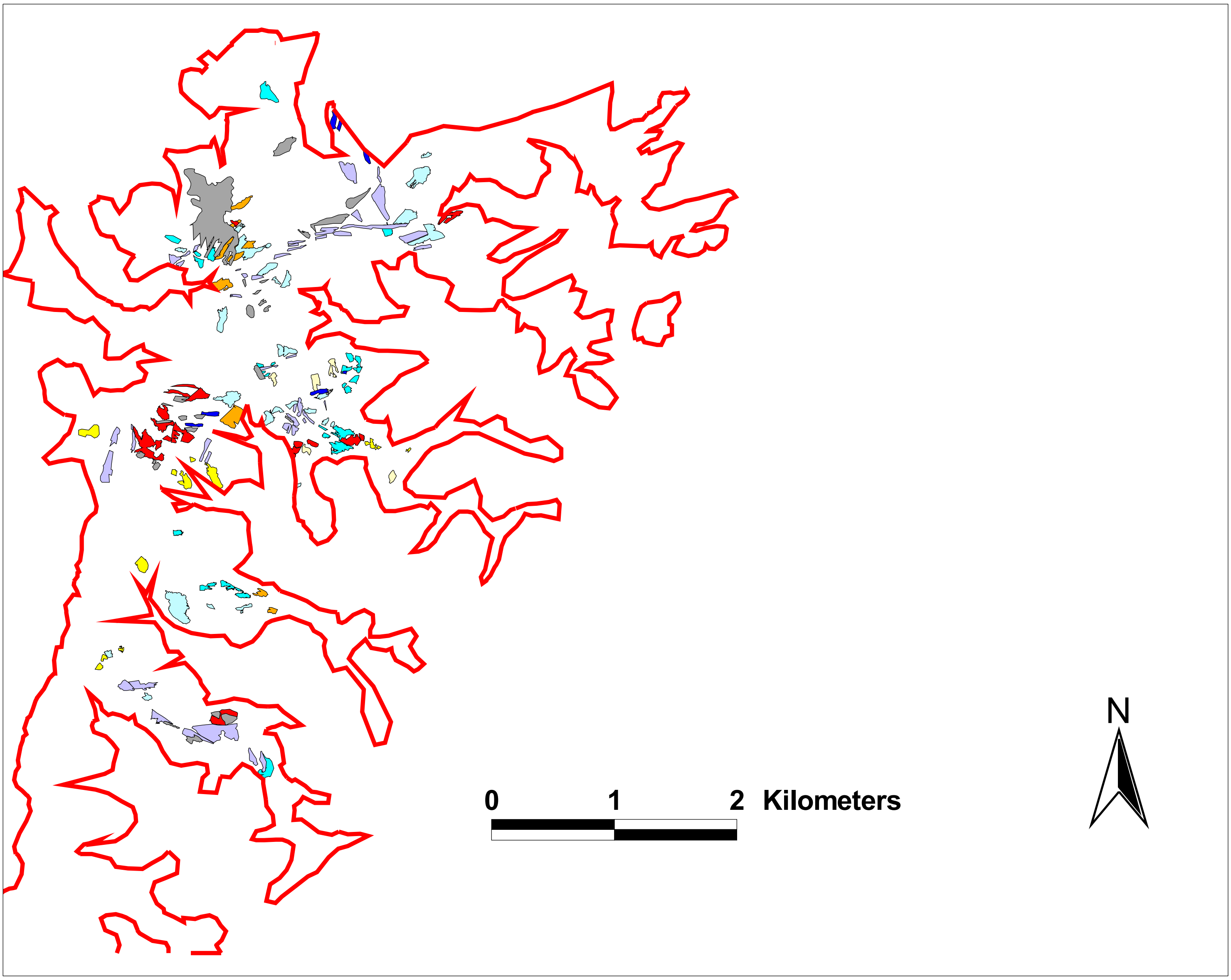

Figure 2.2.1. Areas of heather managed by burning or subjected to unofficial burns in the period 1994-2006. Data from Dr Caroline Uff and The National Trust.

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╱╲╱ Plateau boundary
■ 1994-98
■ 1999
■ 2000
■ 2001
■ 2002
■ 2003
■ 2004
■ 2005
■ 2006

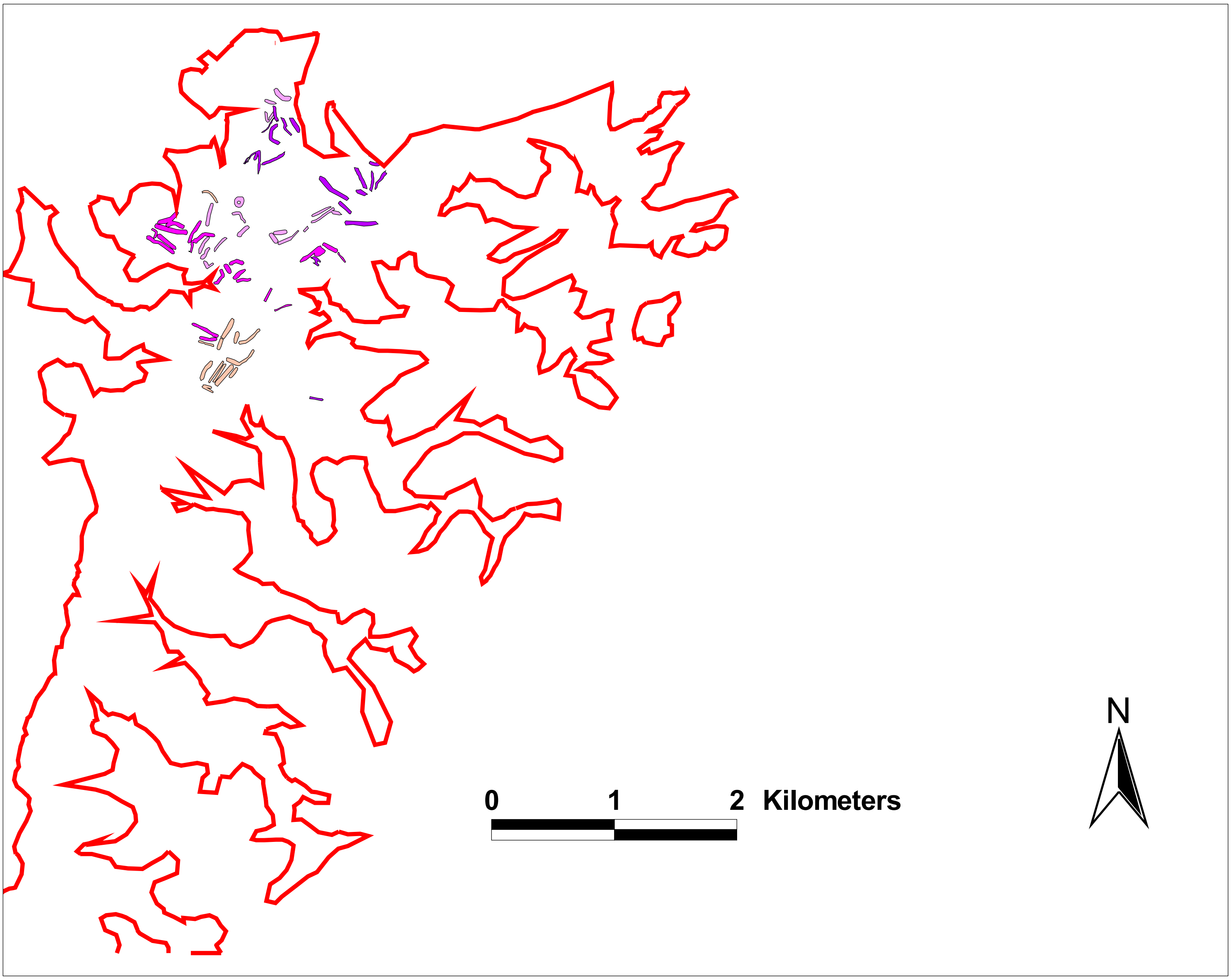

Figure 2.2.2. Areas of heather managed by cutting period 2002-2005. Data from Dr Caroline Uff and The National Trust.

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∧ Plateau boundary

■ 2002

■ 2003

■ 2004

■ 2005

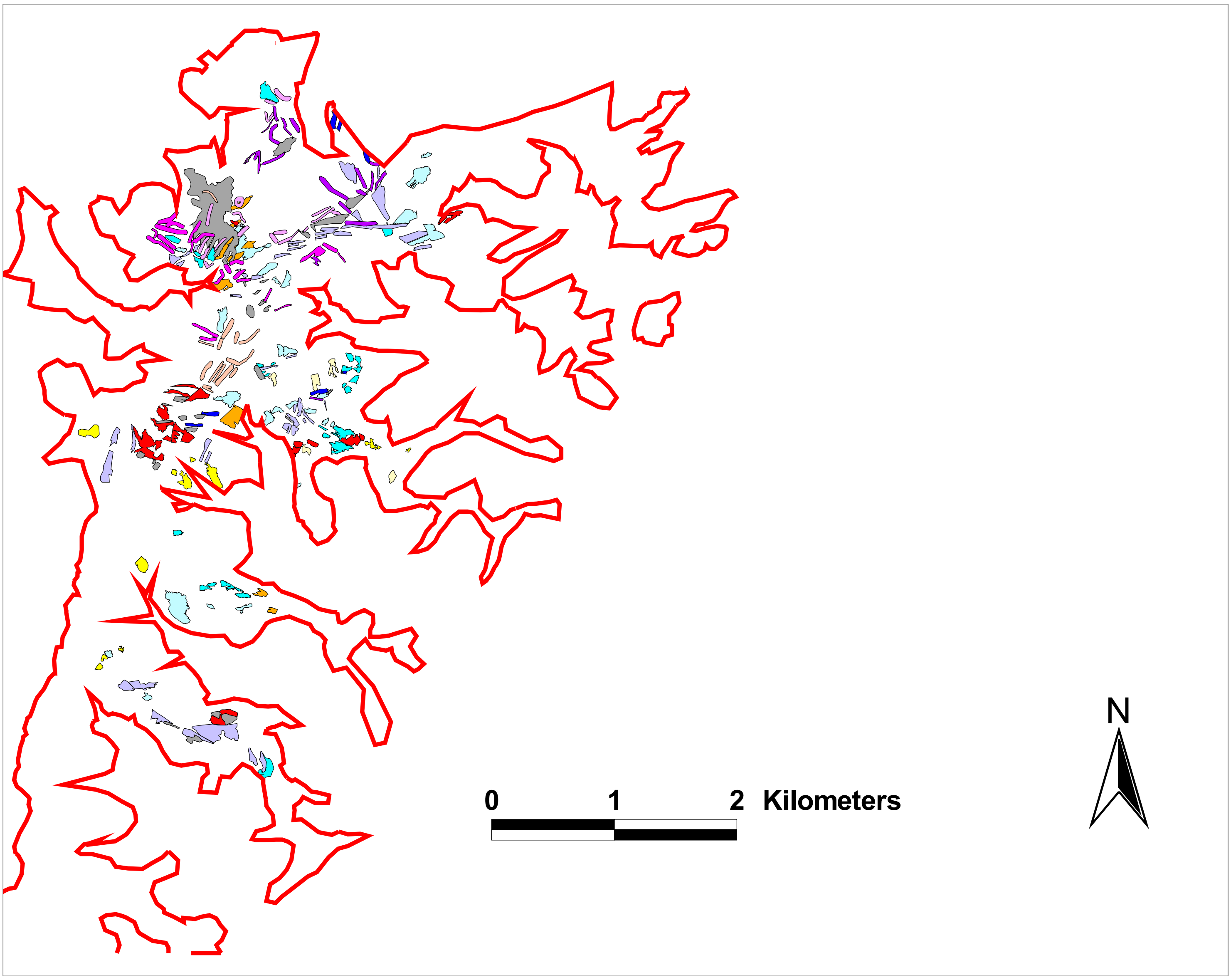

Figure 2.2.3. Areas of heather subject to burning and cutting, some areas burned in the early years have subsequently been cut. Data from Dr Caroline Uff and The National Trust.

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Colour conventions as for Figures 2.2.1 and 2.2.2.

The effect of management is monitored through an Assessment of Heather Recovery of Recent Burns (Uff, 2001). Figure 2.2.4, which shows the pattern of increase in percentage cover of *Calluna* following burning or cutting, gives the regeneration of *Calluna* on burnt and cut areas respectively after various intervals. Figure 2.2.5 shows the pattern of increase in dwarf shrub *Calluna* and *Vaccinium* taken together.

Uff (2005) noted the concerns of some commoners that recovery of cut areas would not be as good as from burnt areas. However, early data which showed that mean cover of regenerated heather on 38 cuts from 2001 exceeds that from the 20 burns carried out in the same year, suggests this was not the case.

In addition to the monitoring of recovery from recent burns, the long term Heather Consumption Survey continues; this annual survey was established in 1997 (Jenkins and Anderson, 1999) to assess grazing levels on 34 fixed plots distributed across the hill.

Figure 2.2.6 shows changes in the amounts of heather shoots grazed and levels of flowering before and after entry into the ESA agreement in 1999. The effects of the overall post ESA grazing reduction are apparent: a decrease in shoots grazed and an attendant increase in shoots flowering which will have positive implications for the regeneration of *Calluna*. The potential increase in seed production should ensure more propagules are available, either to increase the seed bank under the heather or to be harvested for subsequent re-seeding operations.

Whilst existing *Calluna* has generally been managed by burning or cutting, some attempts have been made to restore other areas by direct seeding or by strewing *Calluna* brash to supplement or provide a seed bank. Reseeding has been used to supplement or replace the seed bank on certain unrecovered burns where part ‘rotavation’ has been used to disturb the surface and to provide regeneration niches. These reseeded areas have not reached the same level of heather cover as the undisturbed control so there are no firm data to support or reject this technique (Uff, 2005) although there is subsequent evidence that some ‘may have caught up’ (C.Uff, *pers. comm.*)

During 1999 and 2000 attempts were made to restore *Calluna* to grassy areas of several sites: turf was mechanically stripped and the area ‘seeded’ with a mixture of seed and brash collected from Wildmoor (Uff, 2001). Pywell *et al.* (1996) record the importance of brash in the seed mix as it provides micro-sites for germination of the seeds and also acts as a mulch which conserves moisture in skeletal soils. They also note the possibility of the seeds from other species in the community being harvested along with the *Calluna* and also being spread with the heather seed.

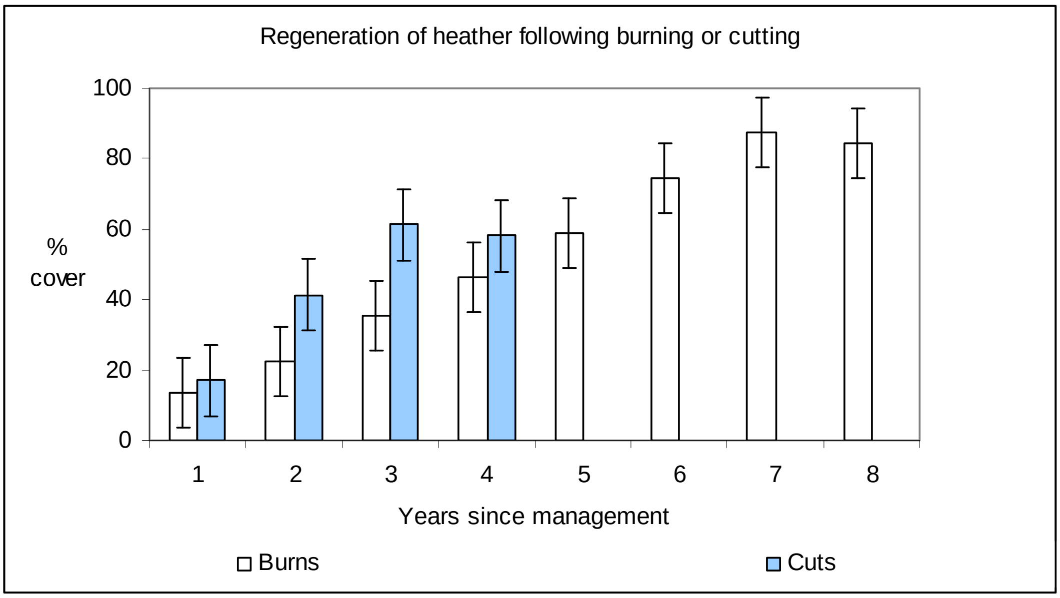

Figure 2.2.4. Regeneration of heather on burnt and cut areas, mean cover values with SE. Redrawn from data from Uff (2007b). Cuts were compared to burns carried out in the same year but the results are an average of a series of surveys over several years. i.e. the same burn or cut will be assessed each year and included in the appropriate year class. Each year there will be more burns and cuts of 'year 1' age to be included but some 'older' areas may be lost through re-burning or cutting. Numbers of samples varied from 23 [year 8 burn] to 109 [year 1 burn] and 42 [year 4 cut] to 65 [year 1 cut]. All areas were under the same grazing regime for each year although there could be year to year variations and is not adjusted for the [unknown] stock preferences for particular areas.

The operation originally appeared unsuccessful on all sites except an enclosed site at Pole Cottage, and Uff (2005) suggested this technique was only viable in cases such as this where sheep can be excluded. However subsequent monitoring indicated that under current grazing levels heather has become established on around half of the stripped and reseeded sites and that only in areas of heaviest grazing has it failed (C.Uff, *pers.comm*).

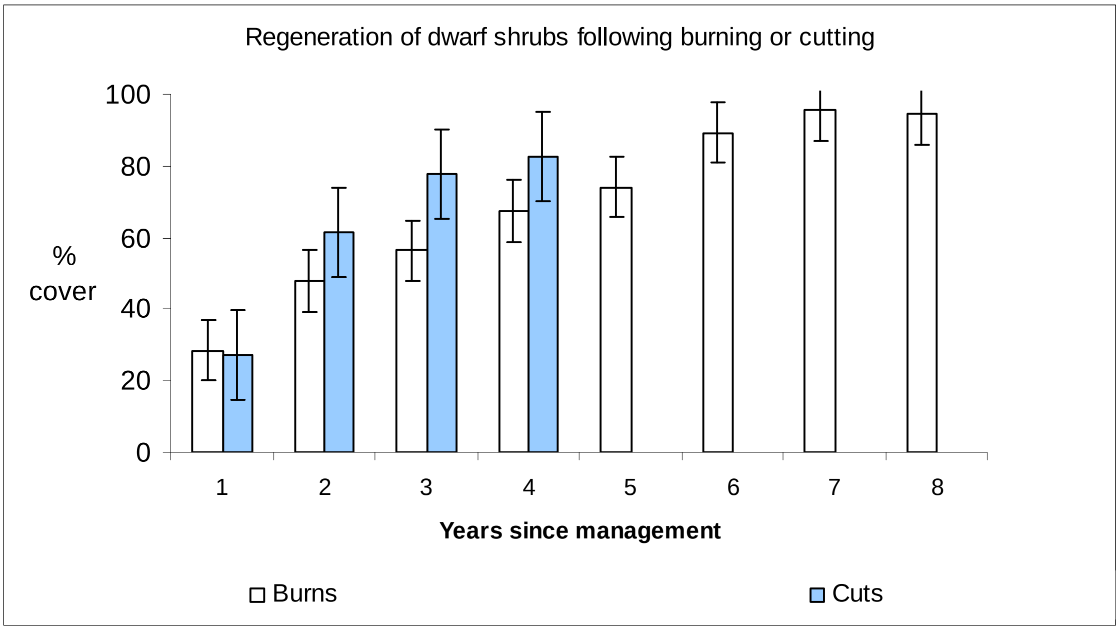

Figure 2.2.5. Regeneration of dwarf shrubs on burnt and cut areas, mean cover values with SE. Redrawn from data from Uff (2007b).

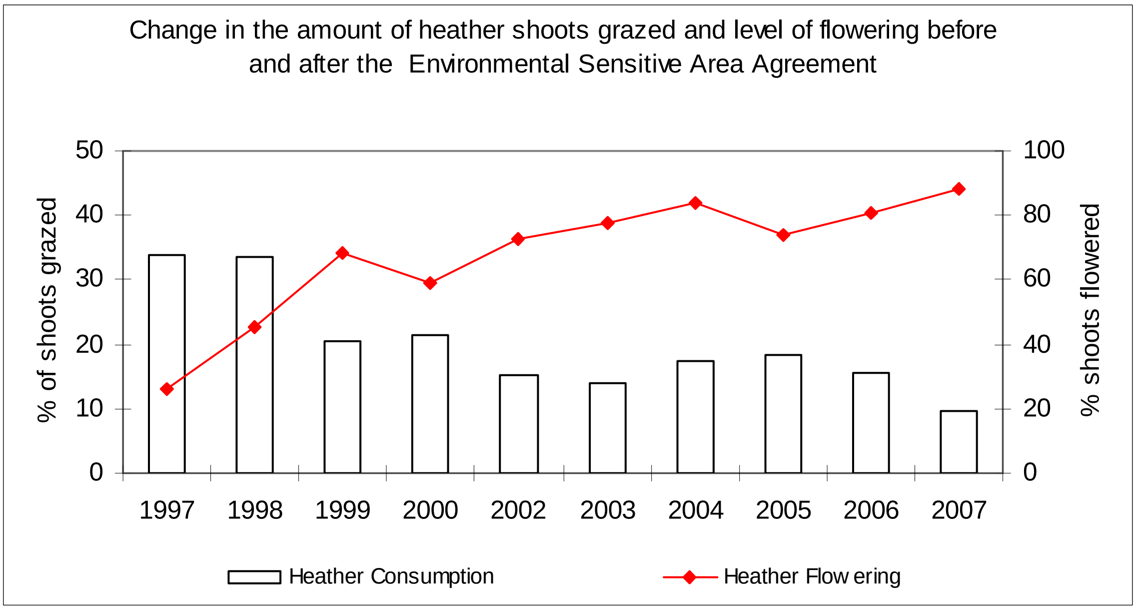

Figure 2.2.6. Changes in grazed heather shoots and in levels of flowering pre and post ESA agreement (1999). Redrawn from data from Uff (2007b) No data are available for 2001 owing to FMD restrictions on survey work.

Coleshaw (1989) considered that bracken could be tolerated on the skeletal soils of valley slopes where it was unlikely to become dominant, but that it should be eliminated from the plateau, possibly by aerial spraying, on a compartment by compartment basis.

MacKenzie (1991, 1992, 1993, 1994) undertook a series of monitoring exercises on a group of permanent quadrats on the Long Mynd, comparing the effects of cutting and spraying bracken against control areas where no management had been carried out.

The overall conclusion was that the dead stems and fronds produced by both spraying and cutting initially led to an increase in bracken litter, greater than that accumulated in the control plots although the current practice of cutting and gathering the litter for composting should to eliminate this problem in areas subject to this method. Both spraying and cutting produced a decrease in *Pteridium,* although in the cut plots this tended to stabilise at around 30% cover despite annual cutting and thus pointed to the need for an annual cut in order to maintain this level. Other vegetation generally responded positively to the removal of bracken, with evidence of increases in *Deschampsia flexuosa, Rumex acetosella* and *Galium saxatile.*

Bracken control areas are selected primarily where *Pteridium* has invaded heathland, or areas of grassland where bracken incursions are of concern to graziers. Archaeological features, principally barrows and other earthworks, also have a high control priority. Areas with specific conservation value, e.g. as whinchat (*Saxicola rubetra)* habitat or where there is an understorey of *Viola riviniana or Viola palustris,* food plants of the larvae of the dark green fritillary (*Argynnis aglajay*) or small bordered fritillary (*Boloria selene*), are excluded. Other areas of ecological sensitivity such as watercourses or flushes or slopes susceptible to erosion are also excluded (Uff, 2005).

The presence of rare fern species such as *Hymenophyllum wilsonii* (Packham, 1976) pose difficulties; their scarcity demands protection yet the uncertainty of their location makes setting buffer zones or exclusions zones difficult if not impossible.

Spraying is undertaken by helicopter, tractor or back-pack spray and buffer zones, i.e. areas where no application is permitted, are established along watercourses and flushes or other sensitive areas. The width of the buffer zone is necessarily related to the method of application.

On the flatter areas, particularly where *Pteridium* is encroaching on to more open heath or grassland areas, cutting is increasingly the method of choice. The resultant litter is collected, composted and sold locally, particularly at the Carding Mill Visitor Centre, as compost from sustainable sources which can replace peat-based materials.

Figure 2.2.7 shows the areas sprayed in 2002 and 2004 programmes and Figure 2.2.8, areas cut in 2006. Spraying is undertaken on a proposed cycle of *circa* ten years (C.Uff, *pers.comm.*), whereas cutting to control as opposed to eliminate bracken may be repeated on a three year cycle or even shorter (Carty and Jenkins, 2000).

Bracken control is likely to become an increasing part of the management of the common and will have an effect on heather communities. There is evidence that burning mixed heather and bracken stands favours the dominance of bracken owing to the slower recovery rate of *Calluna* and it was proposed (Uff, 2006a) that no further areas of mixed bracken and heather be burnt even in areas targeted for aerial spraying.

Other changes in the vegetation post-ESA, and indeed following the culls and restrictions of the 2001 Foot and Mouth outbreak, may need attention in the future. *Nardus stricta* is currently under surveillance (Uff, 2006a) as there is some concern amongst both graziers and conservationist about its apparent spread. The debate centres on whether the spread is real or merely that this species is growing taller, and hence more visible although the possibility of its increasing due to the availability of increased nutrients (Hartley and Amos, 1999) should also be considered.

The grasslands of the Long Mynd are also prone to invasion; the U1 areas are subject to encroachment by gorse and the other grasslands, generally U4, by bracken. Gorse control, generally by cutting or burning, was undertaken to break up the stands and open up the grass to grazing by sheep or rabbits; follow up treatments were made using Glyphosate to prevent regrowth (Uff, 2005).

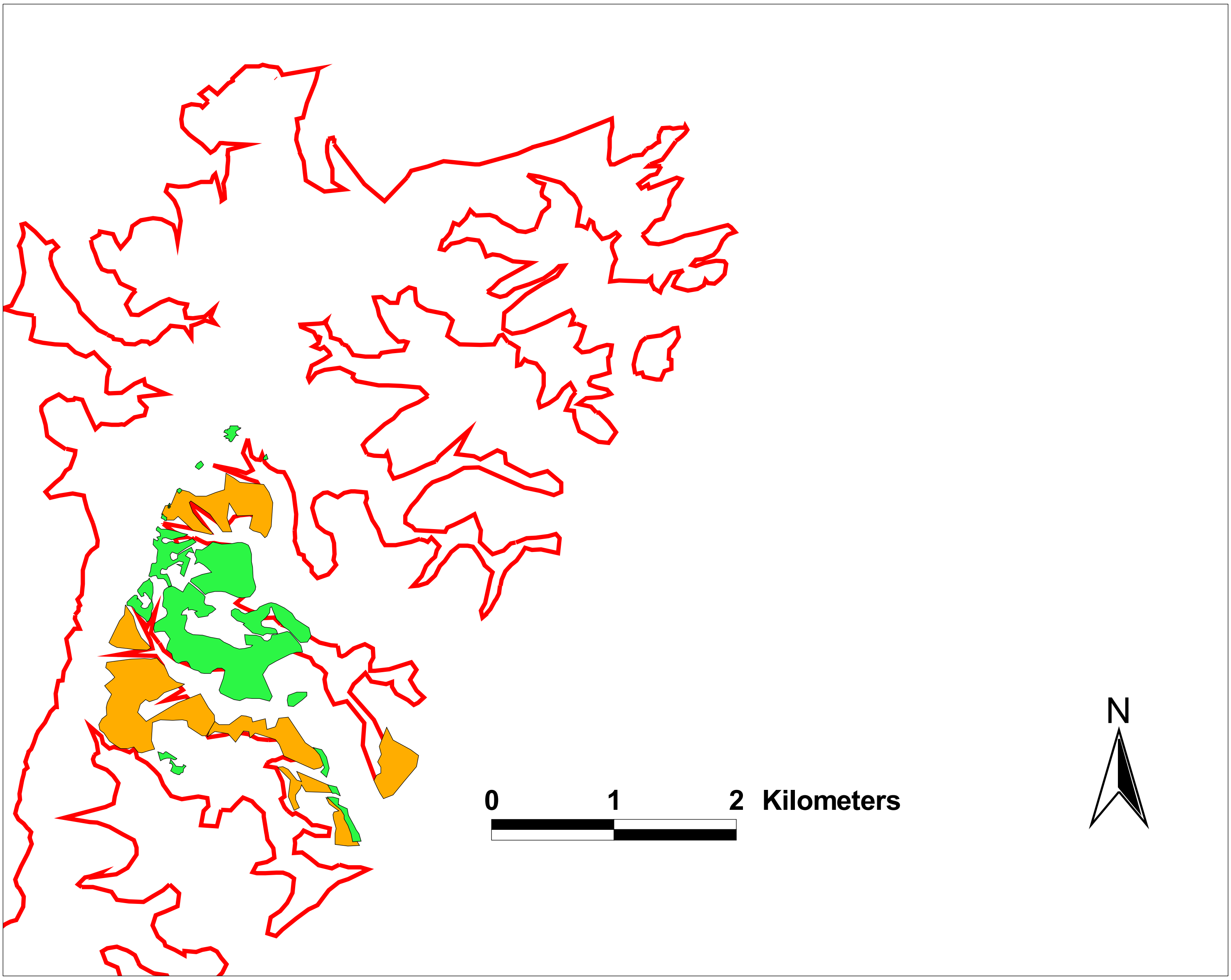

Figure 2.2.7. Areas of bracken sprayed in 2002 and 2004. Data from Dr Caroline Uff and The National Trust.

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╱╲╱ Plateau boundary

🟩 2002

🟧 2004

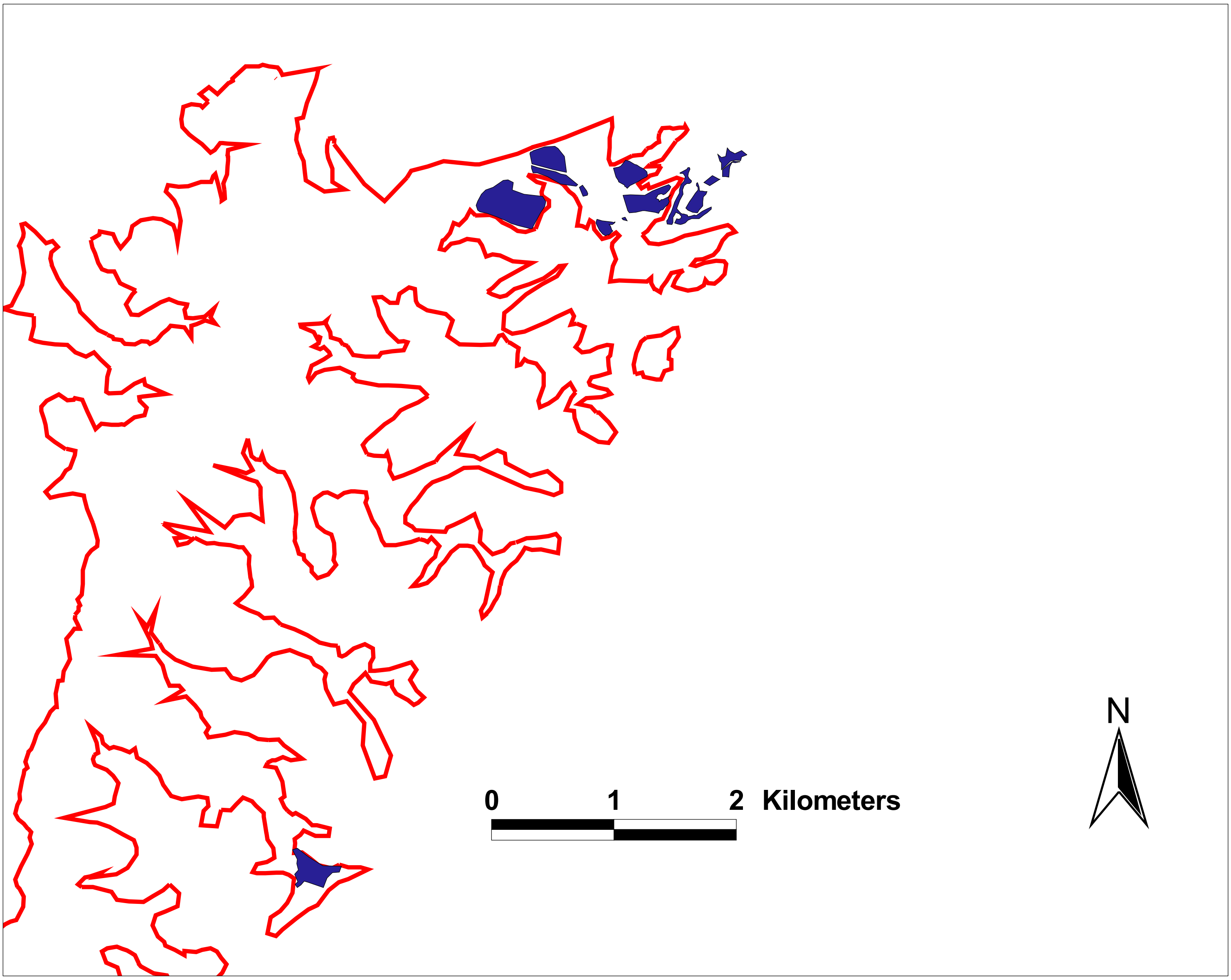

Figure 2.2.8. Areas of bracken cut in 2006. Most of the areas had also been cut in 2003,2004 and 2005. Data from Dr Caroline Uff and The National Trust.

Base maps removed to ensure copyright compliance

Plateau boundary

2.2.3 Track use, access and visitor management

The Long Mynd is crossed by three principal public roads: from Church Stretton via the Burway, from Asterton via Pole Cottage and from Ratlinghope via Belmore [See Figure 1.2.1]. All three intersect at a junction near to Boiling Well. A fourth road enters at High Park and passes Duckley Map and Wildmoor Pool before leaving the Common at Upper Durnford to skirt the hill via Ratlinghope, Medlicott and Asterton. There are other roads which pass through or terminate in the lower regions, e.g. at Jinlye, at Gogbatch and the most significant, the road to Carding Mill Valley.

A series of footpaths and track ways ascend many of the batches and ridges from the Church Stretton valley; Yapsel Bank, Minton Hill, Callow and Round Hill, Ashes Hollow, Townbrook Hollow, Carding Mill Valley, and Haddon Hill. Other tracks which form part of designated Long Distance Paths traverse the Hill from Plowden to High Park.[15]

This level of accessibility causes various problems which can best be considered under two basic headings: those associated with grazing and feeding practices, and those associated with recreation and visitor pressure.

The pre-ESA supplementary winter feeding attracted and concentrated sheep to particular sites, at the same time producing vehicle tracks to these sites. These tracks ‘flattened’ the existing vegetation and either compacted the soil or produced ruts in the ground surface. Where these ruts formed in the deeper soils and became waterlogged, the tracks widened as users attempted to avoid the morass.

Strategies to monitor the condition of both ‘agreed use’ and ‘disused’ feed tracks were then instituted (Jenkins, 1998) The general elimination of winter feeding has reduced the use of these tracks during the most vulnerable period and allowed re-vegetation to take place in many instances. The nature of this vegetation, however, may not be the same as that of the surrounding areas.

The use of tracks by sheep, both as pathways and grazing sites, and also by walkers, cyclists and horse riders often discourages colonisation by dwarf shrub species and encourages the development of grass lawns. Liddle and Chitty (1981) noted the results of horse trampling in increasing compaction of the soil and erosion of the upper horizons and in increases in the nitrogen levels in the path and path edges. There was a reduction in both species and biomass on areas immediately adjacent.

Charman and Pollard (1995) found that following their closure or abandonment, vehicle tracks in areas of acid grassland on Dartmoor ultimately recovered whereas tracks in dwarf scrub–blanket bog communities moved towards a grassland-heath community.

Although not generally considered attractive features, ruts can often provide important habitats for invertebrate fauna, e.g. water-filled ruts on the Wildmoor heath provide small linear pools of importance for Odonata, whilst dry ruts in mineral and peat soils provide sites for solitary bees (Cheeseborough, 2007).

Although access to the Long Mynd common has not been restricted, even prior to the recent Countryside and Rights of Way Act 2000 [CROW], visitor pressure tends to be localised around ‘honeypot’ sites, frequently car parks, or at the principal attraction, the Carding Mill Valley Visitor Centre facilities.

The visitor pressure associated with the Carding Mill Valley results in erosion damage to car park surfaces and to the paths and slopes. ‘Mottes Road’, a principal route for walkers from the New Pool car park to the plateau, requires regular maintenance and areas in the valley proper are closed to cars, generally in winter and spring, to ameliorate erosion and to permit re-vegetation of the parking areas.

Other ‘hot spots’ of erosion have occurred, for example, the path at Devils Mouth suffered considerable erosion by visitors climbing to its summit. This required the use of geotextile mats to reduce run off and the closure of the adjacent car park to reduce accessibility and to facilitate its recovery.

An important facet of visitor pressure, particularly visitors with dogs, is disturbance; ground nesting birds e.g. waders such as the Curlew (*Numenius arquata)* and the Common Snipe (*Gallinago gallinago*) can be particularly susceptible whilst Merlin (*Falco columbarius*) and Red Grouse (*Lagopogus lagopogus scoticus*) can be similarly affected. Disturbance can cause incubating adults to leave the nest, exposing eggs to increased risk of chilling or predation and the survival rates of precocial and nidifugous chicks can be decreased. Work by Pearce-Higgins and Yalden (1997) suggest that well

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[15] Jack Mytton Way/The Portway/The Marches Way.

maintained paths reduce ‘straying’ by walkers into adjacent areas with a consequent reduction in the ‘avoidance’ zone for many birds.

A positive contribution to the reduction of vehicle pressure has been the institution of the ‘Shuttle Bus’ service. Passengers can board the shuttle buses at various points, principally in Carding Mill Valley but also at Church Stretton railway station, and alight on the plateau area. A popular option is to take the bus to the upland area and then return to Carding Mill via one of the many paths. The scheme is now operating at a larger scale with some routes encompassing the Stiperstones and the intervening valleys.

Visitor awareness is encouraged by courses and exhibitions organised by the National Trust, and Trust staff and volunteers lead ‘guided walks’ at various times of the year, usually on particular themes, such as the ‘Blooming Marvellous’ walk which coincides with the flowering of the heather. The education service hosts fieldwork sessions for students and pupils from primary school upwards.

3 Vegetation Surveys

Changes in the distribution of the communities, particularly the expansion of the areas under *Pteridium* on the Long Mynd over the past 75 years or so, can be demonstrated, despite difficulties associated with the variety of mapping techniques employed. Although Leach's (1931) description and map [Figure 3.1.1] gives a useful 'snapshot' of the situation, the mapping technique he used does not provide the precision associated with modern survey and GIS techniques.

The Long Mynd was surveyed by Sinclair (1965) as part of the Second Land Utilisation Survey (SLU). Figure 3.2 is based on Ellett's (1984) map of the original Sinclair survey data. Comparison with later surveys is somewhat difficult owing to subtle or even gross differences in methodologies used. Ellett (*ibid*) notes that communities used in the Land Utilisation Survey were defined as composites with vegetation types based on a dominant species, with one or more subdominants as appropriate, viz:

C	*Calluna*	F	*Festuca / Agrostis* sp.	J	*Juncus effusus*	Pt	*Pteridium*
S	*Sphagnum* spp.	V	*Vaccinium*	U	*Ulex*	HG	Degenerate grassland

Thus a community described as 'acid grassland and bracken' could be coded as FPt where the grasses were the dominant species or as PtF where *Pteridium* was the dominant. Similarly 'shrubby heath with bracken' was variously coded as VPtC, PtC and VCPt, according to which genus, *Vaccinium, Pteridium* or *Calluna* was the dominant. Perhaps Ellett's most telling point was that this approach did not distinguish between mixtures and mosaics of species and vegetation types.

Sinclair (1978) pointed out that the mapping for the SLU Survey was 'carried out on foot without the use of air photographs or measuring instruments' and that it was midway between ' being a subjective art and an objective science.'

His comment that 'to ensure seasonal consistency certain species have to be consciously over or under recorded at periods when they are relatively inconspicuous or prominent' suggests potential for confusion, as does his point that 'many communities do not adjoin starkly with differing and discernable dominants' and that 'there is frequently a broad zone of transition which may well be between communities sharing the same dominant.'

Greenall carried out a survey in 1975; after delineating community boundaries on aerial photographs taken in 1972. The boundaries were checked by field surveys, but she noted it was frequently not possible to define a distinct change in vegetation types. Having identified and confirmed the bounds of a unit, a representative area of vegetation within that unit was identified and species enclosed by a 10 metre [*sic*][16] quadrat were recorded. The number of quadrats used was determined by the size of the unit. The remaining copy of the map (Greenhall, 1975) does not lend itself to scanning or reproduction and in some areas it is difficult to interpret. However, it appears to be broadly in agreement with Ellett's interpretation of the Owen and Tapper (1983) data [see below].

A later survey undertaken by Owen and Tapper (1983), as part of the NCC Upland Survey Project [USP], used the classification system produced by Birks and Ratcliffe (1980) 'for interim field surveys until the NVC became available' which was based on previous classifications principally that of McVean and Ratcliffe (1962).The classification (originally given as Figure 6.2-3/A in an Internal NCC memo in 1980 and listed by Ellett) is shown as Table 3.1.

Table 3.1. Birks and Ratcliffe (1980) Interim Classification

Ordinal Sequence: indicates decreasing representation.

% Cover conventions:

a.)	Brackets ( )	vegetation types which occupy less than 25% of the total area
b.)	Slash /	indicates a mosaic of separate patches of 2 (or, rarely, more) distinct vegetation types each of which occupies 25% or more of the total area
c.)	Plus +	Indicates a vegetation type which appears to be intermediate between 2 defined communities (e.g. B1+B3) or indicates the presence of a conspicuous species as an addition to a main vegetation type (e.g. C1+Pt, +T indicates scattered trees.)

Hierarchical Classification Codes:

B Dwarf-shrub communities
  1 Sub-montane *Calluna vulgaris* heaths
    a. *Calluna vulgaris* dry heather moor [p.28 and Table11)[17]
  3 *Vaccinium myrtillus-Empetrum nigrum / hermaphroditum* heaths
    a. Sub-montane *Vaccinium myrtillus* heath
C Grasslands.
  1 *Agrostis – Festuca* grassland
    a. Species poor Agrosto-Festucetum low *Festuca* [p.52 and Table 24]
    b. Species poor Agrosto-Festucetum high *Festuca*

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[16] Described as such by Greenall.

[17] First page number refers to the descriptive section in McVean and Ratcliffe (1962) and the table number to community and facies tables.

- 2 *Nardus stricta* grasslands
    - A Nardetum sub-alpinum species poor facies [p.58 and Table 28]
- D Herb rich and fern rich communities
  - 1 *Pteridium aquilinum* communities
    - A Dense stands of *Pteridium* with reduced ground flora.
- H Soligenous Mires
  - 2 *Juncus* – moss mire.
    - A *Juncus effusus-Sphagnum recurvum* mire [p.113 and Table 54]
  - 3 *Carex* – moss mire

Other Codes

Pt	*Pteridium aquilinum*
+T	Scattered trees
IC	Improved grassland
Ue	*Ulex europaeus*

Owen and Tapper used 1973 aerial photographs to identify vegetation boundaries and these were transferred (as overlays) on to 1:10,000 OS maps. Field surveys were used to categorise vegetation characteristics of communities identified by variations in tone and texture etc. in the aerial photographs - ‘ground truthing.’

Ellett undertook his own surveys and mapping during 1984, using the Birks and Ratcliffe (1980) classification. He used 1983 1:10,000 aerial photographs to identify community boundaries and overlaid these on 1:10,000 OS maps repeating the operation with the Owen and Tapper boundaries. On comparing these, he found discrepancies between the two sets of boundaries which could only be explained either by mapping differences or by gross community changes in the intervening 12 months or so.

Subsequent site visits were undertaken by Ellett and a representative from NCC to ‘ground truth’ Ellett’s mapping .The conclusion from this exercise was that ‘USP’s vegetation boundaries, although drawn in 1983, were really representative of 1973 vegetation boundaries’. Ellett stated that additional support for this interpretation was provided by a high correlation between his boundaries and those he established from Landsat images from a 1984 overflight.

The most recent survey to date was undertaken in (1995b) by ADAS as part of their work on grazing and management for the Farming and Rural Conservation Agency

[FRCA[18]]. 1:10,000 false colour infra red photographs, flown in June 1993, were used to delineate community boundaries which were subsequently confirmed by extensive ground truthing. These infra red images were particularly useful in distinguishing areas of *Pteridium* (Dr Frances McCullagh, *pers.comm.*). The mapping definitions used by the FRCA were broadly based on Phase 1 Habitat Definitions (Nature Conservancy Council, 1990) and are reproduced in Table 3.2.

Figure 3.3 gives Owen and Tapper's communities [modified by the present author from Ellett (1984) and labelled as 1973 as per Ellett]. Figure 3.4 shows Ellett's communities (again modified by the present author from Ellett, 1984) whilst the 1995 FRCA communities are shown in Figure 3.5 modified to use the same colour conventions as the other figures.

Table 3.2. Mapping definitions used in the 1995 'FRCA' Longmynd Habitat Survey (*pers comm.* Dr Frances McCullagh)

Habitat Category	**Mapping Definition**
Continuous bracken with a litter understorey.	Area dominated by bracken which forms a dense closed canopy, often on rich mineral soils on steep slopes. Understorey with little or no living vegetation.
Continuous bracken with a grass understorey.	Area dominated by bracken which forms a dense closed canopy. Understorey dominated by grass.
Continuous bracken with a heath understorey.	Area dominated by bracken which forms a dense closed canopy. Understorey with at least 25% dwarf shrub cover.
Continuous bracken with a mosaic (heath and grass) understorey.	Area dominated by bracken which forms a dense closed canopy with about 10% -25% dwarf shrub cover combined with grasses.
Heath.	Vegetation with more than 25% cover of dwarf shrub species combined with grasses. Usually found on unenclosed moorland on thin peat (<.05m deep) or mineral soils.
Heath plus grass.	Vegetation with 10% to 25% cover of dwarf shrub species combined with grasses.
Heath with scattered bracken.	Vegetation with more than 25% cover of dwarf shrub species plus scattered bracken, where fronds do not touch when mature.
Heath with grass plus scattered bracken.	Vegetation with 10% to 25% cover of dwarf shrub species plus scattered bracken, where fronds do not touch when mature.
Grass.	Unenclosed, unimproved grassland dominated by plants which tolerate low fertility and acid soils.
Grass plus heath.	Unenclosed, unimproved grassland dominated by plants

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[18] The survey, its maps and data are referred to as FRCA.

	which tolerate low fertility and acid soils with less than 10% dwarf shrubs.
Grass plus scattered bracken.	Unenclosed, unimproved grassland dominated by plants which tolerate low fertility and acid soils plus scattered bracken where the fronds do not touch when mature.
Grass plus heath and scattered bracken.	Unenclosed, unimproved grassland dominated by plants which tolerate low fertility and acid soils with less than 10% dwarf shrubs plus scattered bracken where the fronds do not touch when mature.
Gorse scrub.	Vegetation with more than 25% cover of *Ulex* sp.
Acid flush	Linear flush with water movement, consisting of *Sphagnum* and *Polytrichum* moss carpet overlain by rushes *Juncus* and sedges *Carex* spp.
Bare ground.	An area of bare soil or other substrates with less than 10% vegetation cover.

Comparison of these Sinclair, Owen and Tapper and Ellett maps is beset with difficulties. These fall within three broad areas: a) differences in approach to community designation noted above and difficulties in assigning equivalent communities; b) differences in digitising methods which have produced minor variations in polygon dimensions even where boundaries are not in dispute[19], and, c) 'unlikely changes' which may be attributable to 'observer bias', a view held by Ellett (1984).

Such difficulties are not unique to Long Mynd mapping exercises, for example Jones and Wyatt (1988) highlighted the problems caused by the wide species diversity and complexity in the composition of upland vegetation types together with the diffuse nature of their boundaries and their spatial variability.

Following the adoption of Phase 1 Survey (Nature Conservancy Council, 1990) as a standard methodology for community mapping, various investigations were undertaken to determine the reliability of this approach.

Cherrill and McClean (1995) compared maps produced from Phase 1 field surveys in the Northumberland National Park for two successive years, 1991 and 1992. They found the overall spatial correspondence between maps was only 44.4%; a maximum of 14.4% of the area surveyed was found to have undergone genuine land cover change and the remaining discrepancies [41.2%] were attributed to classification error.

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[19] For example, the enclosed area at Pole Cottage shown as 'improved pasture' in the Sinclair, Owen & Tapper and Ellett maps returns areas of 1.79 ha, 1.76 ha and 1.71 ha, respectively.

In subsequent work (Cherrill and McClean, 1999a) they identified two principal error types, misclassification of vegetation and spatial displacement of boundaries; they also found that inaccurate georeferencing of field observations could give an impression of misclassification when maps were overlaid for comparison.

They also identified areas where mapping precision could be increased (Cherrill and McClean, 1999b); recommending the placing of greater emphasis on the use of aerial photographs and other mapped data both prior to and during field surveys, making greater provision for the mapping of mosaics and increasing the level of floristic information in habitat definitions, recording greater detail in target notes during field surveys and the provision of cross checking of field surveyors' preliminary classifications against the target notes and habitat definitions.

In their work on the 'repeatability' of Phase 1 Surveys, Stevens *et al.* (2004) found that whilst the methodology provides a robust means of gathering first level information on the location and amount of semi-natural habitat; estimates of land cover change for some individual habitats, particularly semi-natural grasslands and mires, carried a degree of uncertainty through between-surveyor differences in habitat designation and in habitat boundary positions .

Notwithstanding Cherrill and McClean's (1999b) recommendation for increased use of aerial photography, particular species or communities can bring their own problems. Birnie *et al.* (2000) noted that various studies, e.g. Birnie and Miller (1986), Miller *et al*. (1989) and Miller *et al.* (1990) all found defining 'bracken' was a problem in both ground and aerial photo based methods, and that areal estimates were strongly dependent on the survey method used.

Bracken occurs in a large number of NVC communities, of the order of 36 (Pakeman and Marrs, 1992). Such a wide range of occurrence, coupled to a variation in spatial configuration, isolated fronds, dense patches, and coverage of complete hillsides, as well as its phenological differences in appearance, makes it a particularly difficult species to map accurately from remotely-sensed data (Birnie *et al.*, 2000) with the consequences described in Chapter 3.

Both the Landsat TM images used in the 1990 Countryside Survey (Barr *et al.*, 1993), and Landsat images used by Ellett (1984) for his boundary confirmations, had a 30 metre pixel size; Pakeman *et al* (1996) cite the estimates of Townshend *et al.* (1983) which indicated that the minimum unit which can be reliably mapped from these images would be of the order of 2.7-3.8 ha.

Pteridium occurs in mosaics and dissected blocks, many of which could be below the resolution of the TM sensor, consequently mapping accuracy for bracken was very poor, the worst for all classes measured in the Countryside Survey (Pakeman *et al.*, 1996).

In addition to these resolution difficulties there may be discrimination problems. Pakeman *et al.* (2000) suggest that satellite based remote sensing often cannot differentiate between bracken and other vegetation, particularly areas dominated by *Molinia caerulea.*

There is an increasing use of high resolution digital aerial photography (Groom *et al.*, 2006) which can provide digital images with resolutions of less than 1 metre. For example, Tong *et al.* (2006) monitored their bracken control experiments using high-resolution aerial photographs which gave a ground resolution of 25 cm x 25 cm and allowed very small areas, of the order of 0.005 ha to be detected.

The success of overflights for photography or of satellite passes for acquiring multi-spectral data, will depend on the phenology of the target species. Overflights made between June and August when frond expansion is at its greatest (Tong *et al.*, 2006) will obviously be more successful in detecting bracken whereas those made during the latter half of August and September when *Calluna* is in flower (Gimingham, 1960) may be more appropriate to delineating heather. Vanha-Majamaa *et al*. (2000) found that whilst digital images could be useful in detecting changes in vegetation with a simple vertical structure, in taller, multilayered vegetation or higher species numbers, the reliability of the cover estimates was lower.

National or regional scale surveys have frequently used various algorithms to automate the classification of satellite imagery [*cf.* (Haines-Young, 1992)] , however, recent high definition small scale surveys, e.g. Tong *et al.* (2006) have used visual interpretation of the images supplemented by subsequent ground survey data to delineate vegetation polygons for use with GIS.

Whilst noting that aerial photography is often the only remote sensing data source that provides sufficient spatial resolution to monitor sites of special interest, Mehner *et al.* (2004) point to the increasing availability of data from the IKONOS satellite. This has resolutions of 4m per pixel which is as fine as the minimum possible on a 1:10000 Phase 1 Map. Their work in Northumberland (*ibid*) suggests that the overall accuracy of the classification of 'summer' images was of the order of 75% compared to Phase 1 Survey maps but there were difficulties in determining if discrepancies were due to misclassification or to the innate low accuracy of Phase 1 maps (Cherrill and McClean, 1999a).

The survey maps shown in Figures 3.1, 3.2, 3.3, 3.4, and 3.5 have been modified so that communities have been represented by standard colours throughout which helps to make comparison easier.

Whilst Leach's (1931) map shows only two simple zones, bracken and heather, he noted that where bracken was dominant, it did not grow so tall or so dense as to produce the 'monocultures' found in other parts of Britain. It often held an understorey of *Vaccinium* and *Festuca-Agrostis* turf as well as heath plants such as *Festuca ovina, Agrostis vulgaris* [*c.f. capillaris*], *Galium saxatile, Campanula rotundifolia* and *Potentilla erecta* suggesting 'grassy heath with bracken' and 'shrubby heath with bracken' areas identified by Ellett (1984) were present in the 1930s.

The simplicity of this bracken-heather demarcation is disturbed by aspect preferences: bracken favoured the south facing slopes of the valleys and extended right up to the *Calluna* region, whereas, on the northern slopes, bracken was not evident in the higher levels and there was often a 'transition zone' of up to 100 metres where rabbit grazed turf graded into a zone of grazed *Vaccinium* which merged with the *Callunetum* proper extant on the plateau.

Given the indicative nature of Leach's map, meaningful comparison with subsequent, more precise surveys is generally not possible and its use in further comparisons is limited.

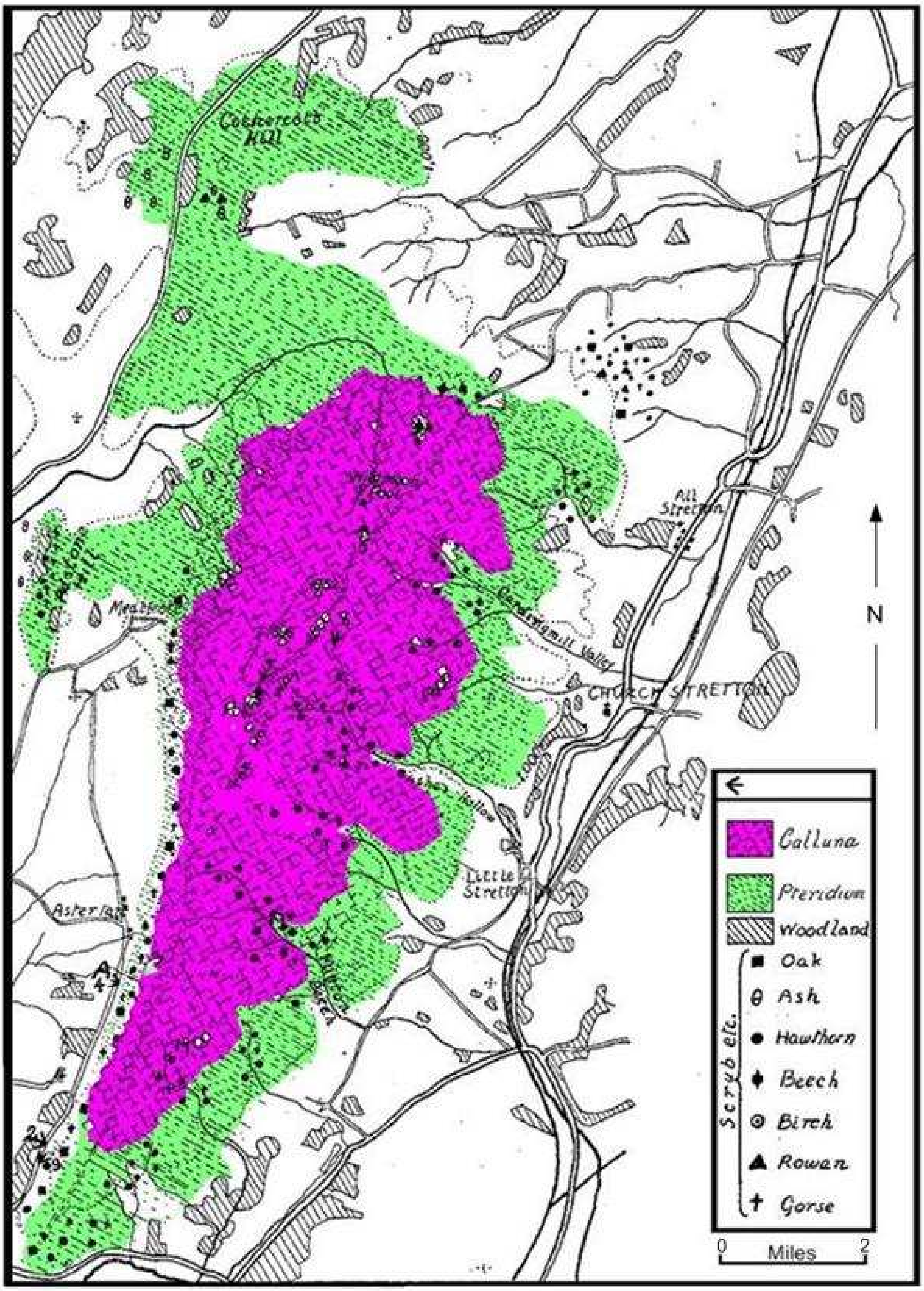

Figure 3.1. Leach’s principal vegetation zones (modified from Leach, 1931).

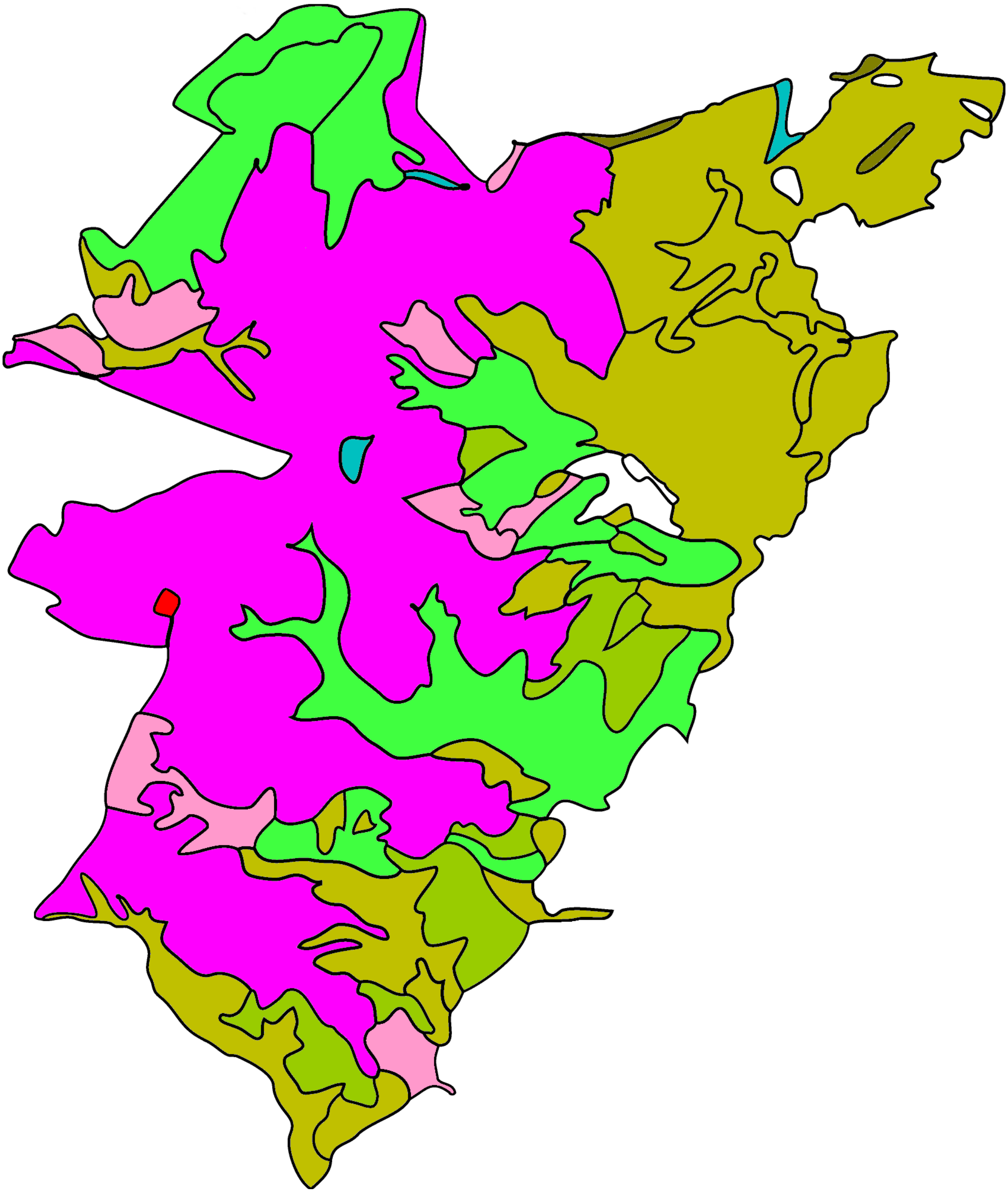

Figure 3.2. Sinclair’s (1965) communities on the Long Mynd (modified from Ellett, 1984)

Community codes used in this figure and in Figures 3.3, 3.4 and 3.5.

■ Soligenous mire
■ Soligenous mire – acid grassland
■ Acid grassland
■ Acid grassland and bracken
■ Acid grassland with gorse
■ Grassy heath
■ Grassy heath and bracken
■ Shrubby heath
■ Shrubby heath and bracken
■ Dense bracken
■ Improved pasture
□ Unidentified/not specified

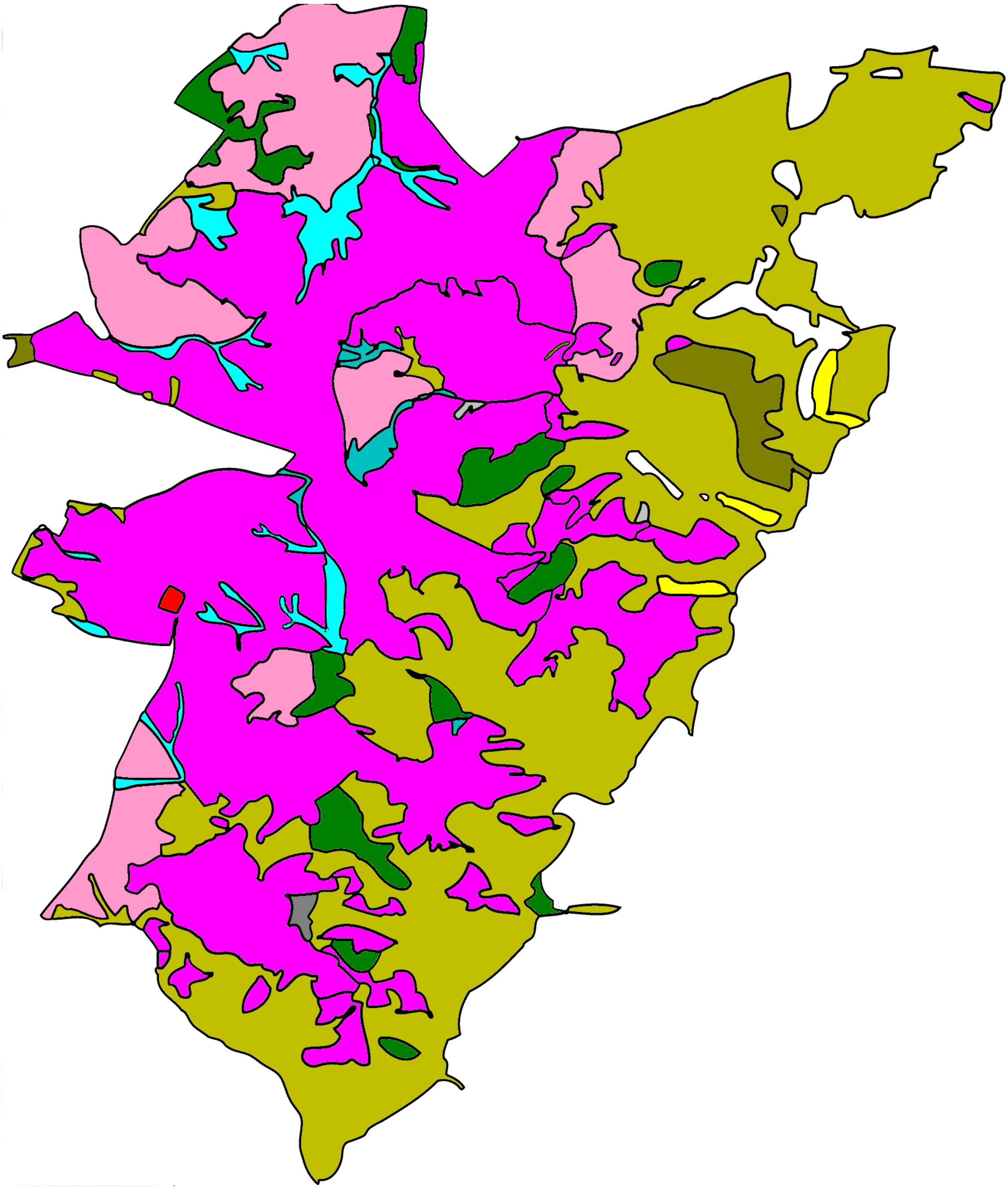

Figure 3.3. Owen and Tapper 1973 communities (modified from Ellett, 1984).

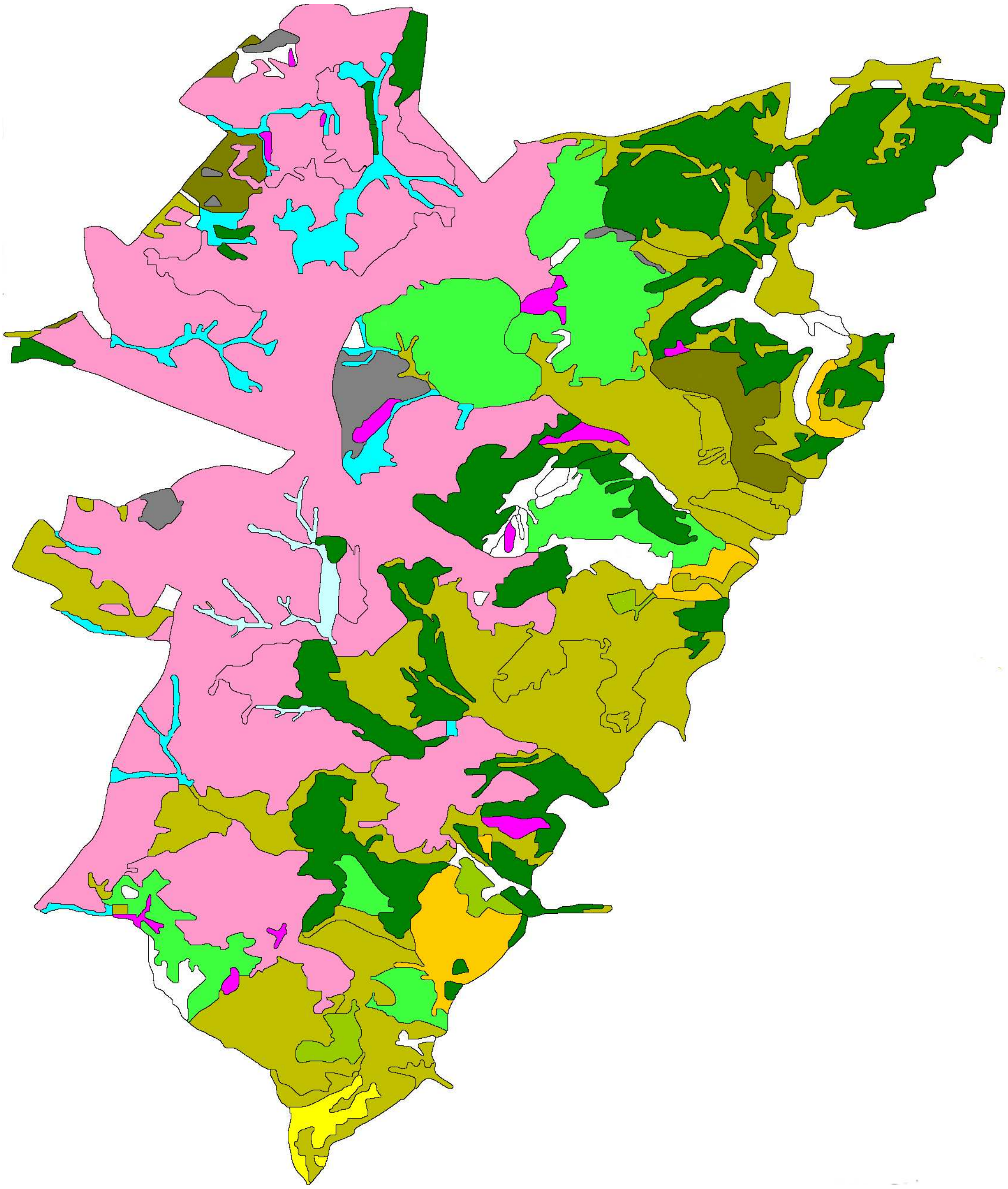

Figure 3.4. Ellett's 1984 communities (modified from Ellett, 1984).

🟦	Soligenous mire	🟦	Soligenous mire – acid grassland		
🟫	Acid grassland	🟨	Acid grassland and bracken	🟨	Acid grassland with gorse
🟩	Grassy heath	🟩	Grassy heath and bracken		
🟪	Shrubby heath	🟪	Shrubby heath and bracken		
🟩	Dense bracken	🟥	Improved pasture		
⬜	Unidentified/not specified				

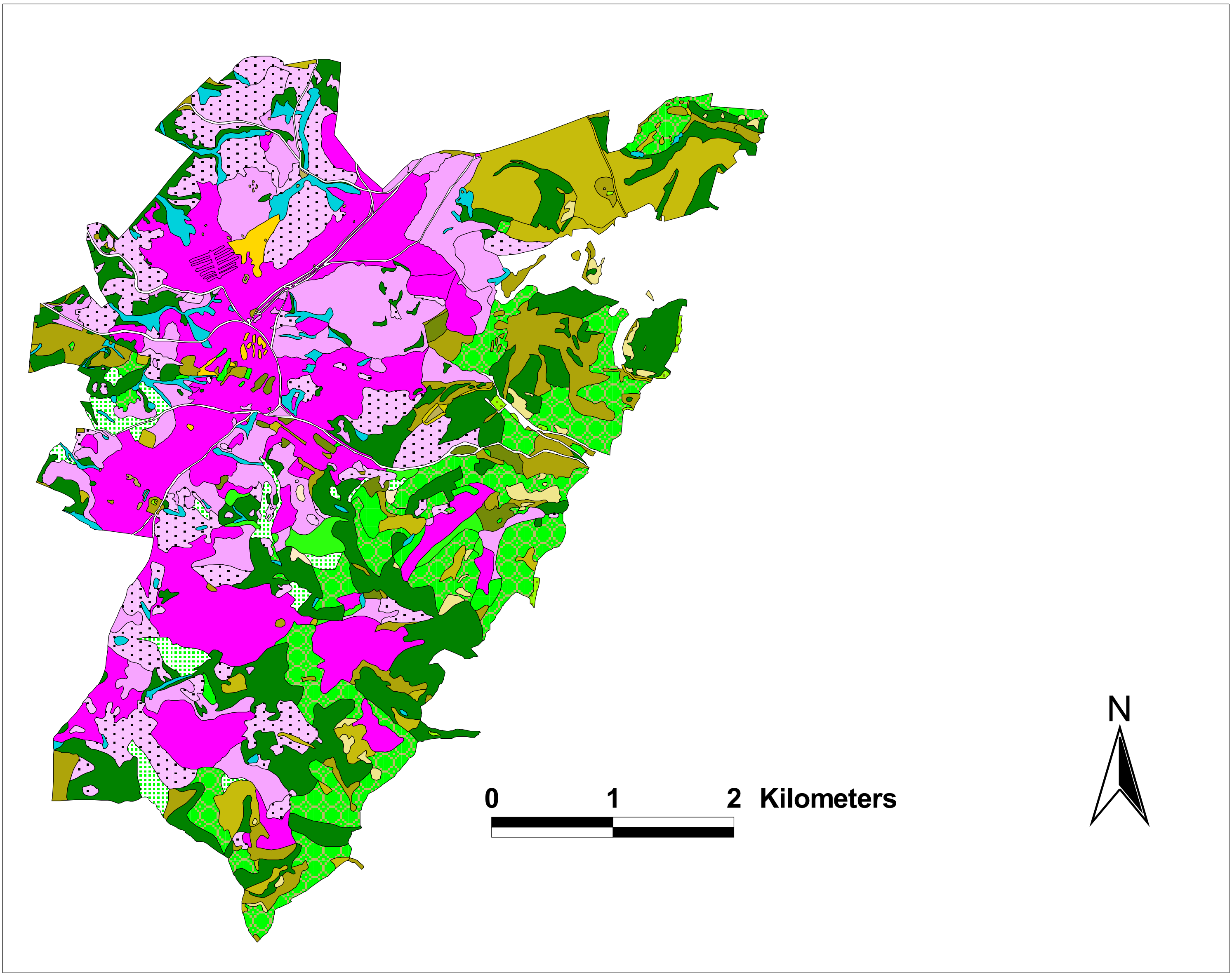

Figure 3.5. Long Mynd Habitat Map (FRCA 1995)

Colour conventions and categories as for Figures 3.2, 3.3 and 3.4. Hatching differentiates the FRCA communities aggregated in to 'Ellett communities'.

Base maps removed to ensure copyright compliance

🟦 **Acid flush**
🟨 **Bare ground**
🟩 **Continuous bracken with a grass understorey**
▨ **Continuous bracken with a heath understorey**
🟩 **Continuous bracken with a little understorey**
▨ **Continuous bracken with a mosaic (heath & grass) understorey**
🟨 **Gorse scrub**
🟫 **Grass**
🟩 **Grass plus heath**
▨ **Grass plus heath and scattered bracken**
🟨 **Grass plus scattered bracken**
🟪 **Heath**
🟩 **Heath and grass**
🟩 **Heath with grass + scattered bracken**
🟪 **Heath with scattered bracken**
🟫 **Pools**
🟨 **Roads**
⬜ **Woodland and non-gorse scrub**

Whilst simple visual comparison of the maps resulting from the later Sinclair, Owen and Tapper, Ellett and FRCA surveys is possible, formal GIS overlays were not produced due to the imprecise nature of original scans, and the difficulties of georeferencing without introducing additional unquantifiable errors.

However it was considered that reference to areal values would be useful and figures for the categories used in the Sinclair, Owen and Tapper, Ellett surveys and their equivalents in the FRCA survey are given in Table 3.4.

These data were abstracted from Ellett's tables of basic polygon areas and subsequently aggregated into the categories he used in his analyses of the Sinclair and the Owen and Tapper data as well as his own survey. For the present study these measurements have been re-aggregated and recalculated even where similar calculations were made in previous studies.

The FRCA Survey used different community categories and these were allocated to the closest 'Ellett' category as shown in below.

Table 3.3. FRCA categories as allocated to the equivalent Ellett category

FRCA Category	Ellett Equivalent
Acid Flush	Soligenous mire
Continuous bracken with a grass understorey	Grassy heath and bracken
Continuous bracken with a heath understorey	Shrubby heath and bracken
Continuous bracken with a litter understorey	Dense bracken
Continuous bracken with mosaic (heath and grass) understorey	Grassy heath and bracken
Gorse scrub	Acid grassland and gorse
Grass	Acid grassland
Grass plus heath	Grassy heath
Grass plus heath and scattered bracken	Grassy heath and bracken
Grass plus scattered bracken	Acid grassland and bracken
Heath	Shrubby heath
Heath and grass	Grassy heath
Heath with grass and scattered bracken	Grassy heath and bracken
Heath with scattered bracken	Shrubby heath and bracken

Table 3.4. Areas (hectares) of communities identified in the various surveys. Areal data taken from Ellett (1985), and FRCA (1995). Following Ellett, the effective date of the Owen and Tapper survey is taken as 1973

Survey Date of survey	Sinclair 1965	Owen & Tapper 1973 [20]	Ellett 1984	FRCA 1995
Grassy heath	138.1	-	17.3	38.5
Grassy heath and bracken	414.2	-	198.9	330.2
Shrubby heath	917.6	921.1	51.0	526.7
Shrubby heath and bracken	107.6	268.7	856.0	561.8
Dense bracken	-	85.7	408.9	418.6
Acid grassland	8.7	35.0	38.4	144.5
Acid grassland and bracken	622.4	827.1	537.2	147.9
Acid grassland and gorse	-	12.4	65.6	21.4
Soligenous mire	5.32	61.2	58.5	62.4
Soligenous mire & acid grassland	4.6	12.1	5.1	-
Improved pasture	1.8	1.8	1.7	-
	2220.2	2225.1	2238.6	2252.2

The areas of the sub-groups within the principal communities, i.e. grassy heath, shrubby heath, dense bracken and acid grassland, have been further aggregated to examine any advance or retreat in their various components. These derived areas of species groups are shown in Table 3.5.

Table 3.5. Areas of aggregated categories

	Sinclair 1965	Owen & Tapper 1973 [21]	Ellett 1984	FRCA 1995
Grassy heath	138.1	-	17.3	38.5
Grassy heath and bracken	414.2	-	198.9	330.2
Grassy heath and grassy heath and bracken	**552.3**	-	**216.3**	**368.7**
Shrubby heath	917.6	921.1	51.0	526.7
Shrubby heath and bracken	107.6	268.7	856.0	561.8
Shrubby heath and shrubby heath and bracken	**1025.1**	**1189.8**	**907.0**	**1088.6**
Dense bracken	**-**	**85.7**	**408.9**	**418.6**
Acid grassland	8.7	35.0	38.4	144.5
Acid grassland and bracken	622.4	827.1	537.2	147.9
Acid grassland and gorse	-	12.4	65.6	21.4
Acid grassland, bracken and gorse	**631.1**	**874.6**	**641.2**	**313.9**

Sinclair [Figure 3.2 and Table 3.4] shows no areas of dense bracken although he identifies areas of ‘grassy heath with bracken’ and ‘acid grassland with bracken’. Ellett

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[20] Following Ellett and treating the effective data as being 1973.

considers that there would have been areas of dense bracken in 1965 and that its absence is a function of Sinclair's mapping approach rather than real absence.

The total area of the 'bracken categories'[21] in Sinclair and in Owen and Tapper is in broad agreement at 1144 ha and 1181 ha, respectively, despite Owen and Tapper recording no 'grassy heath with bracken'. They also failed to record 'grassy heath' which Ellett suggests reflects their bias when mapping. The 'grassy heath' and 'grassy heath with bracken' areas identified by Sinclair, appear to have been subsumed into areas of 'shrubby heath with bracken' or 'acid grassland' by Owen and Tapper [Figure 3.3 and Table 3.5].

Comparison of the observations of Sinclair [Figure 3.2 and Table 3.4], Owen and Tapper [Figure 3.3 and Table 3.4], Ellett [Figure 3.4 and Table 3.4] and the FRCA [Figure 3.5 and Table 3.4] suggests recognisable trends in the communities.

Ellett points out that a direct comparison of the total areas of 'grassy heath' and 'grassy heath with bracken' found by Sinclair [552 ha] with that found by him [216 ha] suggests major decrease of in these communities over the intervening years. To what extent this is an artefact of Owen and Tapper's not recording these categories is not known, however the area recorded in the FRCA survey [368 ha] suggests that this trend, if real, has been reversed.

Examination of the 'acid grassland[22]' communities [Table 3.5] points to relatively stable levels followed by a contemporary decline. Both Sinclair and Ellett recorded similar levels at 631 ha and 641 ha, respectively. The intervening record by Owen and Tapper shows 875 ha, but if the view that they failed to record 'grassy heath' and 'grassy heath with bracken' is accepted, the actual levels in 1973 may well have been similar to those of Sinclair and Ellett. There appears to have been an overall decline in these categories since 1984: although 'acid grassland' seems to have increased to some 145 ha whilst 'acid grassland with bracken' has decreased to 148 ha. If this increase in acid grassland is the result of the bracken control measures, it is encouraging, particularly if the reduction of some 300 ha in the 'acid grassland' group can be explained by the increase of some 150 ha in the 'grassy heath' and some 180 ha in the 'shrubby heath' group

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[21] Shrubby heath with bracken, acid grassland with bracken, dense bracken, and grassy heath and bracken.

The overall levels of the ‘shrubby heath’ group [Table 3.5] have been maintained at around the 1000 ha level. However, the large increase in the ‘shrubby heath with bracken’ element’ between 1973 and 1984 ~ from 268 ha to 855 ha ~ appears to have been reversed with a fall between 1984 and 1995 to some 526 ha.

The area of ‘dense bracken’ rose from 85 ha in 1973 to some 408 ha in 1984. It is difficult to establish general rates of expansion of bracken for this period, though some pointers do exist. Work by Davies (2007)[23] showed a mean rate of advance of the order of 0.38m y^{-1} in the enclosed area of Belmore Ring, which is near the lower quartile of the range [0 -1.27 m y^{-1}] reported in Marrs and Watt (2006) for various areas of lowland heath and high moorland. By 1995 the levels appear to have been stabilised at around 418 ha.

Notwithstanding the various possibilities for error, overlaying the bracken control maps [Figures 2.2.7 and 2.2.8] onto the FRCA community map [Figure 3.5] suggested bracken continued its expansion in the period since the FRCA survey.

The areas sprayed in 2002 included obvious bracken areas; e.g. those categorised as ‘continuous bracken communities’ with, ‘grass understorey’, ‘heath understorey’, and ‘litter understorey’, respectively, but also held areas classed as ‘heath’ or ‘grass with heath’. Similarly the 2004 spraying included areas categorised as ‘heath’

The areas shown as cut in 2003, 2004, 2005 and 2006 suggest a somewhat stronger case since these repeated cutting operations took place on areas that the FRCA classified as ‘grass with scattered bracken’ albeit in areas adjacent to ‘dense bracken with litter understorey’.

The soligenous mire group[24] [Table 3.4] appears to have been relatively stable since Owen and Tapper at the 60-70 ha level and the apparent increase since Sinclair is unlikely to represent a real increase in flushing or wetland creation.

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[22] Acid grassland, acid grassland with bracken, and acid grassland with gorse.
[23] Carried out in the mid 1980s but not reported until 2007.
[24] Soligenous mire, and soligenous mire and acid grassland.

An obvious, albeit simplistic, conclusion from a comparison between the maps of Leach (1931) and the other surveys is that *Pteridium* has advanced from its former stronghold in the batches on to the upland areas of the plateau.

Much of the area of ‘acid grassland with bracken’ identified in the High Park area by both Sinclair (1965) and Owen and Tapper (1983) is shown as having been subsumed into areas of dense bracken by Ellet (1984) however the FRCA (1995b) survey shows much of this area to be ‘ grass with scattered bracken’ but where subsequently bracken cutting was carried out in the period between 2003 and 2006.

The area of the plateau classed as shrubby heath in Sinclair and Owen and Tapper appears as ‘shrubby heath with bracken’ in Ellet whereas the FRCA survey, although showing some parts as ‘continuous bracken with heath understorey, shows a considerable proportion as being ‘heath.’

The methodology of the FRCA survey is the closest to that advocated by Cherrill and McClean (1999a 1999b). The possibility of errors due to scale-dependent effects associated with the accuracy of the input data and also the accuracy of the ground information (Birnie *et al.*, 2000) are reduced to some extent by the comparatively small extent of the Long Mynd and the relative ease of ground truthing both boundaries and communities, although the potential for ‘between observer’ differences (Stevens *et al.*, 2004) may still exist.

Thus the FRCA survey is probably the most reliable of those considered although other data suggest there have been subsequent changes in vegetation cover as evidenced by some of the areas selected for bracken control. In a subsequent exercise Uff (personal communication) found that ‘quite a few’ of the ‘continuous bracken with litter understorey’ areas identified by FRCA on the steeper slopes had a ‘reasonable scattering of heath / grass underneath’.

Explaining this apparent increase in bracken is not easy. Marrs and Watt (2006) note the general increase of *Pteridium* in the UK, variously attributed to changes in grazing from cattle to sheep in Wales and the Highlands, a change from heavy wether sheep to lighter ewes in north Wales, reduction in severe winters, increase in nitrogen deposition and even the fall in the rabbit populations following myxomatosis.

Notwithstanding the general incidence of milder winters, it is likely that local influences have provided a greater effect. Bracken is susceptible to damage from trampling, both through damage to the emerging fronds, and by crushing or severing of the rhizomes (Pakeman and Marrs, 1992).

Accepting the 1965 Commons Registration claims of grazing rights for 1,146 ponies was unlikely to reflect the actual level of pre-war grazing; a ‘real’ exploitation level as low as 25% would still result in a large amount of trampling and bracken damage. The effect of the National Coal Board ending the use of ponies in pits was to reduce demand and there followed a huge reduction, indeed for practical purposes a cessation, in the practice of grazing ponies on the Long Mynd common.

These heavier types of grazers, ponies or cattle, have a greater effect on bracken than sheep, where their increased weight can provide deeper penetration through the turf or other surface vegetation and damage the underground structures, rhizomes etc.

The increase in post-war sheep stocking continued, and its effects in preventing regeneration in *Calluna* and other heathland species on the Long Mynd have been well documented, e.g. Coleshaw (1989), Jenkins and Anderson (2000). The consequences of overgrazing for bracken is less well known although Marrs and Watt (2006) cite Miles (1979) and note that overgrazing may lead to permanent replacement of *Calluna* by *Pteridium.*

Bracken generally expands through three basic means: consolidation of existing patches with rhizome spread from their edges, by colonisation of new areas through movement of rhizome fragments, e.g. by stock, or through dispersal of spores. It is unlikely that sheep hooves penetrate deeply enough to fragment rhizomes and spore release tends to be variable in both occurrence and extent. Marrs and Watt (2006) note there is little evidence of *Pteridium* spores being incorporated into diaspore banks.

Such consolidation and expansion from existing patches tends to support the Sinclair (1965) and Owen and Tapper (1983) maps [Figures 3.2 and 3.3] which indicated that the expansion started from existing bracken areas outside the Common or from batches within the Common.

Whatever the actual mechanism, it may be more than a coincidence that the period of greatest invasion by bracken [*cf.* Ellett (1984)] occurred at the same time as the greatest stocking levels on the hill, estimated at around 8.1 ewes/ha in the 1980s (Jenkins and Anderson, 2000) possibly reflecting Miles' (1979) claim that overgrazing may lead to permanent replacement of *Calluna* by *Pteridium.*

Under current climate warming and eutrophication scenarios expansion of bracken is likely to continue, increasing dominance in its current areas as well as expanding into currently unoccupied zones. The Pakeman and Marrs (1996) model demonstrated the potential for *Pteridium* to respond to environmental changes such as temperature and water availability. Werkman and Callaghan (1999) found that bracken reacted to increased nitrogen and higher temperatures with increased vigour, fronds emerged earlier in spring and senesced later in autumn. A 'pure' *Pteridium* canopy intercepted some 90% of the light (Werkman and Callaghan, 1999); which, together with an extended growing season makes bracken an even stronger competitor.

Werkman and Chapman (2002) used a different model to Pakeman and Marrs (1996) but reached a similar conclusion; heather would continue to be displaced by bracken in a warmer climate. In a slightly different context the Chapman *et al.* (2009) model also predicted warmer temperatures are likely to reduce dwarf shrub cover and increase bracken.

4 Sites, Materials and Methods

4.1 Sites

Sampling was carried out on the plateau, within the limits used by Smith (Smith, 2004), generally at locations with an altitude >400 m OD. Potential locations were based on the 1 km OS grid squares [1:25000 Pathfinder Map, Sheet SO 49/59] with additional intermediate points, based on a 250m x 250 m subsidiary grid within each grid square. Locations falling on major metalled tracks or car park areas were discarded, however any falling on ‘green’ tracks, generally sheep runs, were considered eligible to be used as a sample site or as part of one.

The grid points although not random in a formal sense, can be considered independent of the landscape, as were the locations from the subsidiary grid. However, the sample points used were selected in a somewhat subjective manner to provide comprehensive cover of most of the plateau with a bias towards the larger contiguous areas of vegetation , the ‘selective element strong enough to ensure adequate representation’ (Økland, 2007). The chosen sites all lay within a band running roughly north-east /south-west for a distance of ~5.2 kilometres, with a maximum west-east spread ~4.5 kilometres.

These sites, referred to as stands in the present study, were located in the field using a MAGELLAN GPS 300 receiver with a claimed accuracy of the order of ± 10 metres (approximate lateral error ±4%) based on at least four satellite signals. However, initial calibration and ‘ground truthing’ at the Pole Bank trig station (SO 341294) suggested a greater degree of precision, of the order of ±5 metres (approximate lateral error of ±2%). Stand locations and the plateau limits are displayed in Figure 5.1.1.

4.2 Stands

Økland (1990) maintained that any choice of plot size was a compromise between homogeneity, which implied the use of small plots and representivity, which suggested the use of large plots. In terms of homogeneity a plot should be small enough that it holds little variation along the most finely grained gradient of interest (Otypkova *et al.*, 2006), whereas in terms of representivity it should be large enough to enable reliable prediction of site conditions from the species composition. Økland (1990) suggests major gradients can be identified in grassland and alpine heaths using plot sizes of 0.25 m^2. He noted that whilst plots with <5 species may frequently behave poorly when subjected to ordination, representivity can be enhanced by including the full species composition of the vegetation [vascular plants, bryophytes and lichens] identified down to species level

In this work, basic plots (stands), were delineated using an approach developed from the system used by Hill and Jones (1978); this defined a stand encompassing 200 m^2; species cover abundance and environment factors were recorded for 20 (subsequently 21[25]) 0.25m^2 quadrats located as shown in Figure 4.2.1.

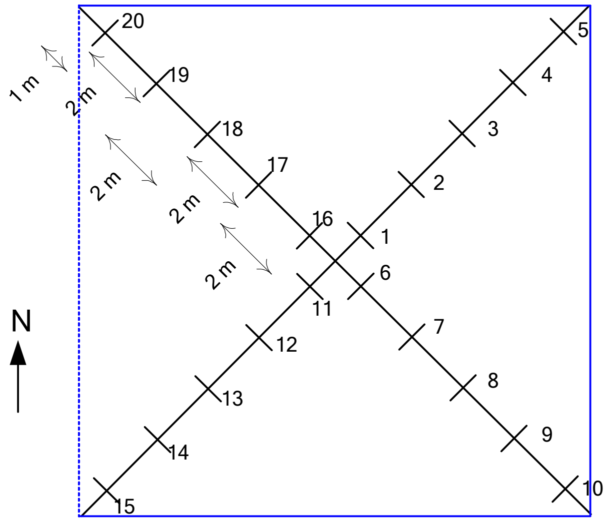

Figure 4.2.1. Quadrat location system [modified from Hill and Jones (1978)] showing orientation and location of sub-quadrats within the stand. The diagonals measure 10 m from the intersection to the tip and collectively enclose an area of 200 m^2. The positions and numbers of the quadrats on each diagonal are as indicated. A further quadrat, numbered 21, was later added, positioned at the intersection of the diagonals.

This allowed an aggregation of the cover values, based on a total area sampled within each stand of 5 m^2, subsequently 5.25 m^2, by taking a mean of the percentage cover values of each of the constituent species (subsequently converted to the Domin Scale), to give broad characteristics of each stand. The use of the individual 0.25 m^2 quadrats allowed the details of the mosaic and any fine scale variations within each stand to be explored.

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[25] The initial 10 stands were sampled using 20 quadrats and the subsequent 27 stands with 21 quadrats.

A central post with a ‘floating’ cruciform plate carrying the four locating cords was set up so the centre of the stand lay on the designated grid point. The position of the diagonal cords was adjusted until they lay north-east, south-east, south-west and north-west, respectively, and thus the stand was orientated north-south. A 0.25 m^2 tubular-frame quadrat was placed at each position on the diagonal, parallel to the cord and measurements and cover scores were made. A similar ‘small quadrat ‘ and analogous sample designation approach has been used by Burch (2008) in her work on post-burning regeneration of bryophytes on moorland.

4.3 Vegetation and environmental sampling

The angle of slope and aspect azimuth of each stand was measured using a Suunto compass-clinometer. Soil depth (top of litter layer to rock substrate) was measured for each quadrat using a probe, while quadrat canopy height was assessed against a metre rule. Cover abundance for all vascular plants, bryophytes and lichens in each quadrat were recorded by species and estimations of bare soil, bare rock, litter and, where appropriate, open water, were also made.

Subsequently soil samples were taken from five quadrats within each stand [quadrats 5,10,15,20 and 21] for pH determination where the litter layer was discarded and the organic layer and mineral soil sampled to trowel depth (~20 cm). Samples were processed at the end of each session using the National Trust schools laboratory in Carding Mill Valley. Soil pH was measured using a HANNA Model 8521 meter and glass electrode, which was calibrated with standard buffers before use. A standard volume of soil from each sample was added to three equivalent volumes of distilled water, stirred with a glass rod and the suspension allowed to settle. The process was repeated with the remaining four samples from the stand. Readings were taken from each of the five suspensions and these were used to calculate a mean pH value for the stand.

Cover abundance values were recorded as percentage values for convenience and were converted to a standard Domin Score[26] as shown in Table 4.3.1 below. See also Section 4.4.1.

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[26] Rodwell (1991) version used for compatibility with modern practice.

Table 4.3.1. Percentage cover scores and their Domin equivalents (taken from Rodwell, 1991)

Plant cover	Domin
<4% with few individuals	1
<4% with several individuals	2
<4% with many individuals	3
4 -10%	4
11 - 25%	5
26 - 33%	6
34 – 50%	7
51 – 75%	8
76 – 90%	9
91 – 100%	10

Following their use in the NVC, e.g. Rodwell (1991) and later recommendations (Rodwell, 2006), Domin scores have been regarded as the ‘standard’ for use in NVC community description as well as being used with multivariate analyses in other work e.g. Angold (1997), Yeo *et al.* (1998), Mulder and Janssen (1999) and Vandvick *et al.* (2002).

There has been a recent interchange between Podani (2006), Ricotta and Avena (2006), van der Maarel (2007) and Podani (2007) regarding the validity of using ‘conventional’ multivariate analysis methods on data scored using Braun-Blanquet and similar ordinal scales.

Podani (2006) took the view that since abundance / dominance (AD) values express performance on an ordinal scale on which differences are not interpretable, using these with Principal Component analysis and variants of Correspondence Analysis is not appropriate.

van der Maarel (2007) acknowledged Podani’s (2006) assertion that it was ‘basically inappropriate to use ordinal scale values in numerical analyses’, but argued that ‘mathematical elegance should be pursued with ecological common sense’ and that numerical analysis of vegetation data can be mathematically acceptable if ordinal data are converted to an appropriate metric scale [*cf*. van der Maarel (1979)].

It can also be argued that the Domin scale, is not ordinal but a ‘quasi’ metric scale and as such meets van der Maarel’s (1979) requirements for use in Correspondence and similar analyses.

4.4 Data analysis

4.4.1 Stand Classification

Classification of the first 10 stands sampled was carried out using TWINSPAN – **Tw**o-way **in**dicator **sp**ecies **an**alysis (Hill, 1979) as implemented in the VESPAN lll package (Malloch, 1997), and these results were used in Musgrove (2001).The choice of scoring systems ~ cover abundance (percentage / Domin) as opposed to simple presence/absence ~ was compared by analysing the original Domin data set and a derived presence/absence set.These analyses[27] suggested that whilst presence/absence scoring would be appropriate in classifying communities for mapping purposes, Domin scoring was superior in giving a fuller picture of the dynamics driving the classification and so this approach was retained. It had been suggested that given the likely nature of the vegetation on the plateau, the numbers of quadrats scored in each stand could be reduced without appreciable loss of information. To test this premise, the Domin scored data set was divided into two, based on the 'odd numbered' and 'even numbered' quadrats and these subsets were analysed using Twinspan[28]. Comparing the two outputs suggested that information would be lost if the number of quadrats was reduced therefore it was decided to retain the original numbers; in fact for subsequent stands an additional quadrat ~ number 21, was added at the 'central' position [see Figure 4.2.1].

Hill and Smilauer released Twinspan for Windows [WinTWINS] in 2005 and the final classifications were made using this software. Comparisons were made between the results from the TWINSPAN and the WinTWINS analyses of the initial 'all species' data set and no significant differences were evident.

The initial process in TWINSPAN / WinTWINS produces a dichotomy which takes place in several stages (Hill and Smilauer, 2005).

- A direction of variation in the data is identified by carrying out an ordination on the samples; the first axis of this ordination – the primary ordination - is made using reciprocal averaging [correspondence analysis].

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[27] See Appendix 1.
[28] See Appendix 2.

- The resulting ordination is divided at its centre to make a crude dichotomy of the samples.
- Differential species are identified, *viz*. species which are preferential to one side or the other of the crude dichotomy i.e. those species and pseudospecies (see below) that are at least twice as likely to occur on one side of a division.
- An improved ordination, the refined ordination, is derived from the primary ordination through the identification of the differential species, and is divided at an appropriate point to derive the desired dichotomy.
- This process is repeated separately for the two groups resulting from the dichotomy Subsequent dichotomies are carried out until a user determined cut off point, is reached or until there are insufficient data to enable further divisions to be made.

These calculations are based on species presence–absence data and in order to incorporate quantitative differences in cover, the concept of ‘pseudospecies’ was developed (Hill *et al.*, 1975). This treats a species occurring at different levels of abundance, as being different species i.e. to be a ‘pseudospecies; these are defined by a minimum abundance of the species ~ the cut level. The default cut levels In WinTWINS are, 0-4% [1], 5%-25% [2], 26%-50% [3], 51%-75% [4] and 76%-100% [5]. Pseudospecies levels are accumulative; a species present at pseudospecies level 3 is, by definition, also present at levels 1 and 2 and a species present at pseudospecies level 5 is also present at levels 1, 2, 3 and 4.

The output from Twinspan / WinTWINS gives tables lists of dichotomies, indicators, and preferentials etc. for each division (from which dendrograms can be constructed) as well as an ordered two way table.

The data were analysed using the WinTWINS default options viz; 4 cut levels, 0,2,5 and 10, all with a weighting of 1. The maximum number of divisions was set at 6, with a minimum number of 5 occurrences in a group for division and a maximum of 7 indicators per division. In the majority of analyses no divisions past 5 were subsequently used.

4.4.2 Stand Ordination

Ordination is a generic term for those multivariate techniques that arrange samples along axes on the basis of species data; the result is a diagram where points which are close together are similar in species composition and those far apart are dissimilar in species composition (ter Braak, 1995).

Initial analyses made using *DECORANA* [**DE**trended **COR**respondence **AN**alysis and **R**eciprocal **A**veraging][29] (Hill and Gauch, 1980). Subsequently, CANOCO [**CANO**nical **C**ommunity **O**rdination] for Windows 4.5 (ter Braak and Smilauer, 2002a) was adopted.

CANOCO implements a series of indirect (unconstrained) gradient analysis routines including DCA [Detrended Correspondence Analysis] and PCA [Principal Component Analysis] as well as direct (constrained) techniques such as CCA [Canonical Correspondence Analysis – a constrained DCA] and RDA [Redundancy Analysis – a constrained PCA].

PCA and DCA detect different types of structure in the data. PCA is appropriate to a linear response model where the abundance of any species varies with variations in the latent environmental variables (ter Braak, 1995), whereas DCA is appropriate to a unimodal response model where any species occurs in a limited range of values for each of the latent environmental variables (ter Braak, *ibid*).

The data were initially examined using indirect gradient analysis, DCA, which in addition to providing an initial overview, indicated the suitability of subsequent analysis methods. As with the WinTWINs analyses in 4.4.1, Canoco analyses were carried out using Domin scores for species cover. DCA analyses were undertaken using the rescaling by segments option, there was no transformation of species data, no species-weights or sample-weights were specified and there was no downweighting of rare species. There was no rescaling of axes.

The output log provides a table which gives the ‘Lengths of the Gradients’ found in the analysis, e.g.

	Axis 1	Axis 2	Axis 3	Axis 4
Lengths of gradient	5.906	4.334	4.217	5.174

Gradient lengths are measures of the ‘beta diversity’, the extent of species turnover along individual ordination axes. If the largest gradient length exceeds a value of 4, unimodal methods, DCA, CA [Correspondence Analysis] or CCA, are suitable for

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[29] As implemented in the Vespan lll package (Malloch, 1997).

subsequent analyses, whereas a gradient length <3, suggests the linear approach is appropriate (Lepš and Smilauer, 2003).Subsequent analyses used constrained techniques, where measures of environmental parameters [Section 3.3] were used as constraining [explanatory] variables.

In these CCA analyses the ordination scores were scaled using the ‘Hills scaling’ option; there was no transformation of species data, no species-weights or sample-weights were specified and there was no downweighting of rare species.

The environmental parameters, litter, open water, bare rock, canopy height and soil depth were measured in each quadrat and the remainder, grid reference [northing and easting], altitude, aspect [southness and westness] and pH were established for the entire stand and then attributed to each quadrat in the stand.

CANOCO has a facility, the Monte Carlo Permutation Tests, to test the significance of constrained ordination models. These assume a null hypothesis that the species data are unrelated to the environmental data, and an alternative hypothesis that species respond to the environment (ter Braak and Smilauer, 2002b).

Leps and Smilauer (2003) described the process:

- A ‘permutation’ randomly shuffles the rows of the environmental variables data table whilst keeping the species data table intact. If the null hypothesis is correct, any combination of species and environmental data is as probable as the ‘real’ data.
- The constrained ordination model is calculated for each of these ‘permutation data sets’ and a ‘test statistic’ produced. This is akin to the ‘*F* statistic’ used in regression models and operates on the variance explained by the first canonical axis.
- The value of this statistic is recorded for each ‘permutation’ and the distribution of these values defines their distribution under the null model.
- If it is highly probable that the test statistic value from the ‘real’ data set comes from that distribution we can accept the null hypothesis. The probability that the ‘real data’ value originates from the calculated null model, represents the probability of rejecting a correct null hypothesis.

Where forward selection was used it was implemented in ‘manual’ mode, parameter by parameter using the default (499) permutations level; any parameter whose significance level was >0.020 was discarded. CANOCO also has the facility to remove variation in the data set which can be explained by variables of known effect, and also those whose effect is of no interest, before ordination (ter Braak and Smilauer, 2002b). Such variables of known effect are selected as co-variables.

4.4.3 NVC Categorisation

Categorisation of the Endgroups into their NVC communities was facilitated by *MATCH* (Malloch, 1998). NVC communities are characterised by the frequency of occurrence of each species, their constancy and the range of cover-abundance (on the Domin scale) of that species (Malloch, 1998). Each community or subcommunity will have a unique constancy profile with species of high constancy (V and IV) which together form the best diagnostic features for that community. Species having lower constancies may be found in a wider range of communities, or be of high constancy in other communities.

Constancy tables of the species in each endgroup were produced using the Table function in VESPAN lll and these data were used as input for the MATCH routine. MATCH compares the constancy profile from these data with the constancies profile of those established in the NVC communities, to produce the 10 best ‘matches’ against the NVC profiles. Since these communities may have subcommunities, the program compares the entered data with the diagnoses of the subcommunities for the selected communities.

MATCH provides a list of the 10 NVC communities most closely matching the test data, with the option to provide details of their constancy class and maximum cover values compared to those from the input data. Major discrepancies between the two lists are indicated. A second option provides similar details for the subcommunities within a given community. Species present in the sample, but not in the communities, are also indicated.

MATCH diagnoses do not identify the samples to a given community (Malloch, 1998) but merely provides pointers to the most likely possibilities, thus enabling comparisons to be made with the ‘standard’ communities characterised in the appropriate volumes of British Plant Communities (Rodwell, 1991; Rodwell, 1992).

4.4.4 Geographic Information Systems.

The majority of mapping used in this investigation was based on industry standard Geographic Information Systems [GIS]. Two systems were involved; the University of Wolverhampton System is ArcView 3.3[30] (E.S.R.I., 2002), whilst the National Trust used successive versions [V6.0, V7.0 and V8.0] of the MAPINFO system (MAPINFO Corporation, 2001).

Where required, MAPINFO format files were converted to the Arcview format using the MIFSHAPE Utility (E.S.R.I., 2002) and field data for use in Arcview were processed in CARTALINX (Clarke Labs, 1999). The mapping is based on 1:25000 contour ‘tiles’ from the Ordnance Survey which are used under licence.

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[30] Subsequently upgraded to ArcGIS 9 but this investigation continued to use Arcview 3.3 to maintain continuity with the system.

5 Analysis of Quadrat Data

5.1 Quadrats in the landscape

The sites of the stands described earlier [See section 4.1.] are displayed in Figures 5.1.1 and the two principal environmental parameters measured for each stand [See 3.3], pH and soil depth are displayed in Figures 5.1.2 and 5.1.3

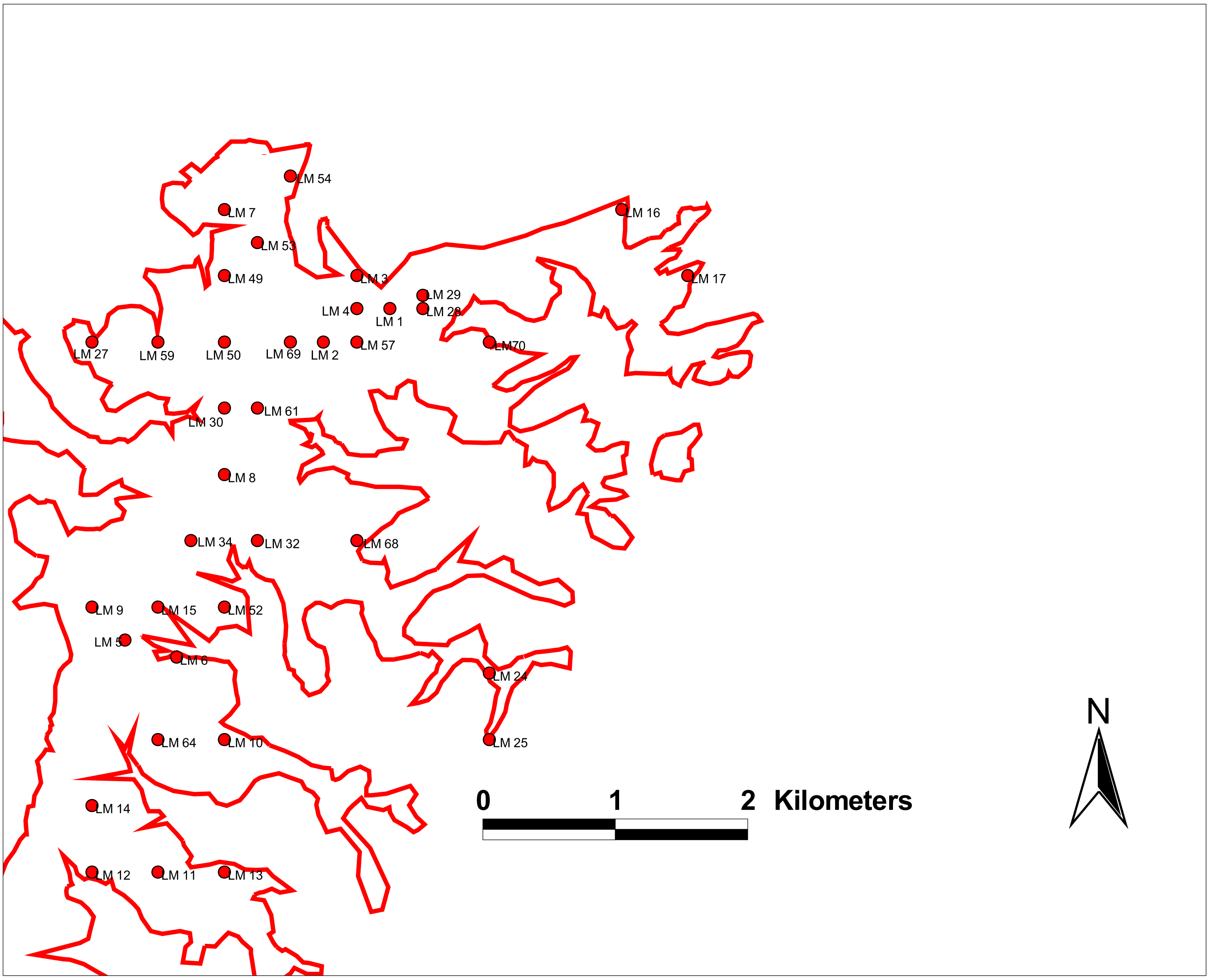

Figure 5.1.1. Location and Designation of stands.

Base maps removed to ensure copyright compliance

Plateau boundary

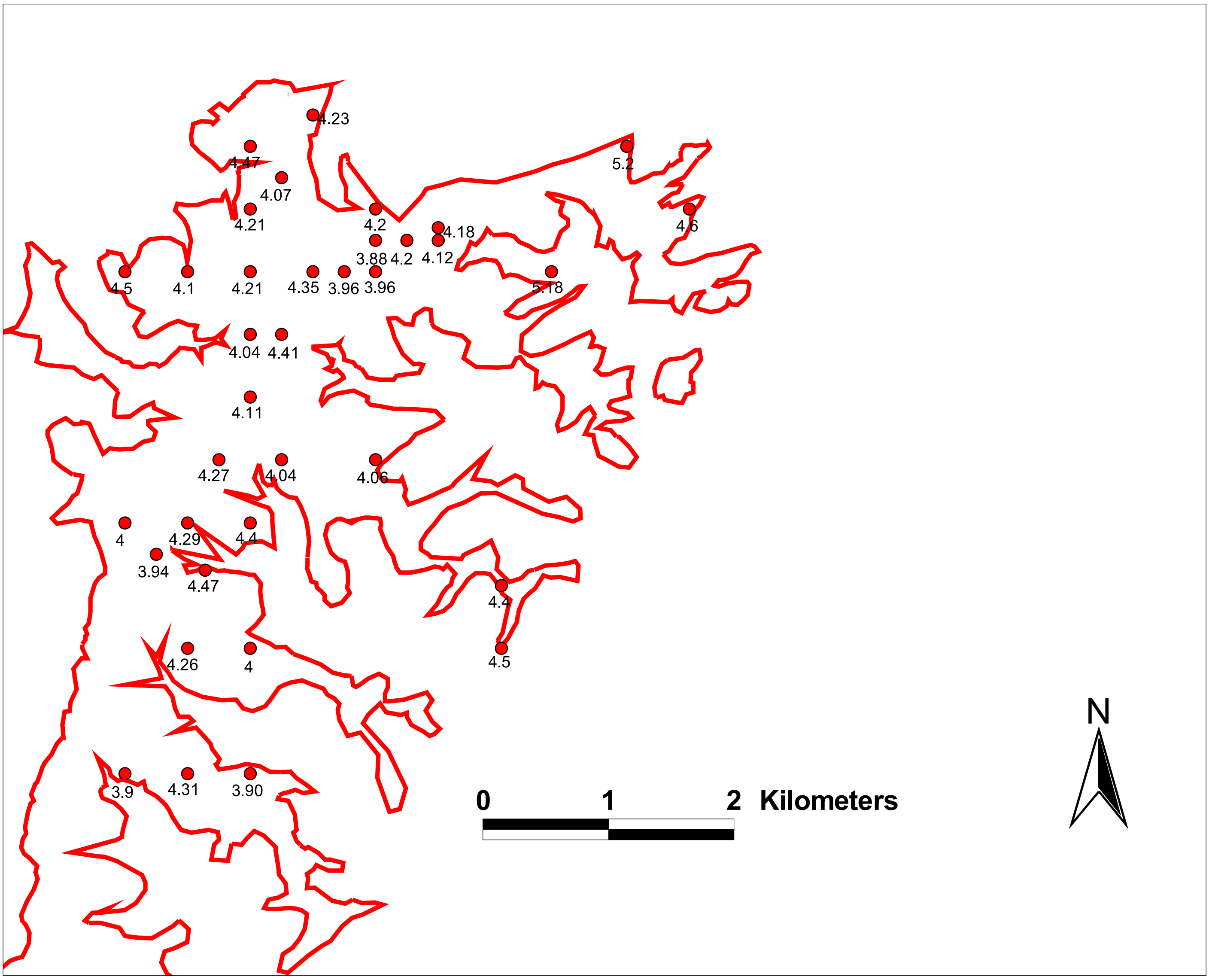

Figure 5.1.2. Mean soil pH (n=5) at stands

Base maps removed to ensure copyright compliance

Plateau boundary

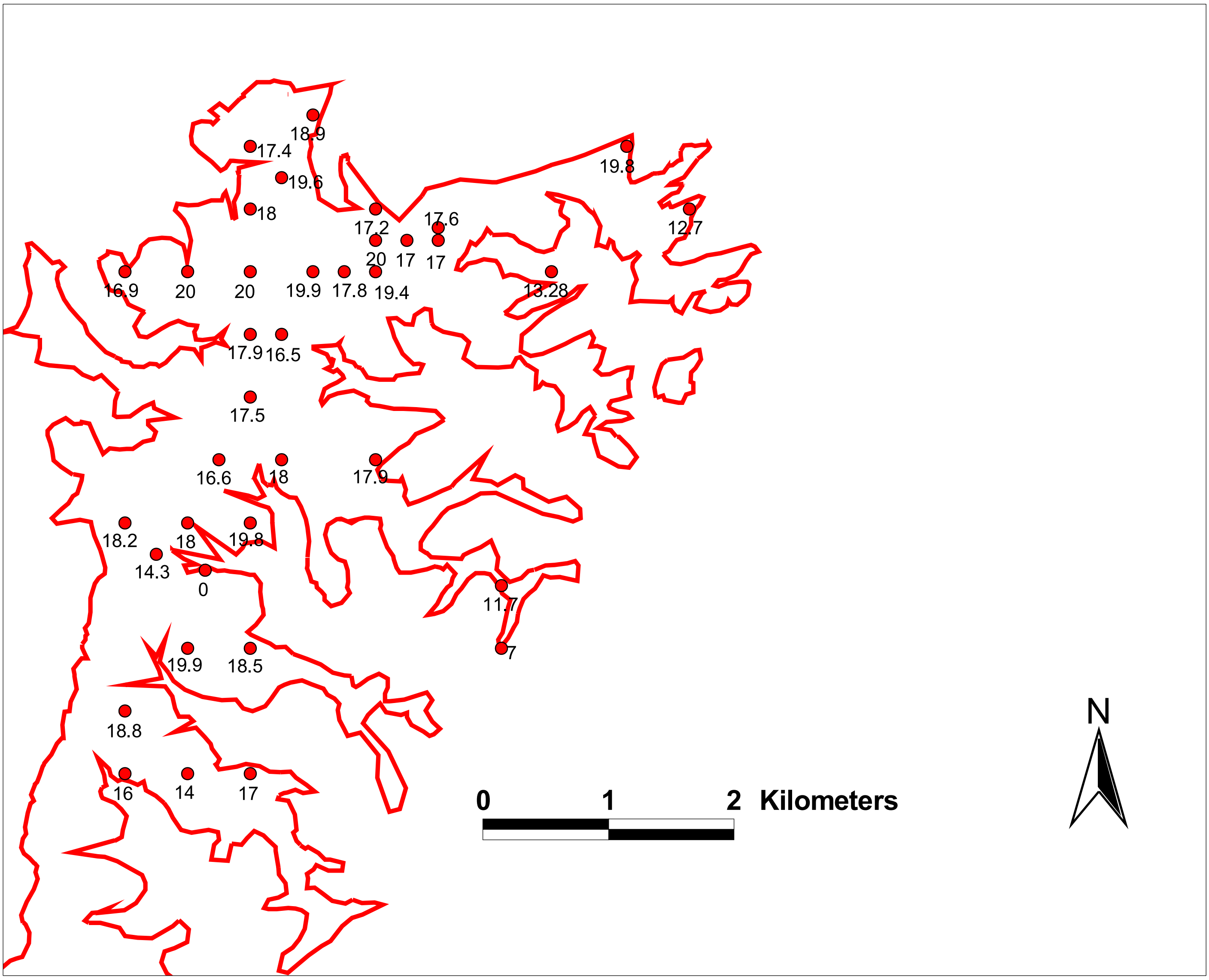

Figure 5.1.3. Soil depth at the stands. Maximum depth recorded 20cm.

Base maps removed to ensure copyright compliance

Plateau boundary

Table 5.1.4. Species abbreviations are used in WinTWINS dendrograms and CANOCO plots. The vascular taxonomy follows Stace (1997), bryophyte taxonomy follows Hill *et al.* (2007) and lichen taxonomy (Hawksworth, 2003)

Agro stol	*Agrostis stolonifera*	Care viri oedo	*Carex viridula* ssp *oedocarpa*	Moli caer	*Molinia caerulea*
Agro capi	*Agrostis capillaris*	Circ sp.	*Cirsium* seedling	Mont font	*Montia fontanum*
Agro vine	*Agrostis vinealis*	Dant decu	*Danthonia decumbens*	Myos secu	*Myosotis secunda*
Alop geni	*Alopecurus geniculatus*	Erio angu	*Eriophorum angustifolium*	Nard stri	*Nardus stricta*
Achi ptar	*Achillea ptarmica*	Eleo quin	*Eleocharis quinquefolia*	Nart ossi	*Narthecium ossifragum*
Aira prae	*Aira praecox*	Erio vagi	*Eriophorum vaginatum*	Oxal acet	*Oxalis acetosella*
Anag tene	*Anagallis tenella*	Fest rubr	*Festuca rubra*	Plan lanc	*Plantago lanceolata*
Desc flex	*Deschampsia flexuosa*	Eleo mult	*Eleocharis multicaulis*	Poa annu	*Poa annua*
Dryo dila	*Dryopteris dilatata*	Fest ovin	*Festuca ovina*	Poa humi	*Poa humilis*
Anth odor	*Anthoxanthum odoratum*	Gali palu	*Galium palustre*	Poa prat	*Poa pratensis*
Desc cesp	*Deschampsia cespitosa* ssp *cespitosa*	Gali saxa	*Galium saxalite*	Poa triv	*Poa trivialis*
Cyno cris	*Cynosurus cristatus*	Holc moll	*Holcus mollis*	Pote erec	*Potentilla erecta*
Bell pere	*Bellis perennis*	Glyc decl	*Glyceria declinata*	Prun sp.	*Prunus* seedling
Call vulg	*Calluna vulgaris*	Holc lana	*Holcus lanatus*	Prun vulg	*Prunella vulgaris*
Care pilu	*Carex pilulifera*	Junc squa	*Juncus squarrosus*	Pter aqui	*Pteridium aquilinum*
Care echi	*Carex echinata*	Junc bulb	*Juncus bulbosus*	Ranu acri	*Ranunculus acris*
Care flac	*Carex flacca*	Junc cong	*Juncus conglomeratus*	Ranu flam	*Ranunculus flammula*
Dryo fili	*Dryopteris filix-mas*	Luzu pilo	*Luzula pilosa*	Ranu repe	*Ranunculus repens*
Card prat	*Cardamine pratense*	Junc arti	*Juncus articulatus*	Rsella	*Rumex acetosella*
Camp rotu	*Campanula rotundifolia*	Junc acut	*Juncus acutiflorus*	Rtosa	*Rumex acetosa*
Care nigr	*Carex nigra*	Junc effu	*Juncus effusus*	Sagi proc	*Sagina procumbens*
Care pani	*Carex panicea*	Leon saxa	*Leontodon saxatilis*	Sorb aucu	*Sorbus aucuparia*
Cera font	*Cerastium fontanum*	Leon autu	*Lotus autumnalis*	Trif repe	*Trifolium repens*
Cirs palu	*Cirsium palustre*	Lotu corn	*Lotus corniculatus*	Vacc myrt	*Vaccinium myrtillus*
Care puli	*Carex pulicaris*	Luzu camp	*Luzula campestris*	Vero scut	*Veronica scutellata*

Aneu ping	*Aneura pinguis*
Aula palu	*Aulacomnium palustre*
Brac ruta	*Brachythecium rutabulum*
Call cusp	*Calliergonella cuspidata*
Camp intr	*Campylopus introflexus*
Cera purp	*Ceratodon purpureus*
Dicr hete	*Dicranella heteromalla*
Dicr maju	*Dicranum majus*
Dicr scop	*Dicranum scoparium*
Eurh prae	*Eurhynchium praelongum*
Hylo sple	*Hylocomium splendens*
Hypn cupp	*Hypnum cupressiforme*
Hypn jutl	*Hypnum jutlandicum*
Loph sp.	*Lophocolea* sp.
Mniu horn	*Mnium hornum*
Palu comm.	*Palustriella commutata*
Phil font	*Philonotis fontanum*
Plagmn undu	*Plagiomnium undulatum*
Plagth undu	*Plagiothecium undulatum*
Pleu schr	*Pleurozium schreberi*
Poly form	*Polytrichum formosum*
Poly juni	*Polytrichum juniperinum*
Poly pili	*Polytrichum piliferum*
Ptil cili	*Ptilidium ciliare*
Rhyt squa	*Rhytidiadelphus squarrosus*
Scle puru	*Scleropodium purum*
Spha capi	*Sphagnum capillifolium*
Spha palu	*Sphagnum palustre*
Spha recu	*Sphagnum recurvum*
Spha sub	*Sphagnum subnitens*

Hypo phys	*Hypogymnia physodes*
Clad sp.	*Cladonia* sp.

5.2 WinTWINS analyses

Analyses were undertaken on four data sets: the original ‘all species’ set and three derived selections: ‘vascular plant species’, ‘bryophyte and lichen’ species and ‘stands.’

Appropriate species were removed from an ‘all species’ set to leave each derived set. The removal of the ‘bryophyte and lichen‘ species isolated the ‘vascular species’ in one set and also removed four quadrats, whose only vegetation cover was bryophytes and lichens, to leave 763 quadrats in the set. In a similar way, removing those quadrats where the only cover was vascular species reduced the number of quadrats available to 630.

The mean scores of all species in the quadrats in each stand were used to used to give an overall characterisation of that stand in the ‘stands’ data set.

5.2.1 ‘All species’ analyses

The number of species present in each quadrat fell within the range 1–18 with a mean of 4.87; the distribution is given in Figure 5.2.1.

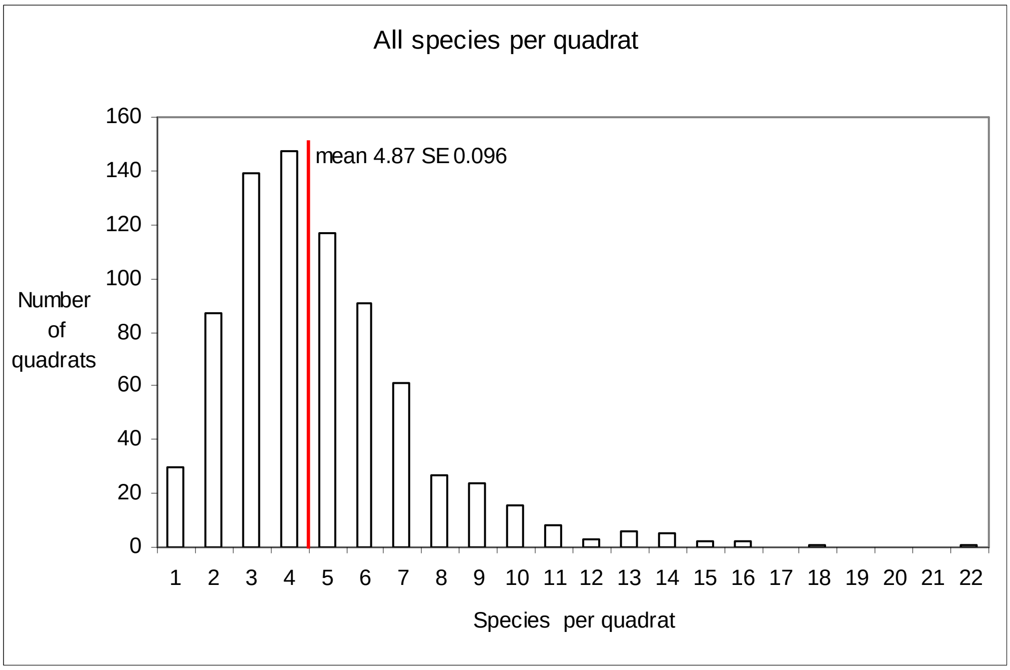

Figure 5.2.1. Number of species present in quadrats in the ‘all species’ data set.

Figure 5.2.2 shows the distribution of quadrats and end groups for this analysis. The initial division of the 767 quadrats allocates 52 to the first level positive Group 1 (characterised by the indicator species *Nardus stricta* [1] [31], *Carex echinata* [1], *Juncus bulbosus* [1] and *Calliergonella cuspidata* [1]) with the balance (715 quadrats) allocated to the first level negative Group 0 (characterised by the indicator species *Calluna vulgaris* [2] and *Vaccinium myrtillus* [2]).

These species suggest an initial separation between 'wetland' communities forming Group 1 and those containing the typical heathland/grassland/bracken vegetation characteristic of these uplands. The quadrats allocated to Group 1 all fall within three stands (90% ~LM6, 100% ~LM16 and 65% ~LM70) and no further divisions were undertaken on this group.

The division of the negative Group 0 allocates 149 quadrats to the second level positive Group 01 and 566 to the second level negative Group 00. The positive indicator species associated with this division were: *Agrostis capillaris* [1], *Galium saxatile* [1], *Rhytidiadelphus squarrosus* [2] *Rumex acetosella* [1], and *Festuca ovina* [2], and the negative indicators were *Calluna vulgaris* [3] and *Vaccinium myrtillus* [2]. These suggest a separation of predominantly grassy communities from heath communities.

The second level negative Group 00 division places 304 quadrats to the negative group 000 and 262 quadrats to positive Group 001. The indicator species (negative ~*Calluna vulgaris* [3] and positive ~*Pteridium aquilinum* [1], *Pleurozium schreberi* [1], *Vaccinium myrtillus* [3] and *Rhytidiadelphus squarrosus* [1]) may be seen as describing a separation between the 'archetypal' *Callunetum* areas and the heathland mosaic with substantial amounts of other species, notably bracken.

The positive Group 01 dichotomy splits off a small group of 26 quadrats to the positive Group 011 (indicator species *Aira praecox* [1] and *Dicranum scoparium* [1]) and the balance (123 quadrats) are diverted to the negative Group 010 (indicator species *Rhytidiadelphus squarrosus* [2]). Group 011 holds 100% of stand LM25, 10% of stands LM17 and LM24 and 5% of LM64; the indicators point to differentiating conditions (perhaps open areas with drier, shallower soils) which isolate these quadrats from the balance of the 'grassy heath' group.

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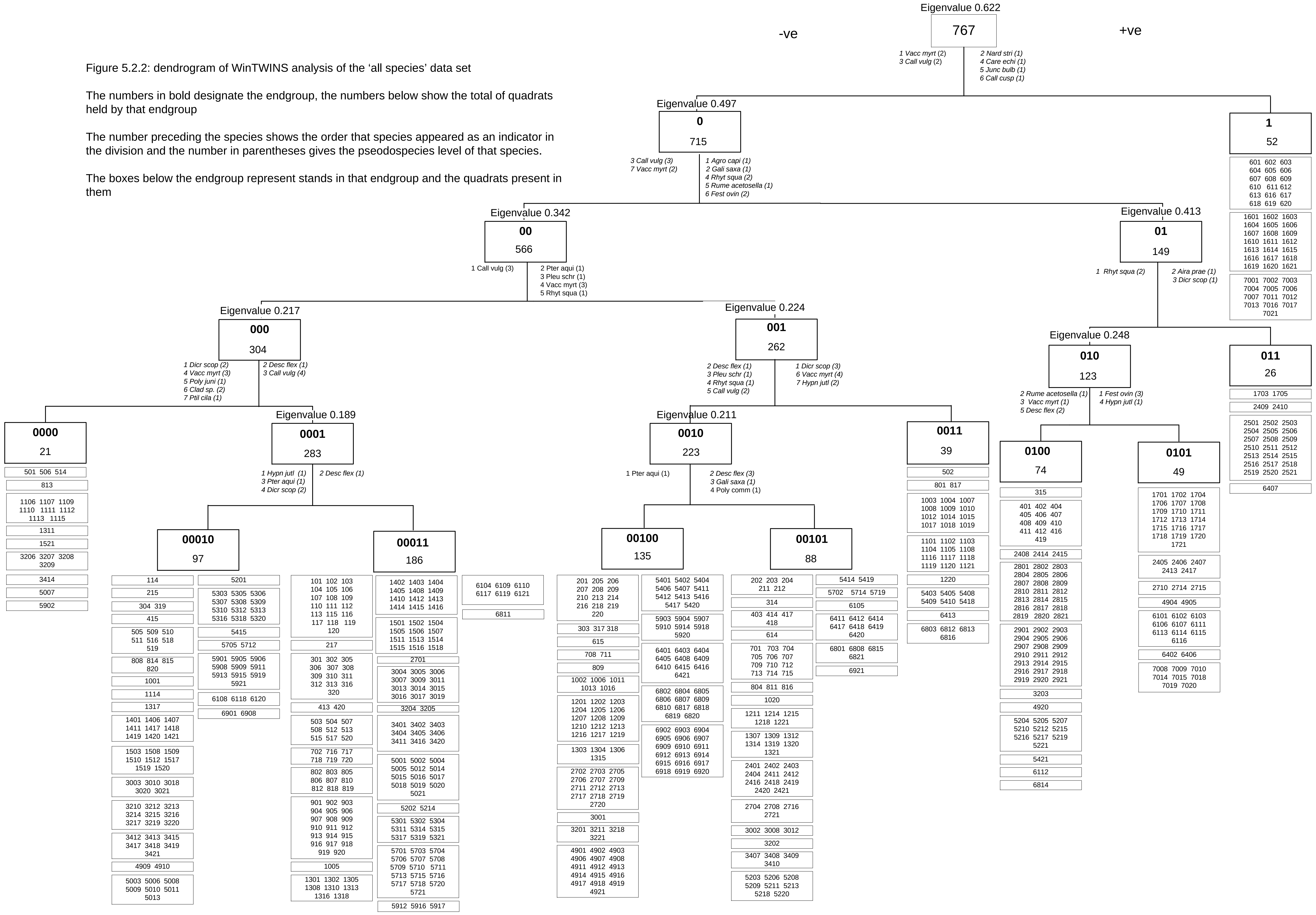
[31] Figure in square brackets represents the pseudospecies level of that indicator species.

Figure 5.2.2: dendrogram of WinTWINS analysis of the ‘all species’ data set

The numbers in bold designate the endgroup, the numbers below show the total of quadrats held by that endgroup

The number preceding the species shows the order that species appeared as an indicator in the division and the number in parentheses gives the pseudospecies level of that species.

The boxes below the endgroup represent stands in that endgroup and the quadrats present in them



Partition of the negative Group 000 allocates 21 quadrats to the negative Group 0000 and 283 quadrats to the positive Group 0001, respectively. The negative indicator species (*Dicranum scoparium* [2]*, Vaccinium myrtillus* [3], *Polytrichum juniperinum* [1] *Cladonia* sp*.* [2] and *Ptilidium ciliare* [1]) for this group point to a more open heathland shrub community with an understorey of lichens and mosses whereas the positive indicator species (*Deschampsia flexuosa* [1] and *Calluna vulgaris* [4]) are indicative of heath dominated by *Calluna.*

Subsequent division of Group 0001 diverts 97 quadrats to the negative Group 00010 and the remaining 186 quadrats to the positive Group 00011. *Hypnum jutlandicum* [1] *, Pteridium aquilinum* [1] and *Dicranum scoparium* [2] act as indicators for the negative group and suggest areas of heathland where bracken is encroaching, as opposed to the 'core heathland' suggested by its indicator *Deschampsia flexuosa* [1].

The Group 001 division allocates 223 quadrats to the negative Group 0010 and the balance, 39 quadrats, to the positive Group 0011. This is dividing the bracken invaded areas into those which retain a significant *Calluna* component (indicators *Deschampsia flexuosa* [1], *Pleurozium schreberi* [1] *Rhytidiadelphus squarrosus* [1] and *Calluna vulgaris* [2]) from those where *Calluna* is largely absent (indicators *Dicranum scoparium* [3], *Vaccinium myrtillus* [4] and *Hypnum jutlandicum* [2]. Whilst not an indicator species, bracken is ubiquitous as a non-preferential species[32] throughout the group and although *Vaccinium* appears as positive indicator at pseudospecies level 4, it also occurs as a non-preferential species at pseudospecies levels 1[33] (199,38), 2 (194,35) and 3 (151,30).

The division of Group 0010 directs 135 quadrats to the negative Group 00100 and 88 quadrats to the positive Group 00101. These Groups are characterised by the negative indicator species *Pteridium aquilinum* [1] and the positive indicator species *Deschampsia flexuosa* [3], *Galium saxatile* [1] and *Polytrichum commune* [1]. This separates the *Callunetum* quadrats with encroaching *Pteridium* from those where *Pteridium* is largely absent. *Calluna* [1(66,34), 2(66,34), 3(53,24)] and *Vaccinium* [1(117,80), 2(114,80), 3(87,64)] are non-preferential as are *Pleurozium schreberi* [1(67,44), 2(64,420), 3(22,24), *Rhytidiadelphus squarrosus* [1(64,41), 2 (59,40)] and *Hypnum jutlandicum* [1(45,29),

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[32] *Pteridium aquilinum* 1(131, 20), 2(139, 20), 3(90,17).

[33] The figures in parentheses represent the number of quadrats where the pseudospecies is present on the negative and positive sides of the division.

2(40,28)]. Despite acting as a positive indicator at pseudospecies level 3, *Deschampsia* is also a non-preferential at levels 1(83,81) and 2(59,40).

When Group 010 is divided 74 quadrats go to the negative Group 0100 (indicators, *Rumex acetosella* [1], *Vaccinium myrtillus* [1], and *Deschampsia flexuosa* [2]) and 49 quadrats to the positive Group 0101 (indicators *Festuca ovina* [3] and *Hypnum jutlandicum* [1]) This separation is between the grassy heath areas and grassland areas.

This initial separation in the analysis isolates a group of 'wetland' quadrats [Group 1] from the main body of quadrats which are themselves subsequently divided into two broad groups; as an approximation, these can be described as being heath [Group 00] and acid grassland [Group 01]. The 'major group, 00, separates into what may be considered classic shrubby heath [Group 000] or heath which is degrading [Group 001] and subject to bracken encroachment. This latter group subsequently divides to isolate another shrubby heath group from a tranche which later separates into areas where *Pteridium* is invading the shrubby heath from those where it is largely absent. The second major group, 01, isolates two groups of quadrats and subsequently divides the larger one into what appears to be two sub-communities within the same NVC category.

5.2.2 'Vascular plant species' analyses

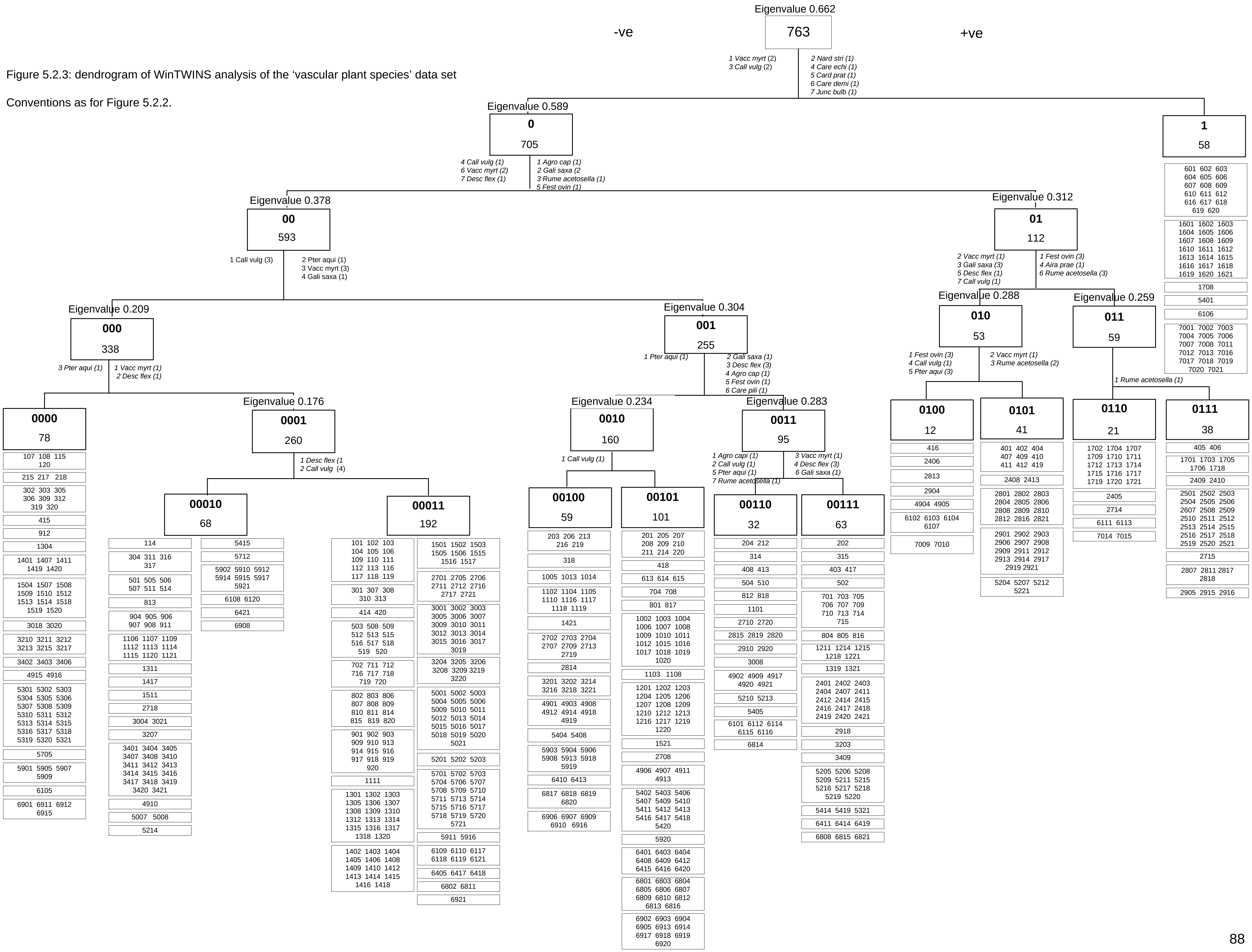
Of the 767 quadrats considered in the all species set [Figure 5.2.2], four held no vascular species thus reducing the number of quadrats available for the WinTWINS analysis to 763. The dendrogram shown as Figure 5.2.3 displays the results from this analysis.

In the principal dichotomy, 705 quadrats are allocated to Group 0 leaving the remaining 58 in Group 1. The negative indicators (*Vaccinium myrtillus* [2] and *Calluna vulgaris* [2]) characterise the 705 Group 0 quadrats as 'heathland', whilst the positive indicators (*Nardus stricta* [1]*, Carex echinata* [1]*, Cardamine pratense* [1] *, Carex viridula* ssp. *oedocarpa* [*demissa*] [1] and *Juncus bulbosus* [1]) show that Group 1 consists of 'wetland' or 'wetland fringe' quadrats'.

Group 0 divides to allocate 593 quadrats to the negative Group 00 (characterised by *Calluna vulgaris* [1]*, Vaccinium myrtillus* [2] and *Deschampsia flexuosa* [1]) and 112 quadrats to the positive Group 01 (characterised by *Agrostis capillaris* [1] *Galium saxatile* [2]*, Rumex acetosella* [1] and *Festuca ovina* [1]).These indicators suggest a separation between 'true heath' and either grasslands or heath significantly affected by expansion of grassland communities.

Figure 5.2.3: dendrogram of WinTWINS analysis of the ‘vascular plant species’ data set

Conventions as for Figure 5.2.2.



Division of Group 00 sends 338 quadrats to Group 000 and the remaining 255 to Group 001. As the negative indicator species is *Calluna vulgaris* [3]*,* with *Pteridium aquilinum* [1]*, Vaccinium myrtillus* [3] and *Galium saxatile* [1] as positive indicators; this separation appears to be between the 'heath' communities on the negative side from the bracken invaded heath of the positive side. *Deschampsia flexuosa* is present as a non-preferential at levels 1(164,172) and 2(163,164) and, notwithstanding its role as a positive indicator (at pseudospecies level 3), *Vaccinium* is also present as a non-preferential at levels 1 (239,224) and 2(239,220).

The second level positive Group 01 splits to send 59 quadrats to group 011 and the remaining 53 quadrats to Group 010. The positive indicators, *Festuca ovina* [3], *Aira praecox* [1] and *Rumex acetosella* [3] suggest dry open grassland areas whist the negative indicators *Vaccinium myrtillus* [1]*, Galium saxatile* [3], *Deschampsia flexuosa* [1] and *Calluna vulgaris* [1] point to vegetation transitional between heathland and grassland.

The division of the negative Group 000 places 78 quadrats into Group 0000 and the remaining 260 into Group 0001. The negative Group 0000 is characterised by its indicator species *Pteridium aquilinum* [1] and the positive Group by *Vaccinium myrtillus* [1] and *Deschampsia flexuosa* [1] which suggests a division between shrubby heath invaded by bracken (but where the effects of the invasion are not sufficient to 'degrade' the character of the community) and heath that does not have significant bracken presence. *Pteridium* is an indicator by virtue of its magnitude of presence as a negative preferential [1(24, 4), 2(24,4), 3(16,0)] but its absolute presence is low compared to the levels as a preferential shown by the positive indicators, *Deschampsia* [1(6,158), 2(6,157), 3(0,61)] and *Vaccinium* [1(11,228), 2(11,228), 3(0,58)]. *Calluna* is a non preferential at 4 pseudospecies levels [1(78,249), 2(78,249), 3(76,233), 4(46, 96)].

The subsequent division of the latter Group 0001 allocates 68 quadrats to Group 00010 and 192 quadrats to Group 00011 (through this group's indicator species: *Deschampsia flexuosa* [1] and *Calluna vulgaris* [4]). This latter group suggests areas with an open *Calluna* canopy, perhaps derelict *Callunetum*, or stands in the early stages of recovery from management (burning or cutting) or, damage (arson burns or heather beetle infestation) whereas, Group 00010 can be seen as 'core' or quality *Calluna* heath. *Deschampsia* is an emphatic positive preferential as well as being an indicator, since its presence is restricted to quadrats on the positive side [1 (0,158), 2(0,157) 3(0, 61)]. In contrast, *Calluna,* whilst serving as a positive indicator at pseudospecies 4 (0, 96) is also present as a non-preferential [1(57,172), 2(57,192), 3(50,183)]. *Vaccinium* is also non-preferential at levels 1(68,160), 2(68,180) and 3(33, 52).

The dichotomy resulting from the division of Group 001 allocates 95 quadrats to the positive Group 0011 and the remaining 160 quadrats to the negative Group 0010 .The indicator species (*Pteridium aquilinum* [1] for the negative group, and, *Galium saxatile* [1], for the positive) are separating bracken-heath areas from grass-heath areas, albeit both with some *Pteridium* presence [1(136,16), 2(135,16), 3(97,11)]. Non-preferential species are *Vaccinium myrtillus* [1(138,86), 2(135,85), 3(109,75)], *Calluna vulgaris* [1(50,33), 2(49,33), 3(37,14)] and *Deschampsia flexuosa* [1(87,85), 2(82,84)] although the latter is also a positive preferential at pseudospecies level 4 (42,67).

The division of Group 0010 places 59 quadrats in the negative Group 00100 and 101 quadrats to the positive Group 00101 through the negative indicator *Calluna vulgaris* [1]. This suggests Group 00100 represents areas of heath with some bracken infestation, whereas Group 00101 represents areas of bracken infested grassy heath. *Pteridium* is present as non-preferential [1(49, 87), 2(48, 87), 3(24, 73)] as are *Deschampsia* [1(26, 61), 2(24, 58)] and *Vaccinium* [1(56, 82), 2 (54, 81), 3(47, 62)]. *Vaccinium* also acts as a positive indicator [4(12, 7)] and *Deschampsia* as a negative indicator [3(9, 33)].

Splitting Group 0011 places 32 quadrats in Group 00110 and 63 in Group 00111. The indicator species: *Agrostis capillaris* [1], *Calluna vulgaris* [1], *Pteridium aquilinum* [1] and *Rumex acetosella* [1] (negative) and *Vaccinium myrtillus* [1], *Deschampsia flexuosa* [3] and *Galium saxatile* [1] (positive), characterise these groups as bracken infested grassy heath and grassy heath, respectively. Although acting as positive indic*ators, V. myrtillus, D. flexuosa,* and *G. saxatile* are also present as non-preferentials, (at levels of [1(25, 61), 2(24, 61), 3(17, 58)], [1(25, 60), 2(24, 60), 3(14, 56)] and [1(22, 41), 2(22,42)], respectively) as is *Festuca ovina* [1(4, 15), 2(4, 15)].The levels for the positive preferentials, *A. capillaris, C. vulgaris, P. aquilinum* and *R. acetosella* are [1(22,4), 2(21,2), 3(9,1)], [1(26,7), 2(26,7), 3 (10,14)], [1(12,4), 2(12,4), 3(9,2)] and [1(11,4), 2(10,4)], respectively.

The division of the positive Group 010 sends 12 quadrats to the negative Group 0100 through its indictor species *Festuca ovina* [3], C*alluna vulgaris* [1] and *Pteridium aquilinum* [3], and 41 quadrats to the positive Group 0101, through its indictors *Vaccinium myrtillus* [1] and *Rumex acetosella* [2]. The positive preferentials, *Calluna* [1(8,4), 2(8,4), 3(6,3)], *Festuca ovina* [1(9,6), 2(9,6), 3(6,3)] and *Pteridium* [1(5,3), 2(5,3), 3(5,1)] suggest this division is based on the presence of these species in a restricted number of quadrats where their abundance is weighting the separation. In contrast, the negative preferentials, *Rumex acetosella* [1(2,32), 2(1,30)] and V*accinium myrtillus* [1(1,29),2(1,24)] are present in a greater number of quadrats with almost no presence in the 'negative' quadrats. The non preferential species, *Agrostis capillaris* [1(10,35), 2(10,34), 3(6,26)], *Deschampsia flexuosa* [1(5,21), 2(5,20), 3(3,8)] and *Galium saxatile* [1 (1,39), 2(11,39), 3 (8,27)] suggest an open grassy component to the communities. In all, the principal differences appear to suggest deeper substrates in Group 0100, possibly in less disturbed or less grazed areas and shallower soils in Group 0101 in perhaps more heavily grazed and/or disturbed areas.

The final division, Group 011, allocates 21 quadrats to the negative Group 0110 and 38 to the positive Group 0111 through the positive indicator, *Rumex acetosella* [1]. The negative preferentials, *Pteridium aquilinum* [1(7, 1), 2(6,1)] and *Agrostis capillaris* [3 (19,16)] point to deeper, possibly damper soils and the positive preferentials *Aira praecox* [1(0,22), 2(0,21)] and *Rumex acetosella* [1(0,38),2(0,38)] to drier ,shallower soils, within the overall grassy areas indicated by the non-preferential species *Agrostis capillaris* [1(21,36), 2(21,35)], *Festuca ovina* [1(21,30), 2(21,35)] and *Galium saxatile* [1(18,23), 2(18,22), 3 (5,6)].

This analysis generally repeats the separations seen in section 4.2.1. The initial dichotomy again isolates the group of 'wetland' quadrats [Group 1] from the main body of quadrats; the latter group of which are again divided into two broad groups in the next separation. These can best be approximated as either heath [Group 0] or heathland affected by grassland expansion [Group 01]. The 'major' group, 00, again separates into classic shrubby heath [Group 000] and heath which is subject to bracken encroachment [Group 001]. This latter group also divides to segregate a shrubby heath group from an aggregation which later divides into areas where *Pteridium* is invading the shrubby heath, and those where it is largely absent. The second major group, 01, isolates two groups of quadrats, identifying transitional heath-grassland areas [010] from grassland areas proper [011]. Group 010 subsequently divides to produce quadrats typifying the extremes of the transition zone with 0100 suggesting less disturbed heath communities, whilst 0101 points to more heavily used areas. Group 011 divides the grassland communities into those of deeper damper soils and those of shallower, drier zones.

5.2.3 **'Bryophyte and lichens' analyses**

Section 5.2 reports the reduction of quadrats in the 'bryophyte and lichens' to 630 due to some holding no bryophyte or lichen species. A preliminary analysis of these data produced an initial segregation which isolated one extreme quadrat, the only quadrat in the data set which held *Sphagnum auriculatum,* its only bryophyte species, from the remainder and which had the effect of displacing subsequent levels of separation without adding to the level of information. This species was removed from the data set and the subsequent analysis is shown in Figure 5.2.4.

The initial separation allocated 30 quadrats to Group 1 and 600 quadrats to Group 0. The positive indicator species, *Calliergonella cuspidata* [1] and *Thuidium tamariscinum* [1] characterise wetland or wet heath quadrats whilst the negative indicators *Hypnum jutlandicum* [1], *Rhytidiadelphus squarrosus* [1], *Dicranum scoparium* [1] and *Pleurozium schreberi* [1] suggest a broad group of 'heathy' quadrats.

Division of Group 0 sends 597 quadrats to the positive Group 01 (indicator species*,* *Hypnum jutlandicum* [1] and *Rhytidiadelphus squarrosus* [1]) and the remaining 3 quadrats to the negative Group 00 (indicators *Polytrichum commune* [1] and *Sphagnum subnitens* [1], thus removing another small group of 'wet heath ' quadrats from the overall 'heath' community.

The next division, Group 01, is separating a group of 20 'heavily shaded' quadrats to Group 010 (characterised by the negative indicator *Eurhynchium praelongum* [1]) from the remaining 578 'heathy' quadrats in Group 011 (characterised by the positive indicator species *Hypnum jutlandicum* [1] and *Rhytidiadelphus squarrosus* [1]).

The Group 011 division sends 187 quadrats to the negative Group 0110 (indicators *Rhytidiadelphus squarrosus* [1], *Polytrichum commune* [1] and *Scleropodium purum* [1]) and 390 quadrats to the positive Group 0111 (indicators *Hypnum jutlandicum* [2]*,* *Dicranum scoparium* [1] and *Pleurozium schreberi* [1]). This division appears to be separating the more open, damper and possibly grassy, areas from the heathland area proper.

Dividing Group 0110 (not shown on Figure 4.2.3) sends 29 quadrats to negative Group 011000 (indicator *Polytrichum commune* [2]) and the balance, 158 quadrats, to Group

01101 (indicator *Rhytidiadelphus squarrosus* [1]) thus isolating a small group of damper quadrats in the more open areas.

The division of its parallel group, the positive 0111, is based on the negative indicator *Pleurozium schreberi* [2] diverting 100 quadrats to the negative Group 01110 with the remaining 290 quadrats going to the positive 01111.

The negative preferential *Pleurozium schreberi* [1(100,6), 2(99,2)] and the positive preferential *Hypnum jutlandicum* [1(36,224), 2(34,222),3(13,126)] exhibit similar shade preferences (Hill *et al.*, 2007) although *Hypnum* is more shade tolerant. There was some difference between the mean canopy height for the two groups at 446 mm and 396 mm, respectively, although there was relatively little variation in the canopy species.

Scandrett and Gimingham (1991) found that where *Calluna* was subject to defoliation by the heather beetle (*Lochmaea suturalis*), *H. jutlandicum* was associated with areas of declining cover, whereas *P. schreberi* was associated with increasing cover. On the other hand, Welch and Scott (1995) found *H. jutlandicum* declined in areas where the heather was subject to heavy grazing although in some cases this decline was accompanied by an attendant increase in *P. schreberi*.

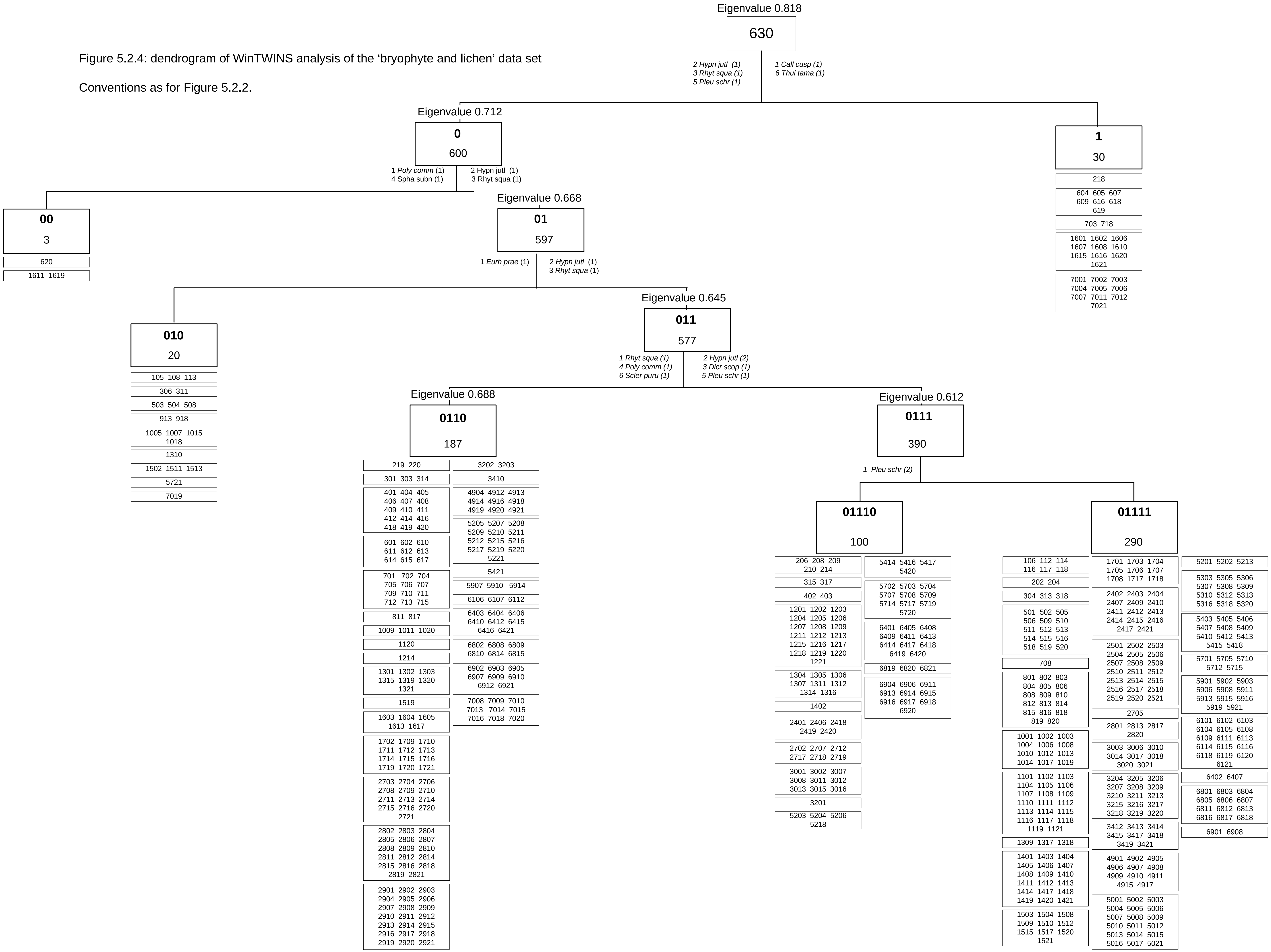
This may represent a difference between total loss of cover which favours *H. jutlandicum* and gap generation which favours *P. schreberi* [*cf* Scandrett and Gimingham (1989)] Burch (2008) found *P. schreberi and H. jutlandicum* to be associated with older stands of *Calluna,* although *H. jutlandicum* was the main species recorded.

5.2.4 Comparison of the three WinTWINS quadrat analyses

The initial division of the ‘all species’ set placed 52 quadrats in the positive Group 1 based on the indicator species *Nardus stricta, Carex echinata, Juncus bulbosus* and *Calliergonella cuspidata*, whilst the remaining 715 quadrats were directed to the negative Group 0 based on *Vaccinium myrtillus* and *Calluna vulgaris* as indicator species. The equivalent separation of the ‘vascular plant species’ used many of the same indicator species, with the addition of the positive indicators, *Cardamine pratensis* and *Carex viridula* ssp. *oedocarpa* [*demissa*] : *Calliergonella* was obviously excluded in the vascular only group. The ‘vascular plant’ analysis, generally allocated the same quadrats to Group

Figure 5.2.4: dendrogram of WinTWINS analysis of the ‘bryophyte and lichen’ data set

Conventions as for Figure 5.2.2.



1 with an additional 4 to stand LM70[7008, 7018, 7019, 7020] and quadrats to 3 other stands LM17[1708] ,LM54[5401] and LM61[6106]. Quadrat LM 613, present in the ‘all species’ Group 1 was not present in the vascular species Group 1.

The majority of the ‘additional’ quadrats, 1708, 6106, 7008, 7018, 7019 and 7020, had been allocated to Group 1 in the ‘all species’ analysis where *Calliergonella cuspidata* was available as an indicator species. None of these quadrats were allocated to Group 1 in the ‘bryophyte and lichen’ analysis where *C. cuspidata* was the only positive indicator species, This is perhaps an indication that whilst bryophytes as indicators are ‘fine tuning’ divisions, the principal influence remains the vascular species. The presence of *C. cuspidata* appears to have displaced *Cardamine pratensis* and *Carex viridula* ssp. *oedocarpa* [*demissa*] in the hierarchy.

The second level separation [Group 0] in the ‘all species’ analysis placed 566 quadrats to Group 00 and 149 to Group 01; the equivalent separation in the ‘vascular species’ data placed 593 quadrats in Group 00, with only 112 quadrats in Group 01. In both analyses this division is characterised by positive indicators, *Agrostis capillaris, Galium saxatile, Rumex acetosella* and *Festuca ovina* and negative indicators *Calluna vulgaris* and *Vaccinium myrtillus* although *Deschampsia flexuosa* appears as an additional negative indicator in the vascular set. The positive bryophyte indicator *Rhytidiadelphus squarrosus* was not available in the ’vascular only’ set, its removal appears to have promoted *Deschampsia* as an indicator but, in keeping with the coincidence of the two species in communities, does not appear to have made any major changes to the dichotomies.

The initial separation of the ‘bryophyte and lichen’ data places 30 quadrats to positive Group 1 based on *Calliergonella cuspidata* and *Thuidium tamariscinum* as its indicators and the remaining 600 quadrats to the negative Group 0 with *Hypnum jutlandicum, Rhytidiadelphus squarrosus, Dicranum scoparium* and *Pleurozium schreberi* as its indicators. The presence of *C. cuspidata* as a positive indicator mirrors its role in the analogous division in the ‘all species’ analysis.

The three major stands of the ‘all species’ and ‘vascular’ Groups 1 [LM6, LM16 and LM70] are represented in the ‘bryophyte and lichen’ Group 1. Two additional stands ~M2 [218] and LM7 [703,718] ~ are present in the bryophyte group but three stands found in the ‘all species’ and ‘vascular’ group are not represented in the bryophyte group: quadrats 1708 and 6108 are allocated to other groups while quadrat 5408 was not included in this analysis.[34] This is the reciprocal of the 'displacement effect' noted above.

The division of Group 0 is made through the positive indicators*, Hypnum jutlandicum* and *Rhytidiadelphus squarrosus,* directing 597 quadrats to Group 01 and the negative indicators, *Polytrichum commune* and *Sphagnum subnitens* directing the remaining 3 quadrats, to the negative Group 00.

The idiosyncratic nature of this division in isolating three 'extreme' quadrats from the main group, has served to confuse the subsequent synchrony of the division levels of the 'bryophyte and lichen' analyses with the 'all species' and 'vascular species' analyses by imposing an additional level of division in the former. It has also transposed the position of the groups compared to the other analyses; its major aggregation of quadrats is allocated to the positive Group 01 whereas the equivalent aggregations in both the 'all species' and 'vascular species' analyses is the negative Group 00.

The next division, of Group 01, diverts a disparate group of twenty 'shaded' quadrats away from the main group, into Group 010, whilst the majority of the quadrats go to Group 011. The 'transposition' of divisions is once again evident, the bryophyte negative Group 010 is equivalent to 'all species' and 'vascular species' positive Groups 01 and the bryophyte negative Group 001 is equivalent to the positive Groups 00 in the other two analyses.

Figure 5.2.4, showing the bryophyte and lichen analyses, divisions involving splitting off small groups, are isolating quadrats which hold species whose distribution is restricted in some way, perhaps by specialist habitat requirements, which set them apart from the major group of 'heathland' species.

The third level separation of Group 00, holding 566 quadrats in the 'all species' set and 593 in the 'vascular plant' set diverted 304 and 338 quadrats to the respective Groups 000 and 262 and 255 quadrats to the Groups 001. In both of the analyses, *Calluna vulgaris* appears as the negative indicator; *Pteridium aquilinum* and *Vaccinium myrtillus* are present as positive indicators in these analyses but with *Galium saxatile* appearing in the vascular set. *Pleurozium schreberi* and *Rhytidiadelphus squarrosus,* positive indicators in the all species set, were not available in the vascular set. Once again the displacement

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[34] LM 5408 held no bryophyte species.

effect appears to be coming into play with *Galium saxatile* appearing in the vascular set in the absence of *Pleurozium schreberi* and *Rhytidiadelphus squarrosus.*

The separation of the bryophyte fourth level Group 011 (analogous to the ‘all species’ and ‘vascular species’ third level Groups 00) divides through the negative indicators *Rhytidiadelphus squarrosus, Polytrichum commune* and *Scleropodium purum* and the positive indicators *Hypnum jutlandicum, Dicranum scoparium* and *Pleurozium schreberi,* with 187 quadrats directed to the negative Group 0110 and 390 quadrats to the positive Group 0111.

Transposition of the divisions is maintained with the bryophyte Group 0110 equivalent to ‘all species’ and ‘vascular species’ Group 000 [304 and 338 quadrats] and the bryophyte Group 0111 equivalent to Group 001 [262 and 255] in the other analyses.

Partition of Group 0110 sends 29 quadrats to negative Group 01100 [equivalent to ‘all species’ and ‘vascular species’ Groups 0000 with 21 and 78 quadrats, respectively] through its indicator *Polytrichum commune* and 158 quadrats to positive Group 01101 [equivalent to Groups 0001 with 283 and 260 quadrats] with *Rhytidiadelphus squarrosus* as the positive indicator.

The Group 0111 division places 100 quadrats to negative Group 01110 [indicator *Pleurozium schreberi*] and 290 to positive Group 01111; the equivalent ‘all species’ and ‘vascular species Groups 0010 hold 223 and 160 quadrats and Groups 0011 hold 39 and 95 quadrats, respectively.

Overall, the separations evident in the ‘vascular species’ analysis follow those in the ‘all species’ analysis, reasonably closely indicating that the vascular component is the principal influence in the divisions. In a few cases in the ‘all species’ analysis, bryophytes act as indicators. Such plants are operating either as a ’specialist species’ i.e. ones associated with restricted range of environmental conditions or niches where their presence is an important diagnostic, or as ‘generalist species’, associated with a less restricted range of niches where their abundance causes them to act as indicators.

5.2.5 ‘Stands’ analysis

The ‘averaging’ process used to produce the mean cover values removed some 52 low occurrence species from the data set, and consequently, the 37 stands are only characterised by 59 species. Figure 5.2.5 shows the distribution of stands and end groups for this analysis.

The initial division of the 37 stands is made by the negative indicators *Vaccinium myrtillus* [1], *Calluna vulgaris* [1], *Deschampsia flexuosa* [1] and *Hypnum jutlandicum* directing 33 stands to the negative Group 0 and four stands, LM6, LM16, LM28 and LM70 to the positive Endgroup 1.

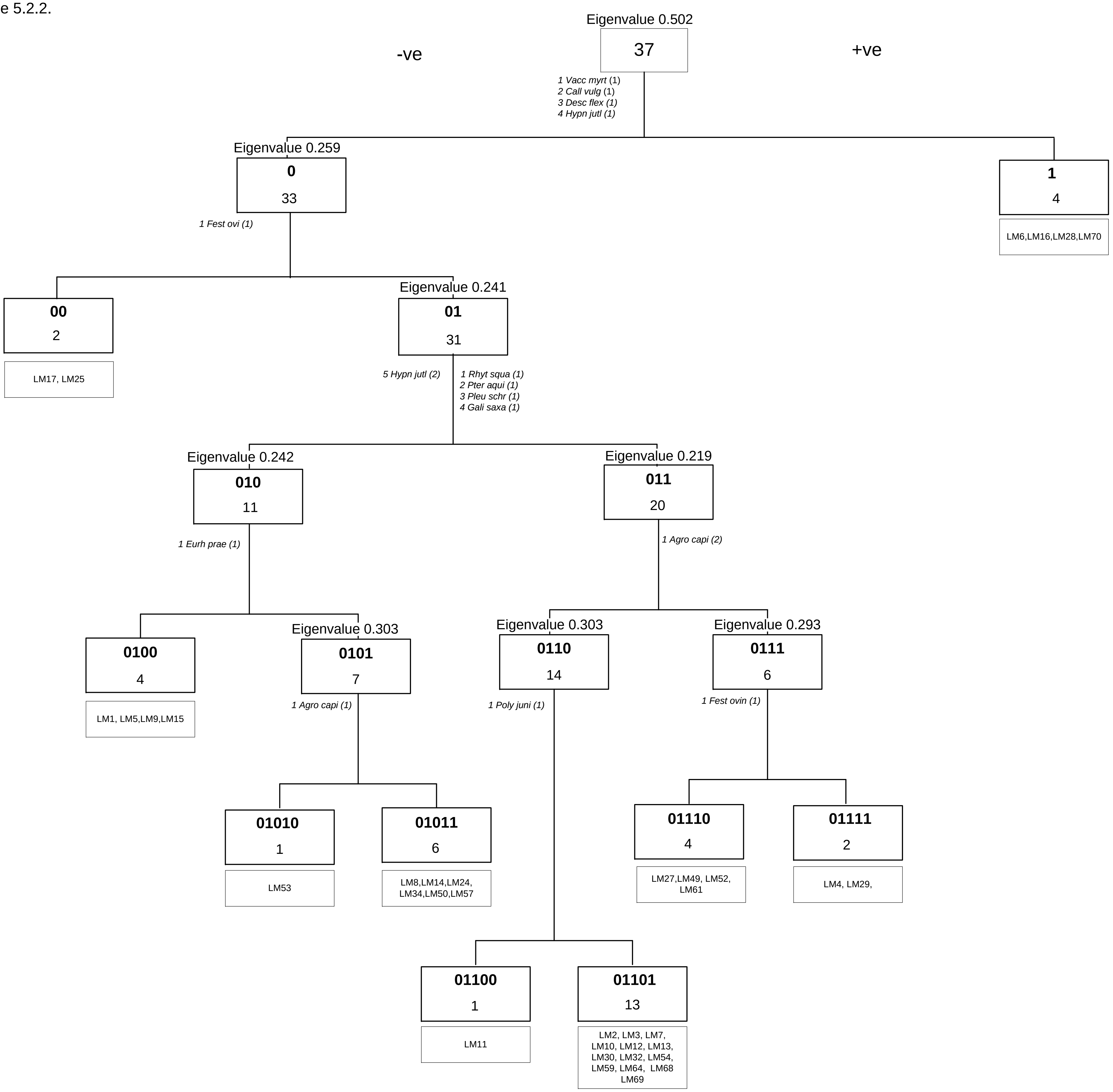
The negative preferentials, *Calluna vulgaris* [1(29,0),2(28,0),3(23,0)], *Deschampsia flexuosa* [1(26,0),2(25,0),3(13,0)], *Dicranum scoparium* [1(14,0),2(11,0)], *Hypnum jutlandicum* [1(26,0),2(23,0),3(10,0)], *Rhytidiadelphus squarrosus* [1(18,1)], *Rumex acetosella* [1(8,0)], *Vaccinium myrtillus* [1(30,0),2(29,0),3(17,0)], *Galium saxatile* [2(12,0)] and *Pteridium aquilinum* [3(10,0)] point to stands which are principally heathland in character. The non-preferential species,*Galium saxatile* [1(16,1)], *Pleurozium schreberi* [1(13,1), 2(12,1)], *Polytrichum commune* [1(10,1),2(6,1)], *Pteridium aquilinum* [1(16,2),2(13,2)], and *Rhytidiadelphus squarrosus* [2(16,1)] confirm the heathy nature of the group and suggest elements of bracken incursion.

The positive preferentials *Agrostis capillaris* [1(11,4),2(9,3),3(3,2)], *Anagallis tenella* [1(0,2),2(0,1)], *Anthoxanthum odoratum* [1(1,2),2(1,1)], *Bellis perennis* [1(0,1)], *Calliergonella cuspidata* [1(1,3),2(0,2),3(0,1)], *Cardamine pratensis* [1(0,1),2(0,2)], *Carex viridula spp oedocarpa* [*demissa*] [1(0,2),2(0,2),3(0,1)], *Carex echinata* [1(0,2),2(0,2)], *Carex nigra* [1(0,1),2(0,1)], *Carex panicea* [1(0,1),2(0,1)], *Cirsium palustris* [1(0,2),2(0,2)], *Cynosurus cristatus* [1(0,1),2(0,1)], *Deschampsia cespitosa* [1(2,2),2(1,1)], *Festuca ovina* [1(6,2),2(6,2),3(2,1)], *Holcus lanatus* [1(0,1)], *Juncus acutiflorus* [1(0,1)], *Juncus articulatus* [1(1,1)], *Juncus bulbosus* [1(0,3),2(0,3)], *Juncus effusus* [2(2,3),2(2,2)], *Juncus squarrosus* [1(2,2),2(0,2),3(0,1)], *Leontodon saxatilis* [1(0,1)], *Lotus corniculatus* [1(0,2)], *Montia fontanum* [1(0,1),2(0,1)], *Nardus stricta* [1(3,2), 2(2,2), 3(0,2)], *Narthecium ossifragum* [1(0,1)], *Potentilla erecta* [1(0,1)], *Ranunculus flammula* [1(0,2),2(0,2)], *Ranunculus repens* [1(0,1),2(0,1),3(0,1)], *Scleropodium purum* [1(3,1)], *Sphagnum capillifolium* [1(0,1),2(0,1)], *Sphagnum fallax* [1(0,1), 2(0,1)], *Sphagnum palustre* [1(0,1),1(2(0,1)], *Sphagnum subnitens* [1(0,1)] and *Pleurozium schreberi* [3(3,1)] indicate wetland or flushed areas.

In the division of the negative Group 0, the negative indicator *Festuca ovina* [3] allocates 2 stands, LM17 and LM25, to the negative Endgroup 00 with the remaining 31 stands allocated to the positive Group 01.

Figure 5.2.5: dendrogram of WinTWINS analysis of the ‘stands’ data set

Conventions as for Figure 5.2.2.



The negative preferentials *Agrostis capillaris* [1(2,9),2(2,7),3(1,2)], *Aira praecox* [1(1,0),2(1,0)], *Ceratodon purpureus* [1(1,0),2(1,0)], *Cladonia* sp. [1(1,0)2(1,2)], *Dicranella heteromalla* [1(1,0)], *Dicranum scoparium* [1(2,12),2(2,9),3(1,1)], *Festuca ovina* [1(2,4),2(2,4),3(2,0)], *Galium saxatile* [1(2,14),2(2,10)], *Polytrichum piliferum* [1(1,0)], *Rumex acetosella* [[1(2,6),2(1,3),3(1,0)] and *Rhytidiadelphus squarrosus* [3(1,3)] suggest acid grassland areas on disturbed or possibly more fertile soils.

The positive preferentials *Calluna vulgaris* [1(0,29),2(0,28),3(0,23)], *Deschampsia flexuosa* [1(0,26),2(0,25),3(0,13)], *Pleurozium schreberi* [1(0,13),2(0,12)], *Polytrichum commune* [1(0,10)] and *Vaccinium myrtillus* [1(1(0,30),2(0,29),3(0,17)] are indicating the heathy component.

Of the non-preferentials, *Hypnum jutlandicum* [1(2,24),2(2,21), 3(1,9)] and *Rhytidiadelphus squarrosus* [1(1,17),2(1,15)] tend to confirm the heathy nature of the stands whilst the presence of *Pteridium aquilinum* [1(1,15),2(1.12),3(1,9)] suggests bracken infiltration to both the heathland and the grassland stands.

The subsequent separation of the 31 stands in Group 01 is made by the positive indicators *Rhytidiadelphus squarrosus* [1], *Pteridium aquilinum* [1], *Pleurozium schreberi* [1] and *Galium saxatile* [1] and the negative indicator, *Hypnum jutlandicum* [2], diverting 20 stands to the positive Group 011 and 11 stands to the negative Group 010.

The non preferentials, *Calluna vulgaris* [1(10,19),2(10,18),3(9,14)], *Deschampsia flexuosa* [1(7,19),2(7,18)], *Dicranum scoparium* [1(5,7),2(3,6)], *Hypnum jutlandicum* [1(11,13)] and *Vaccinium myrtillus* [1(10,20),2(10,19)] confirm the basic ‘heathy’ nature of the stands. This separation is therefore between areas of ‘quality’ heathland without bracken infiltration – as indicated by the negative preferentials *Eurhynchium praelongum* [1(4,2),2(4,2)] and *Hypnum jutlandicum* [2(11,10),3(6,3)], and more open heathland with bracken presence – suggested by the positive indicators *Agrostis capillaris* [1(1,8)2(1,6)], *Galium saxatile* [1(1,13),2(1,9)], *Pleurozium schreberi* [1(1,12),2(1,11)], *Polytrichum commune* [1(2,8),2(0,6)], *Pteridium aquilinum* [1(0,15),2(0,12),3(0,9)], *Rhytidiadelphus squarrosus* [1(1,16),2(0,15), *Deschampsia flexuosa* [3(2,11)] and *Vaccinium myrtillus* [3(3,14)].

Division of ’quality heath’ stands in negative Group 010 proceeds through the negative indicator *Eurhynchium praelongum* [1] diverting 4 stands, LM1, LM5, LM9 and LM15, to the negative Endgroup 0100 and the remaining 7 stands to the positive Group 0101.

The negative preferentials, *Cladonia* sp. [1(2,0),2(2,0)], *Eurhynchium praelongum* [1(4,0),2(4,0)] and *Galium saxatile* [1(1,0),2(1,0)] suggest shaded areas of mature heathland whereas the positive preferentials, *Rumex acetosella* [1(0,2)], *Deschampsia flexuosa* [3(0,2)] and *Calluna vulgaris* [4(0,2)] suggest more open, possibly overgrazed areas of *Calluna* heath

The non-preferentials are *Calluna vulgaris* [1(4,6),2(4,6),3(2,4)], *Deschampsia flexuosa* [1(3,4),2(3,4)], *Dicranum scoparium* [1(2,3),2(1,2)], *Hypnum jutlandicum* [1(4,7), 2(4,7), 3(2,4)], *Polytrichum commune* [1(1,1)] and *Vaccinium myrtillus* [1(4,6),2(4,6),3(1,2).

The separation in the 'open heathland with bracken' stands in the positive Group 011 occurs through the positive indicator, *Agrostis capillaris* [2], allocating 6 stands to the positive Group 0111 and the balance [14 stands] going to the negative Group 0110.

The positive preferentials *Agrostis capillaris* [1(2,6),2(0,6),3(0,2)], *Festuca ovina* [1(0,4), 2(0,4)], *Juncus squarrosus* [1(0,2)], *Nardus stricta* [1(1,2)], *Polytrichum commune* [1(4,4)], *Rumex acetosella* [1(2,2),2(0,2)], *Galium saxatile* [2(4,5),3(0,3)], *Scleropodium purum* [1(1,2),3(1,2)] and *Rhytidiadelphus squarrosus* [3(1,2)] suggest areas of relatively open heath, some with rock outcrops and some with grassy patches, albeit with some bracken incursion. The negative preferentials *Dicranum scoparium* [1(7,0),2(6,0)], *Pteridium aquilinum* [2(10,2)] and *Hypnum jutlandicum* [3(3,0)] indicate areas where the level of bracken is higher and perhaps a major component of the stands.

The 7 'open, possibly overgrazed ' stands in Group 0101 are segregated by the negative indicator *Agrostis capillaris* [1] allocating a single stand, LM53 to the negative Endgroup 01010 with the remainder of the stands, LM8, LM14, LM24, LM34, LM50 and LM57, going to the positive Endgroup 01011. This minor separation is isolating a stand which has probably experienced lower grazing levels - negative preferentials *Agrostis capillaris* [1(1,0),2(1,0)], *Hypnum jutlandicum* [3(1,3)] and *Calluna vulgaris* [4(1,3)], from the remaining stands - positive preferentials *Deschampsia flexuosa* [1(0,4),2(0,4),3(0,2)], *Dicranum scoparium* [1(0,3),2(0,2)], *Rumex* 1(0,2)] and *Vaccinium myrtillus* [1(0,6), 2(0,6),3(0,2)].

Group 0110 is resolved through the negative indicator, *Polytrichum juniperinum* [1] directing stand LM11 to the negative Endgroup 01100 with the balance, LM2, LM3, LM7, LM10, LM12, LM13, LM30, LM32, LM54, LM59, LM64, LM68 and LM69, going to the positive Endgroup 01101.

This separation is removing a open stand with no bracken infiltration, [negative preferentials, *Dicranum scoparium* [1(1,6),2(1,5),3(1,0)], *Festuca rubra* [1(1,1),2(1,0)], *Polytrichum commune* [1(1,3),2(1,3)], *Polytrichum juniperinum* [1(1,0), 2(1,0)], *Rumex acetosella* [1(1,1)] and *Galium saxatile* [2(1,3)] from the remainder of this largely bracken infiltrated and possibly degraded heathland [positive preferentials, *Hypnum jutlandicum* [1(0,9),2(0,7),3(0,3)], *Pleurozium schreberi* [1(0,9),2(0,8)], *Pteridium aquilinum* [1(0,12),2(0,10),3(0,7)], *Rhytidiadelphus squarrosus* [1(0,10),2(0,9)] and *Deschampsia flexuosa* [3(0,8)]].

The final separation, Group 0111, is made by the negative indicator, *Festuca ovina* [1] allocating LM27, LM49, LM52 and LM61 to the negative Endgroup 01110 and the remainder, LM4, and LM29 to the positive Endgroup 01101.

This is dividing a group where *Pteridium* is an major component into those [Endgroup 01110] which still show shrubby heathland characteristics (see negative preferentials~ below) and those [Endgroup 01111] where the presence of bracken is less marked and there is a 'damper' feel to the vegetation.

Negative preferentials*, Anthoxanthum odoratum* [1(1,0),2(1,0)], *Festuca ovina* [1(4,0), 2(4,0)], *Holcus mollis* [1(1,0)], *Scleropodium purum* [1(2,0),2(2,0), *Hypnum jutlandicum* [2(3,0)], *Nardus stricta* [2(1,0)], *Pteridium aquilinum* [2(2,0),2(2,0)], *Calluna vulgaris* [3(4,1)] and *Vaccinium myrtillus* [3(3,0)].

Positive preferentials, *Agrostis vinealis* [1(0,1),2(0,1)], *Juncus effusus* [1(1,1),2(0,1)], *Juncus squarrosus* [1(1,1)], *Nardus stricta* [1(1,1)], *Rumex acetosella* [1(0,2),2(0,2)], *Polytrichum commune* [1(2,2), 2(0,2),3(0,1)], *Agrostis capillaris* [3(1,1)], *Galium saxatile* [3(1,2)] and *Rhytidiadelphus squarrosus* [3(1,1)].

5.2.6 Comparison of 'all species quadrat ' and 'all species stand' analyses'.

The initial separation of the 'stand' data [Figure 5.2.5] separates four stands [LM6, LM16, LM28, LM70] from the remaining ' heath and grassland' areas. This separation mirrors to a large extent the initial separation in the 'quadrat' data [Figure 5.2.2] where the majority of quadrats from the stands [LM6 -90%, LM16 -100% and LM70 -62%] are present. However the quadrats from stand LM28, [100%] were allocated to a 'grassy heath' group and the balance of LM70 to a 'grassland' group.

The second division of the ‘stand’ data isolates two ‘grassland’ stands [LM17, LM25] from the major aggregation which is principally heathland in character; the ‘quadrat’ data analysis also allocates these stands to grassland groups, albeit to two disparate groups. The subsequent division of this ‘major aggregation’ produces two groups, the negative group which is essentially ‘quality heathland’ from the positive group of ‘open heathland with bracken.’

The separation of the ‘quality heathland’ segregates four stands [LM1,LM5,LM9,LM15] of shaded mature heathland from more open, possibly overgrazed heath. The ‘quadrat’ analysis also allocates LM1 [95%], LM5 [45%], LM9 [100%] and LM15 [57%] to this ‘core of quality heath’ section but the remainder of these quadrats are allocated as ‘heath with bracken incursion.’

The subsequent division of the ‘open, overgrazed heath’ isolated a single stand [LM53] from the remainder [LM8,LM14,LM24,LM34,LM50 and LM57]. This separation is probably differentiating differing levels of grazing or openness between these stands. The ‘quadrat’ analysis allocated LM24 between grassland and heathland groups [52% and 48%, respectively] with LM53, LM14, LM24, LM34, LM50 and LM57 allocated to heathland groups.

Division of the ‘open heathland with bracken’ produces a group suggesting relatively open heath with rock outcrops or grassy patches and some bracken and another where the level of bracken is higher.

Division of the former group isolated a single stand, LM11 from the remaining stands LM2, LM3, LM7, LM10, LM12, LM13, LM30, LM32, LM54, LM59, LM64, LM68 and LM69. This is removing an open stand with no bracken from the remainder of a bracken infiltrated degraded heathland group. The ‘quadrat’ analysis allocated LM11 quadrats to heathland groups and the balance to bracken dominated heathland and acid grassland groups.

The separation of the final group allocated stands of bracken invaded heathland [LM27, LM49, LM52, and LM61] from those [LM4, LM29] where the bracken presence is not so marked and which have a ‘damper’ feel to the vegetation.

The ‘quadrat’ analysis designated the latter as a heathland-grassland mix [33-66%] and a grassland stand; LM27 and LM49 were characterised as bracken–heathland-grassland

[62-26-14% and 76-9-14%], respectively, with both LM52 and LM62 a 52-48% heathland grassland aggregation.

This comparison tends to support the earlier view that whilst stand level analyses may be useful the quadrat level analyses provide more detailed information about the community make up at any sample site.

5.3 End Groups as Communities

The WinTWINS analysis of the ‘all species’ data produced a series of end groups which represented disparate vegetation types. The data were examined using MATCH[35] to assist in the allocation of the end Groups to appropriate NVC categories and summaries of these processes are given in Tables 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.3.5 and 5.3.6 below.

Group 0000 [Table 5.3.1]; holds representatives of nine stands which are associated with NVC H12a, *Calluna vulgaris-Vaccinium myrtillus* heath of the *Calluna vulgaris* sub-community. Rodwell (1991) describes this sub-community as one where *Calluna* is vigorous and dominant and tends to suppress or restrict other species, particularly where burning and grazing encourages species-poor ‘building-phase’ areas. These quadrats also exhibit affinities with NVC H1, *Calluna vulgaris-Festuca ovina* heath, but the absence of *Erica cinerea* and the presence of high levels of *Vaccinium* point to H12a being the appropriate community.

Group 00010 [Table 5.3.1]; holds quadrats from some twenty three stands which have affinities with both H12a but also with U2 *Deschampsia flexuosa* grassland. This latter community holds shrubs, typically *Calluna* but also *Vaccinium myrtillus* but generally at constancies lower than those encountered in H12a; although the balance of attributes points to this group being H12a, these dual affinities suggest an area which is perhaps recovering from management, possibly cutting, where *Deschampsia* can recover faster than *Calluna.*

Group 00011 [Table 5.3.1]; represents a further twenty three stands which show similar attributes to Group 00010. As both these groups result from the dichotomy of Group 0001,

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[35] See Section 4.4.3.

this similarity is not unexpected since their separation was principally due to differing levels of *Pteridium* and *Deschampsia.* On balance the attributes again point to H12a.

The 135 quadrats, within 21 stands, of Group 00100 [Table 5.3.2] were categorised as U20b *Pteridium aquilinum-Galium saxatile* community: *Vaccinium myrtillus-Dicranum scoparium* sub-community although they also showed affinities with H12a which suggests a heath community which is suffering bracken incursions.

Group 00101; 88 quadrats in 21 stands [Table 5.3.1] is categorised as H12a although with some attributes of U20b. This group is associated with Group 00100 (components from the same separation) which suggests these quadrats are either tending towards U20b [invasion] or towards H12a [bracken control].

	0000				00010				00011				00101				0011			
Calluna vulgaris	V	(V)	10	-10	V	(V)	10	-10	V	(V)	10	-10	II	(V)*	10	-10	I	(V)*	4	-10
Vaccinium myrtillus	V	(V)	10	(4)*	IV	(V)	9	(4)*	IV	(V)	10	(4)*	V	(V)	10	(4)*	V	(V)	10	(4)*
Deschampsia flexuosa	I	(IV)*	7	(4)*	I	(IV)*	7	(4)*	IV	(IV)	10	(4)*	V	(IV)	10	(4)*	II	(IV)*	8	(4)*
Hypnum jutlandicum	II	(V)*	9	(8)*	V	(V)	10	(8)*	II	(V)*	9	(8)*	II	(V)*	9	(8)*	III	(V)*	6	-8
Dicranum scoparium	V	(V)	7	(5)*	II	(V)*	8	(5)*	I	(V)*	5	-5	I	(V)*	5	-5	IV	(V)	8	(5)*
Pleurozium schreberi	I	(IV)*	4	-8	I	(IV)*	4	-8	I	(IV)*	8	-8	III	(IV)	8	-8	I	(IV)*	7	-8
Hylocomium splendens	.	(II)*	0	-8	.	(II)*	0	-8	.	(II)*	0	-8	.	(II)*	0	-8	.	(II)*	0	-8
Cladonia portentosa	.	(II)*	0	-4	.	(II)*	0	-4	.	(II)*	0	-4	.	(II)*	0	-4	.	(II)*	0	-4
Vaccinium vitis-idaea	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Ptilidium ciliare	II	(I)	4	(3)*	I	(I)	4	(3)*	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Cladonia pyxidata	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Cladonia uncialis	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Polytrichum commune	I	(I)	5	(4)*	I	(I)	5	(4)*	I	(I)	4	-4	I	(I)	10	(4)*	II	(I)	7	(4)*
Cladonia coccifera	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Cladonia squamosa	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Trichophorum cespitosum	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4
Potentilla erecta	.	(III)*	0	-4	.	(III)*	0	-4	.	(III)*	0	-4	I	(III)*	2	-4	.	(III)*	0	-4
Galium saxatile	I	(I)	4	(3)*	I	(I)	4	(3)*	I	(I)	5	(3)*	III	(I)*	8	(3)*	I	(I)	8	(3)*
Festuca ovina	.	(I)	0	-3	.	(I)	0	-3	I	(I)	4	(3)*	I	(I)	7	(3)*	I	(I)	4	(3)*
Nardus stricta	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	I	(I)	5	(4)*	I	(I)	8	(4)*
Agrostis capillaris	I	(I)	4	-4	I	(I)	5	(4)*	I	(I)	8	(4)*	I	(I)	5	(4)*	I	(I)	5	(4)*
Carex pilulifera	.	(I)	0	-2	I	(I)	4	(2)*	I	(I)	1	-2	I	(I)	4	(2)*	.	(I)	0	-2
Festuca rubra	II	(I)	7	(4)*	I	(I)	3	-4	I	(I)	5	(4)*	.	(I)	0	-4	I	(I)	3	-4
Agrostis canina	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Rhytidiadelphus squarrosus	.	(I)	0	-4	I	(I)	7	(4)*	I	(I)	7	(4)*	III	(I)*	8	(4)*	I	(I)	7	(4)*
Campanula rotundifolia	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Scleropodium purum	.	(I)	0	-4	I	(I)	4	-4	I	(I)	4	-4	I	(I)	7	(4)*	I	(I)	4	-4
Danthonia decumbens	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Polygala serpyllifolia	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Anthoxanthum odoratum	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	I	(I)	1	-3	.	(I)	0	-3
Lotus corniculatus	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1
Succisa pratensis	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Viola riviniana	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Lathyrus linifolius	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1
Erica cinerea	.	(III)*	0	-6	.	(III)*	0	-6	.	(III)*	0	-6	.	(III)*	0	-6	.	(III)*	0	-6
Empetrum nigrum spp. *nigrum*	.	(I)	0	-6	.	(I)	0	-6	.	(I)	0	-6	.	(I)	0	-6	.	(I)	0	-6
Juncus squarrosus	.	(I)	0	-4	.	(I)	0	-4	I	(I)	4	-4	.	(I)	0	-4	.	(I)	0	-4
Hypogymnia physodes	I	(I)	3	-3	.	(I)	0	-3	I	(I)	4	(3)*	I	(I)	4	(3)*	I	(I)	3	-3
Rhytidiadelphus loreus	.	(II)*	0	-4	.	(II)*	0	-4	.	(II)*	0	-4	.	(II)*	0	-4	.	(II)*	0	-4
Cladonia arbuscula	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4
Blechnum spicant	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Pteridium aquilinum	.	(II)*	0	-6	II	(II)	10	(6)*	I	(II)	5	-6	I	(II)	8	(6)*	III	(II)	8	(6)*
Barbilophozia floerkei	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Cladonia crispata	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1
Rhytidiadelphus triquetrus	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Pohlia nutans	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4
Lophocolea bidentata	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4
Lycopodium clavatum	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Luzula pilosa	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	I	(I)	4	(3)*	.	(I)	0	-3
Cladonia floerkeana	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1
Trientalis europaea	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Calypogeia muelleriana	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1
Plagiothecium undulatum	.	(I)	0	-6	I	(I)	6	-6	I	(I)	4	-6	.	(I)	0	-6	.	(I)	0	-6
Lophozia ventricosa	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Thuidium tamariscinum	.	(I)	0	-4	.	(I)	0	-4	I	(I)	5	(4)*	.	(I)	0	-4	.	(I)	0	-4
Listera cordata	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Sorbus aucuparia (g)	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Erica tetralix	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4
Cladonia chlorophaea	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Cladonia gracilis	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Molinia caerulea	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	I	(I)	4	-4	.	(I)	0	-4
Empetrum nigrum hermaphroditum	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4	.	(I)	0	-4
Eriophorum vaginatum	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1
Polytrichum alpestre	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3	.	(I)	0	-3
Anemone nemorosa	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1	.	(I)	0	-1

Table 5.3.1 'MATCH' output for the 'H12a' endgroups.

The table follows the standard Match output format: species name, constancy, maximum quantitative value with the constancy and maximum quantitative values of the N.V.C unit in brackets. Any marked discrepancies are indicated by asterisks.

The following species found in the test data at a constancy of ll or more are not recorded in the N.V.C diagnostic table for the unit H12a.
The data for each species `are presented as: species name, constancy, maximum quantiative value.

	0000		00010		00011		00101		0011	
Polytrichum juniperinum	ll	5	-	-	-	-	ll	9	-	-

Pteridium aquilinum	V	(V)	10	-10
Galium saxatile	I	(V)*	5	(4)*
Potentilla erecta	I	(IV)*	4	-4
Festuca ovina	I	(IV)*	5	-7
Agrostis capillaris	I	(III)*	7	(4)*
Anthoxanthum odoratum	.	(III)*	0	-6
Holcus lanatus	.	(I)	0	-4
Viola riviniana	.	(I)	0	-3
Campanula rotundifolia	.	(I)	0	-3
Carex pilulifera	.	(I)	0	-4
Hylocomium splendens	I	(I)	5	-5
Luzula campestris	.	(I)	0	-4
Rumex acetosa	.	(I)	0	-1
Holcus mollis	I	(I)	5	(1)*
Dicranum scoparium	I	(V)*	5	-6
Pleurozium schreberi	III	(IV)	8	(6)*
Deschampsia flexuosa	IV	(III)	9	(6)*
Hypnum cupressiforme	I	(III)*	5	-6
Vaccinium myrtillus	V	(IV)	10	(4)*
Calluna vulgaris	III	(III)	10	(8)*
Nardus stricta	I	(II)	5	(4)*
Campylopus paradoxus	.	(II)*	0	-3
Polytrichum commune	I	(II)	10	(4)*
Lophozia ventricosa	.	(I)	0	-3
Isopterygium elegans	.	(I)	0	-3

Ptilidium ciliare	.	(I)	0	-3
Barbilophozia floerkei	.	(I)	0	-3
Agrostis curtisii	.	(I)	0	-8
Leucobryum glaucum	.	(I)	0	-4
Cladonia portentosa	.	(I)	0	-3
Hypogymnia physodes	.	(I)	0	-3
Cladonia chlorophaea	.	(I)	0	-3
Cladonia squamosa	.	(I)	0	-3
Cladonia coccifera	.	(I)	0	-3
Polytrichum formosum	I	(I)	1	-10
Campylopus pyriformis	.	(I)	0	-1
Scleropodium purum	I	(III)*	6	(4)*
Rhytidiadelphus squarrosus	III	(III)	8	(6)*
Lophocolea bidentata	.	(II)*	0	-3
Rumex acetosella	I	(I)	4	(3)*
Oxalis acetosella	I	(I)	1	-4
Danthonia decumbens	.	(I)	0	-3
Molinia caerulea	.	(I)	0	-4
Luzula multiflora	.	(I)	0	-3
Teucrium scorodonia	.	(I)	0	-1
Agrostis stolonifera	I	(I)	4	-4
Rhytidiadelphus loreus	.	(I)	0	-4
Carex binervis	.	(I)	0	-1
Agrostis canina	.	(I)	0	-3
Oreopteris limbosperma	.	(I)	0	-1

Thuidium tamariscinum	I	(I)	5	(4)*
Erica cinerea	.	(I)	0	-4
Plagiothecium undulatum	I	(I)	4	(3)*

Table 5.3.2 'MATCH' output for the U20B end group ''00100'

Conventions as for Table 5.3.1.
The following species found in the test data at a constancy of II or more are not recorded in the N.V.C diagnostic table for the unit U20b.
The data for each species are presented as: species name, constancy, maximum value.

Hypnum jutlandicum	II	8

Agrostis capillaris	V	(V)	10	(8)*
Anthoxanthum odoratum	I	(III)*	2	-6
Potentilla erecta	I	(V)*	4	-6
Festuca ovina	I	(IV)*	5	-10
Galium saxatile	V	(V)	9	(8)*
Holcus lanatus	.	(I)	0	-3
Cynosurus cristatus	.	(I)	0	-3
Campanula rotundifolia	.	(I)	0	-3
Helictotrichon pratense	.	(I)	0	-2
Viola lutea	.	(I)	0	-4
Carex caryophyllea	.	(I)	0	-3
Anemone nemorosa	.	(I)	0	-3
Luzula multiflora	.	(I)	0	-4
Rhytidiadelphus loreus	.	(I)	0	-3
Deschampsia cespitosa cespitosa	.	(I)	0	-4
Carex panicea	.	(I)	0	-3
Viola palustris	.	(I)	0	-6
Luzula sylvatica	.	(I)	0	-2
Blechnum spicant	.	(I)	0	-3
Carex echinata	.	(I)	0	-3
Vaccinium myrtillus	IV	(V)	9	(6)*
Pleurozium schreberi	I	(IV)*	5	-6
Nardus stricta	I	(IV)*	5	-8
Deschampsia flexuosa	III	(IV)	8	-9
Pteridium aquilinum	I	(II)	9	(4)*

Racomitrium lanuginosum	.	(II)*	0	-4
Rhytidiadelphus squarrosus	V	(III)*	7	(6)*
Luzula campestris	.	(III)*	0	-4
Festuca rubra	I	(II)	4	-8
Hypnum cupressiforme	.	(III)*	0	-4
Dicranum scoparium	I	(III)*	5	-6
Viola riviniana	.	(I)	0	-3
Pseudoscleropodium purun	I	(II)	5	(4)*
Hylocomium splendens	I	(II)	4	-6
Danthonia decumbens	.	(II)*	0	-6
Ranunculus acris	.	(I)	0	-3
Carex pilulifera	I	(I)	1	-2
Calluna vulgaris	II	(II)	9	(6)*
Juncus squarrosus	I	(II)	5	(4)*
Polytrichum commune	I	(II)	9	(6)*
Carex binervis	.	(II)*	0	-4
Polygala serpyllifolia	.	(I)	0	-3
Agrostis vinealis	I	(I)	5	(4)*
Conopodium majus	.	(I)	0	-3
Euphrasia officinalis agg	.	(I)	0	-3
Molinia caerulea	.	(I)	0	-3
Oxalis acetosella	I	(I)	4	-4
Thymus polytrichus	.	(I)	0	-3
Juncus effusus	I	(I)	8	(3)*
Holcus mollis	I	(I)	4	(3)*

Table 5.3.3   'MATCH' output for the U4e end group ''0100'

Conventions as for Table 5.3.1
The following species found in the test data at a constancy of ll or more are not recorded in the N.V.C diagnostic table for unit U4e.
The data for each species `are presented as: species name, constancy, maximum quantitative value.

Rumex acetosella	lV	5

Agrostis capillaris	V	(V)	9	-10
Anthoxanthum odoratum	I	(V)*	7	-8
Potentilla erecta	.	(V)*	0	-6
Festuca ovina	V	(V)	8	-10
Galium saxatile	IV	(IV)	7	(6)*
Holcus lanatus	I	(II)	4	-6
Achillea millefolium	.	(III)*	0	-6
Trifolium repens	I	(II)	3	-6
Cerastium fontanum	I	(II)	1	-4
Poa pratensis	I	(II)	4	-6
Prunella vulgaris	.	(I)	0	-4
Cynosurus cristatus	I	(I)	4	(3)*
Dactylis glomerata	.	(I)	0	-3
Veronica chamaedrys	.	(I)	0	-6
Taraxacum seedling/sp	.	(I)	0	-3
Campanula rotundifolia	.	(II)*	0	-4
Galium verum	.	(I)	0	-4
Lathyrus linifolius	.	(I)	0	-4
Lotus corniculatus	.	(II)*	0	-4
Succisa pratensis	.	(I)	0	-6
Viola lutea	.	(I)	0	-4
Carex caryophyllea	.	(I)	0	-4
Luzula multiflora	.	(I)	0	-4
Rhytidiadelphus loreus	.	(I)	0	-4
Deschampsia cespitosa ces.	I	(I)	4	-4
Thuidium tamariscinum	.	(I)	0	-4
Agrostis canina	.	(I)	0	-4
Carex panicea	I	(I)	1	-4
Viola palustris	.	(I)	0	-6
Luzula sylvatica	.	(I)	0	-6
Blechnum spicant	.	(I)	0	-6
Carex echinata	I	(I)	1	-3
Vaccinium myrtillus	I	(II)	9	(6)*
Pleurozium schreberi	I	(III)*	4	-6
Nardus stricta	I	(II)	5	-6
Deschampsia flexuosa	II	(II)	8	(6)*
Pteridium aquilinum	II	(I)	9	(6)*
Racomitrium lanuginosum	.	(I)	0	-3
Rhytidiadelphus squarrosus	V	(IV)	7	-10
Luzula campestris	I	(IV)*	3	-4
Festuca rubra	.	(III)*	0	-8
Hypnum cupressiforme	.	(III)*	0	-6
Dicranum scoparium	I	(III)*	4	-6
Viola riviniana	.	(III)*	0	-4
Scleropodium purum	I	(III)*	5	-6
Hylocomium splendens	.	(III)*	0	-10
Plantago lanceolata	.	(II)*	0	-4
Rumex acetosa	I	(II)	4	-4
Danthonia decumbens	.	(II)*	0	-6
Ranunculus acris	I	(I)	3	-4
Carex pilulifera	.	(III)*	0	-6
Calluna vulgaris	II	(II)	8	(4)*
Veronica officinalis	.	(II)*	0	-4
Juncus squarrosus	I	(I)	4	-4
Polytrichum commune	I	(I)	4	-6
Carex binervis	.	(I)	0	-6
Polygala serpyllifolia	.	(I)	0	-3
Agrostis vinealis	.	(I)	0	-6
Conopodium majus	.	(I)	0	-6
Mnium hornum	.	(I)	0	-4
Euphrasia officinalis a	.	(I)	0	-4
Molinia caerulea	.	(I)	0	-4
Oxalis acetosella	I	(I)	4	(3)*
Thymus polytrichus	.	(I)	0	-6
Juncus effusus	.	(I)	0	-4
Holcus mollis	.	(I)	0	-8
Polytrichum alpinum	.	(I)	0	-4
Rhytidiadelphus trique	.	(I)	0	-6
Lophocolea bidentata	.	(I)	0	-3
Cirsium vulgare	.	(I)	0	-4
Cirsium arvense	.	(I)	0	-3
Carex nigra	I	(I)	1	-4
Ranunculus repens	I	(I)	4	-4
Poa annua	.	(I)	0	-4

Table 5.3.4 'MATCH' output for the U4a end group ''0101'

Conventions as for Table 5.3.1
The following species found in the test data at a constancy of ll or more are not recorded in the N.V.C diagnostic table for unit U4a.
The data for each species `are presented as: species name, constancy, maximum quantitative value.

Rumex acetosella	lV	5

Festuca ovina	V	(V)	8	-10
Agrostis capillaris	V	(IV)	7	-9
Rumex acetosella	V	(IV)	5	-7
Dicranum scoparium	V	(II)*	7	-8
Coelocaulon aculeata	.	(I)	0	-7
Cladonia arbuscula	.	(I)	0	-6
Polytrichum piliferum	II	(I)	4	-7
Cladonia ciliata var. *tenuis*	.	(I)	0	-6
Cladonia portentosa	.	(I)	0	-7
Cladonia foliacea	.	(I)	0	-6
Cladonia uncialis	.	(I)	0	-5
Cladonia furcata	.	(I)	0	-5
Cladonia squamosa	.	(I)	0	-4
Cladonia gracilis	.	(I)	0	-4
Ptilidium ciliare	I	(I)	2	-6
Pohlia nutans	.	(I)	0	-4
Cladonia fimbriata	.	(I)	0	-4
Cladonia pyxidata	.	(I)	0	-4
Campylopus introflexus	I	(I)	1	-8
Silene otites	.	(I)	0	-4
Silene conica	.	(I)	0	-3
Scleranthus perennis	.	(I)	0	-3
Brachythecium albicans	.	(III)*	0	-7
Aira praecox	V	(III)*	4	-8
Erodium cicutarium	.	(II)*	0	-7
Cerastium fontanum	.	(II)*	0	-7
Teesdalia nudicaulis	.	(I)	0	-4
Aphanes arvensis	.	(I)	0	-5
Myosotis ramosissima	.	(I)	0	-4
Erophila verna agg.	.	(I)	0	-5
Astragalus danicus	.	(I)	0	-3
Veronica arvensis	.	(I)	0	-3
Sedum album	.	(I)	0	-5
Trifolium dubium	.	(I)	0	-4
Ornithopus perpusillus	.	(I)	0	-4
Plantago media	.	(I)	0	-4
Arenaria serpyllifolia	.	(I)	0	-6
Geranium molle	.	(I)	0	-4
Filago minima	.	(I)	0	-4
Cerastium arvense	.	(I)	0	-4
Trifolium seedling/sp	.	(I)	0	-3
Campanula glomerata	.	(I)	0	-4
Viola tricolor curtisii	.	(I)	0	-3
Tortula ruralis ssp. *ruraliformis*	.	(I)	0	-5
Thymus serpyllum	.	(I)	0	-4
Arabidopsis thaliana	.	(I)	0	-3
Rhytidium rugosum	.	(I)	0	-4
Veronica agrestis	.	(I)	0	-2
Arabis hirsuta	.	(I)	0	-3
Anthoxanthum odoratum	.	(II)*	0	-6
Lotus corniculatus	.	(II)*	0	-5
Galium verum	.	(II)*	0	-5
Plantago lanceolata	.	(III)*	0	-4
Holcus lanatus	.	(I)	0	-6
Achillea millefolium	.	(I)	0	-5
Campanula rotundifolia	I	(I)	2	-4
Quercus robur (g)	.	(I)	0	-3
Urtica dioica	.	(I)	0	-4
Galium saxatile	II	(II)	7	(5)*
Potentilla erecta	.	(I)	0	-4
Deschampsia flexuosa	I	(I)	7	(4)*
Ulex europaeus (s)	.	(I)	0	-5
Ulex minor	.	(I)	0	-3
Hypochoeris radicata	.	(I)	0	-4
Centaurium erythraea	.	(I)	0	-4
Leontodon saxatilis	.	(I)	0	-4
Festuca rubra	.	(I)	0	-4
Umbilicus rupestris	.	(I)	0	-4
Sedum anglicum	.	(I)	0	-3
Lychnis viscaria	.	(I)	0	-2
Veronica spicata	.	(I)	0	-2
Pilosella peleteriana	.	(I)	0	-4
Pilosella officinarum agg.	.	(II)*	0	-8
Senecio jacobaea	.	(II)*	0	-5
Koeleria macrantha	.	(II)*	0	-5
Hypnum cupressiforme	II	(II)	7	(5)*
Taraxacum seedling/sp	.	(II)*	0	-5
Calluna vulgaris	.	(II)*	0	-4
Poa annua	.	(II)*	0	-5
Ceratodon purpureus	II	(I)	5	(4)*
Polytrichum juniperinum	I	(I)	4	-9
Plantago coronopus	.	(I)	0	-8
Scleropodium purum	.	(I)	0	-7
Peltigera canina	.	(I)	0	-7
Carex arenaria	.	(I)	0	-7
Pteridium aquilinum	.	(I)	0	-4
Rhytidiadelphus squarrosus	I	(I)	1	-6
Agrostis stolonifera	.	(I)	0	-7
Chamerion angustifolium	.	(I)	0	-4
Luzula campestris	.	(I)	0	-6
Dactylis glomerata	.	(I)	0	-5
Veronica chamaedrys	.	(I)	0	-3
Rumex acetosa	.	(I)	0	-5
Rubus fruticosus agg.	.	(I)	0	-4
Anthyllis vulneraria	.	(I)	0	-6
Trifolium repens	.	(I)	0	-4
Spergularia rubra	.	(I)	0	-5
Stellaria media	.	(I)	0	-4
Crassula tillaea	.	(I)	0	-8
Glechoma hederacea	.	(I)	0	-6
Fallopia convolvulus	.	(I)	0	-5
Senecio vulgaris	.	(I)	0	-5
Leontodon hispidus	.	(I)	0	-5
Sagina procumbens	.	(I)	0	-4
Teucrium scorodonia	.	(I)	0	-5
Bromus hordeaceus ssp. *hordeaceus*	.	(I)	0	-5
Pleurozium schreberi	.	(I)	0	-4
Agrostis vinealis	I	(I)	1	-3
Sagina apetala ssp.*erecta*	.	(I)	0	-3
Gnaphalium uliginosum	.	(I)	0	-4
Veronica polita	.	(I)	0	-4
Sedum acre	.	(I)	0	-4
Phleum pratense	.	(I)	0	-3
Potentilla reptans	.	(I)	0	-4
Vicia sativa	.	(I)	0	-5
Potentilla argentea	.	(I)	0	-4
Reseda lutea	.	(I)	0	-3
Trifolium campestre	.	(I)	0	-4
Stellaria graminea	.	(I)	0	-3
Anisantha sterilis	.	(I)	0	-7

Table 5.3.5 'MATCH' output for the U1 end group ''011'

Conventions as for Table 5.3.1

The following species found in the test data at a constancy of II or more are not recorded in the N.V.C diagnostic table for the unit U1.
The data for each species are presented as: species name, constancy, maximum value.

Cladonia squamules / sp	IV	5

Nardus stricta	IV	(V)	8	-10
Galium saxatile	II	(V)*	4	-6
Potentilla erecta	II	(IV)*	4	-4
Festuca ovina	II	(IV)*	6	-8
Agrostis capillaris	II	(IV)*	8	(6)*
Rhytidiadelphus squarrosus	I	(IV)*	4	-6
Deschampsia flexuosa	I	(III)*	4	-8
Pleurozium schreberi	.	(III)*	0	-6
Vaccinium vitis-idaea	.	(I)	0	-4
Luzula campestris	I	(I)	2	-4
Alchemilla alpina	.	(I)	0	-6
Luzula multiflora	.	(II)*	0	-4
Agrostis canina	.	(II)*	0	-6
Polytrichum commune	II	(II)	9	-9
Ptilidium ciliare	.	(II)*	0	-3
Barbilophozia floerkei	.	(I)	0	-3
Carex bigelowii	.	(I)	0	-7
Campylopus paradoxus	.	(I)	0	-6
Plagiothecium undulatum	.	(I)	0	-3
Carex panicea	II	(II)	5	(4)*
Viola riviniana	.	(I)	0	-4
Lophocolea bidentata	.	(I)	0	-3
Cerastium fontanum	I	(I)	2	-3
Ranunculus acris	I	(I)	1	-4
Thuidium tamariscinum	I	(I)	4	-4

Festuca rubra	I	(I)	1	-6
Polygala serpyllifolia	.	(I)	0	-3
Juncus effusus	I	(I)	6	(4)*
Carex viridula ssp. *oed.*	III	(I)*	8	(4)*
Plantago lanceolata	I	(I)	4	-4
Leontodon autumnalis	I	(I)	4	(3)*
Calliergon cuspidatum	III	(I)*	7	(4)*
Trifolium repens	II	(I)	4	-4
Equisetum palustre	.	(I)	0	-3
Cirsium palustre	II	(I)	5	(4)*
Selaginella selaginoides	.	(I)	0	-3
Carex pulicaris	I	(I)	2	-4
Calluna vulgaris	I	(II)	2	-8
Danthonia decumbens	I	(II)	4	-4
Pseudoscleropodium purun	I	(I)	4	-6
Erica tetralix	.	(I)	0	-6
Trichophorum cespitosum	.	(I)	0	-8
Racomitrium lanuginosum	.	(I)	0	-10
Cladonia uncialis	.	(I)	0	-4
Molinia caerulea	.	(I)	0	-6
Rhytidiadelphus loreus	.	(I)	0	-4
Diplophyllum albicans	.	(I)	0	-6
Narthecium ossifragum	I	(I)	4	-4
Empetrum nigrum nigrum	.	(I)	0	-6
Huperzia selago	.	(I)	0	-4

Cetraria islandica	.	(I)	0	-4
Scapania gracilis	.	(I)	0	-3
Pleurozia purpurea	.	(I)	0	-4
Juncus squarrosus	III	(III)	7	-8
Vaccinium myrtillus	I	(III)*	1	-8
Anthoxanthum odoratum	III	(III)	7	(6)*
Hylocomium splendens	I	(III)*	1	-6
Hypnum cupressiforme	.	(III)*	0	-6
Carex binervis	.	(II)*	0	-4
Carex pilulifera	.	(II)*	0	-6
Dicranum scoparium	I	(II)	2	-6
Carex nigra	II	(II)	5	-6
Luzula sylvatica	.	(I)	0	-6
Campanula rotundifolia	.	(I)	0	-4
Deschampsia cespitosa ces.	I	(I)	4	-6
Polytrichum alpinum	.	(I)	0	-4
Polytrichum formosum	.	(I)	0	-5
Eriophorum angustifolium	I	(I)	2	-6
Calypogeia muelleriana	.	(I)	0	-3
Eriophorum vaginatum	I	(I)	4	-6
Aulacomnium palustre	I	(I)	5	-6
Lophozia ventricosa	.	(I)	0	-3
Pohlia nutans	.	(I)	0	-3
Blechnum spicant	.	(I)	0	-4
Polytrichum juniperinum	I	(I)	2	-4
Anemone nemorosa	.	(I)	0	-3
Dicranella heteromalla	.	(I)	0	-3
Erica cinerea	.	(I)	0	-6
Sphagnum papillosum	.	(I)	0	-9

Figure 5.3.6 'MATCH' output for the U5 end group ''1'

Conventions as for Table 5.3.1

The following species found in the test data at a constancy of II or more are not recorded in the N.V.C diagnostic table for unit U4a.

The data for each species are presented as: species name, constancy, maximum quantitative value.

Carex echinata	III	5
Cardamine pratensis	III	5
Ranunculus repens	III	7
Juncus bulbosus	III	7
Lotus corniculatus	III	5
Ranunculus flammula	III	7
Pteridium aquilinum	III	7

Group 0011 [Table 5.3.1] with 39 quadrats in 8 stands, is in many ways analogous to Group 00101 [H12a with U20b affinities] and is probably best considered part of the same gradient of heathland either progressing towards or retreating from U20b.

Group 0100 [Table 5.3.3] holds two complete stands together with quadrats from a further 9 stands, which all fall within the NVC U4e *Festuca ovina-Agrostis capillaris* grassland: *Vaccinium myrtillus-Deschampsia flexuosa* sub-community although having some attributes of NVC U5d *Nardus stricta-Galium saxatile* grassland: *Calluna vulgaris-Danthonia decumbens* sub-community. This group should perhaps be considered together with Group 0101 [Table 5.3.4]. With 49 quadrats in 7 stands, this has greatest similarity to U4a *Festuca ovina-Galium saxatile* grassland: typical community, although this group too, has affinities with U5. Groups 0100 and 0101, products of the same division, should perhaps be considered as facies of the same community. Rodwell (1992) considers this community as widespread on more base poor mineral soils in areas where high rainfall enhances leaching whilst protecting the soils from drought. The principal differences are the levels of *Calluna* and *Vaccinium,* which are more abundant in the U4e category than in the basic U4a.

Group 011 [Table 5.3.5] holds an entire stand and representatives of three others. These had greatest affinity with NVC U1, *Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland although with some attributes of NVC H1c, *Calluna vulgaris-Festuca ovina* heath; *Teucrium scorodonia* sub-community. U1 is a grassland characteristic of base poor parched soils (Rodwell, 1992) particularly where subject to intensive rabbit or sheep grazing which suppresses any shrubby species. H1c is a community, where as heavy grazing suppresses the growth of heather, open areas may develop which allow expansion of grassland species or *Pteridium* to be established. Group 011 is probably genuine U1.

Group 1 [Table 5.3.6]: holds quadrats from three stands which were characterised as ‘wet’ by the indicator species and which were categorised as having affinities with both NVC U5, *Nardus stricta-Galium saxatile* grassland and with NVC M6B, *Carex echinata – Sphagnum recurvum / auriculatum* mire: *Carex nigra-Nardus stricta* sub-community. Although Rodwell (1991) notes that this mire is the major type of vegetation on peats and peaty gleys throughout the sub-montane zone particularly where the irrigation is by generally base poor waters, the appropriate classification here is more likely to be U5.

5.4 Spatial distribution of stand communities

The proportions of stands found in each NVC community were calculated [see section 4.4.3 and 5.3]. Appropriate files were generated and these data input into ARCVIEW so that both the amplitudes and the spatial distribution of the various NVC groups could be displayed.

Figure 5.4.1 shows the distribution of the stands falling in the NVC 12a community. Their distribution indicates that a main core of heathland exists as a band across the central area of the plateau but its level in some stands, in particular LM 6, LM 49, and LM 69, suggests it is a minor component of the community.

The distribution of NVC U20b *Pteridium* community shown in Figure 5.4.2 indicates not only both those stands where it is the dominant community but also those stands where it is associated with the H12a heathland probably as an encroaching, and in some cases e.g. LM 49 and LM 69, an overwhelming species.

NVC 4e is shown both as a concentration in the High Park area [Figure 5.4.3] as well as being represented at lower levels in other stands, some in the central area of the plateau associated with H12a [LM3, LM32, LM49, LM54, and LM 68] and with both H12a, U4a and U1 in LM 24.

Figure 5.4.4 shows the distribution of NVC 4a with its presence both as a single community stand but also associated with other communities notable with NVC 4e in stand LM 24.

NVC U1 appears [Figure 5.4.5] as both a disparate single community stand as well as being a component of the mosaic in others; it appears with H12a in LM 7 and LM 64 and with H12a, U4a and U4e in LM24.

It is no great surprise that U5 [Figure 5.4.6] is associated with three stands where it is the dominant community although it is associated with U4a in stand LM 70.

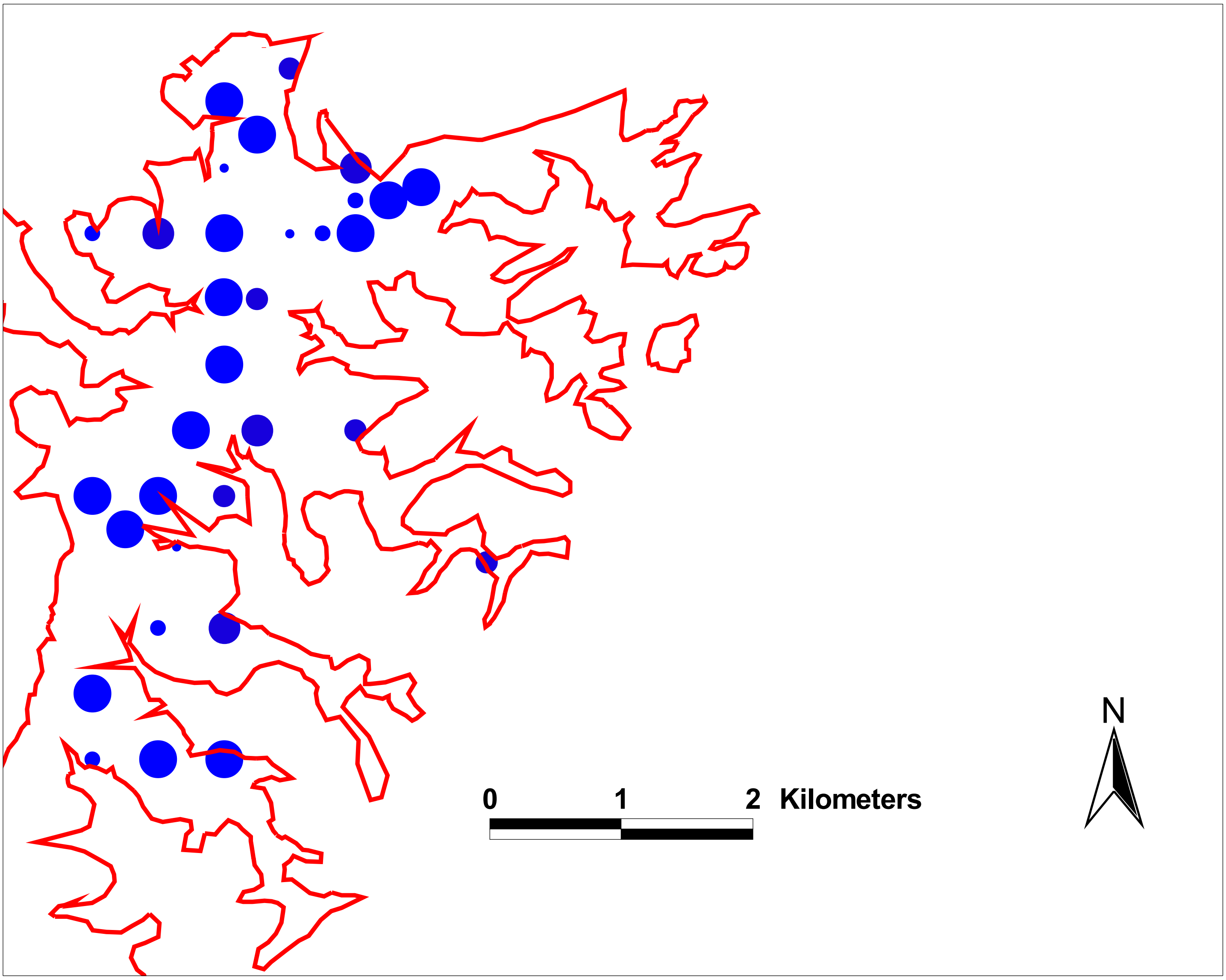

Figure 5.4.1. Location and proportion of stands belonging to NVC H12a.

Base maps removed to ensure copyright compliance

Plateau boundary

• Class 1 [1-20%]

● Class 2 [21-40%]

● Class 3 [41-60%]

● Class 4 [61-80%]

● Class 1 [81-100%]

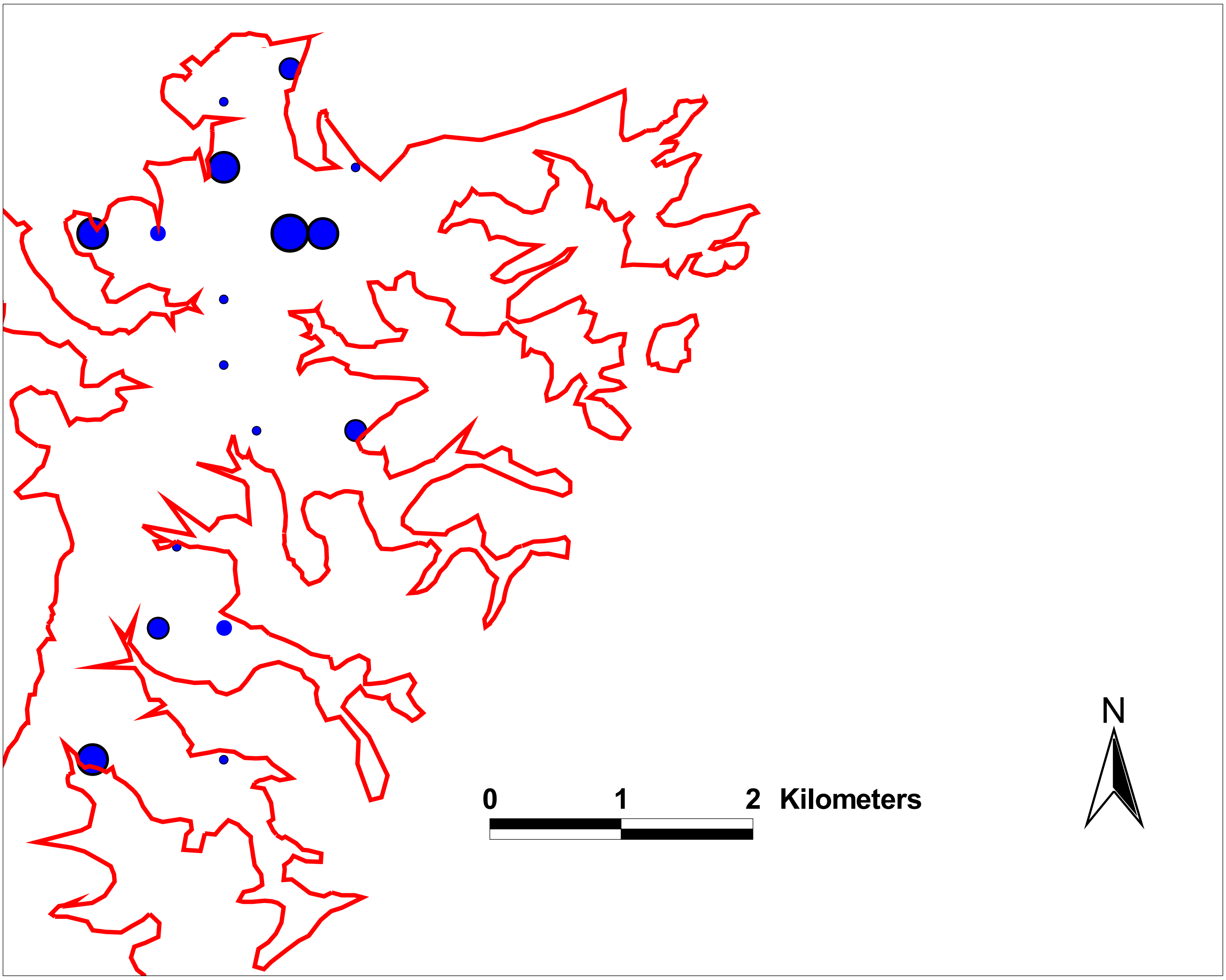

Figure 5.4.2. Location and proportion of stands belonging to NVC U20b

Category details as for Figure 5.4.1

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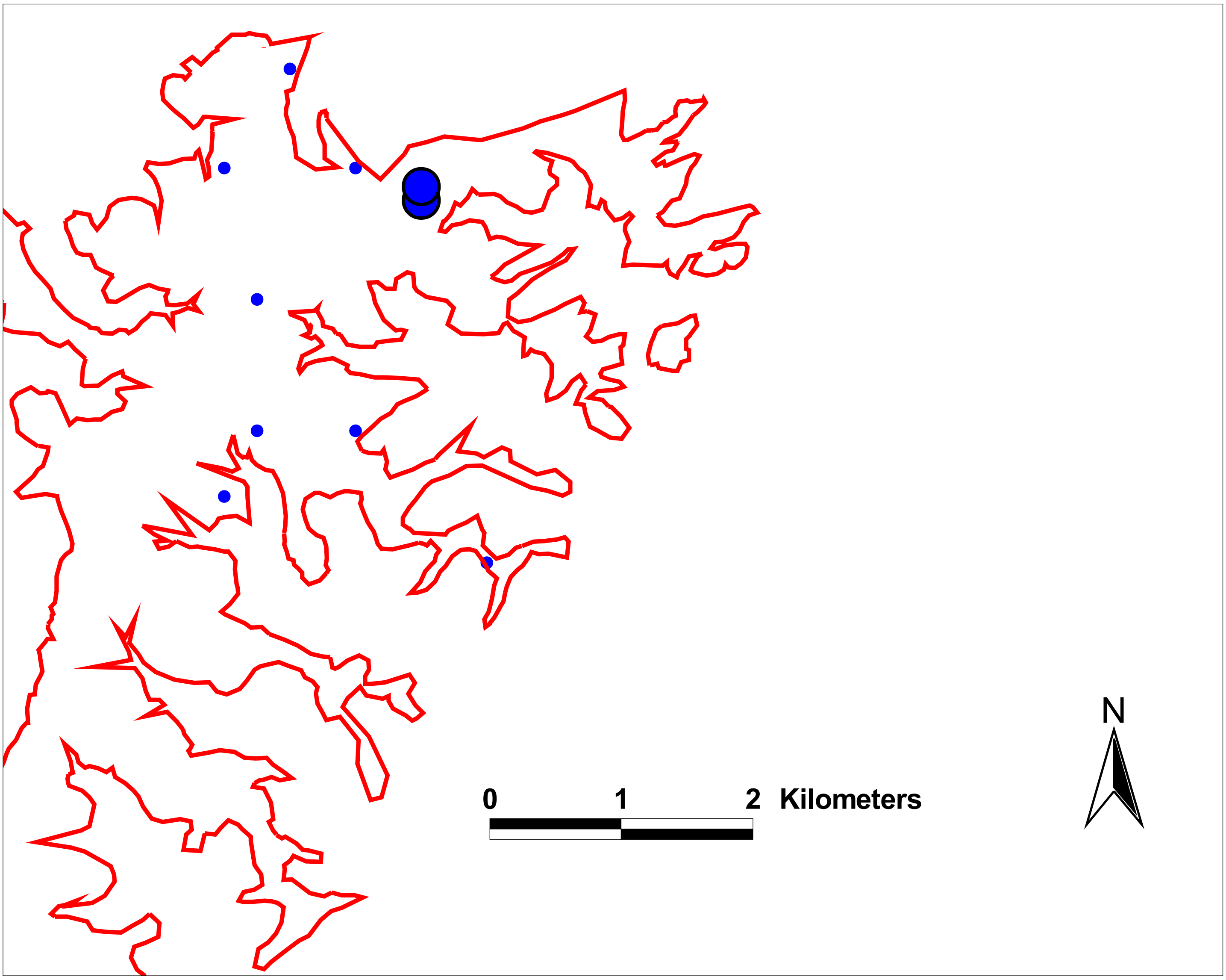

Figure 5.4.3. Location and proportion of stands belonging to NVC U4e

Category details as for Figure 5.4.1

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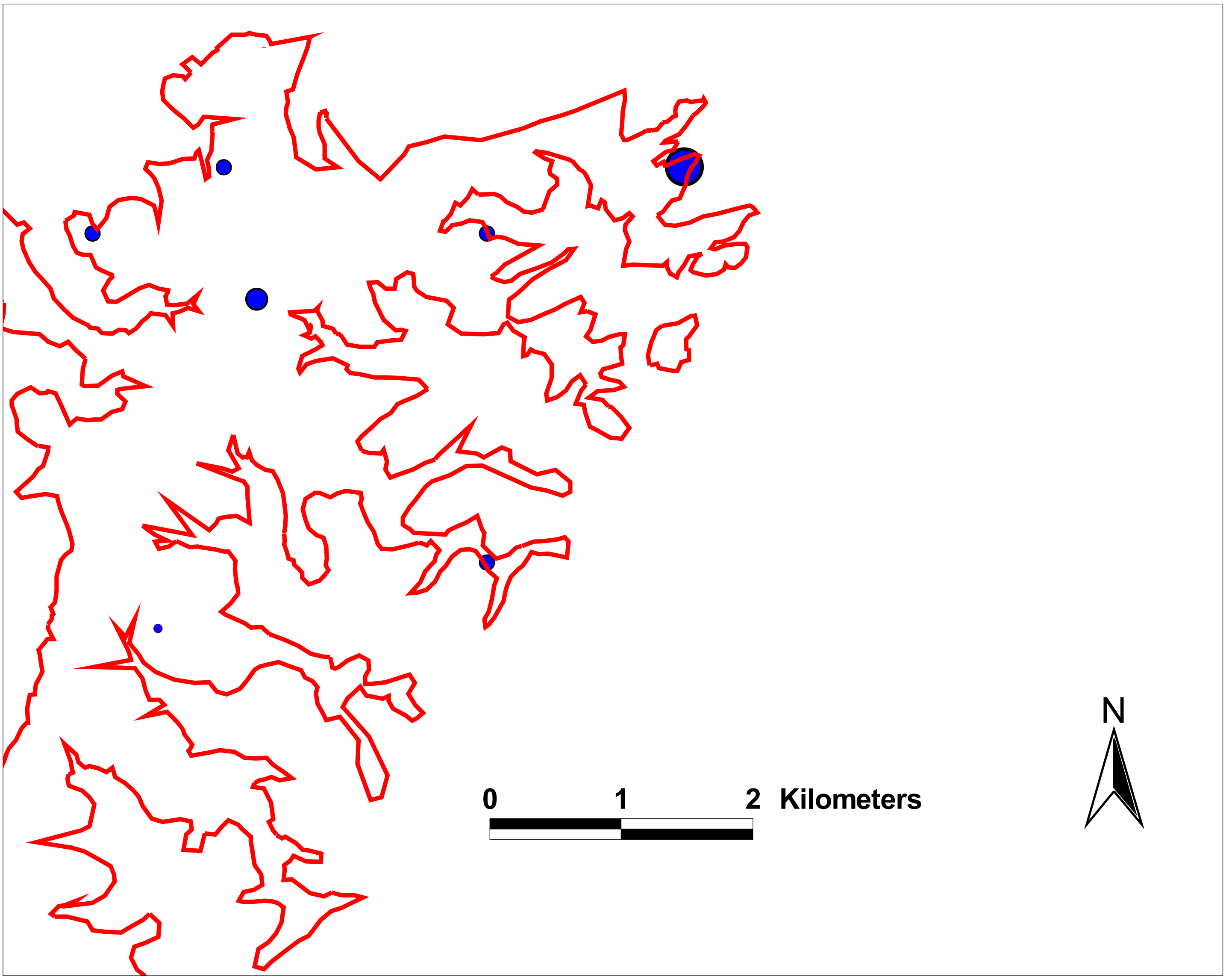

Figure 5.4.4. Location and proportion of stands belonging to NVC U4a

Category details as for Figure 5.4.1

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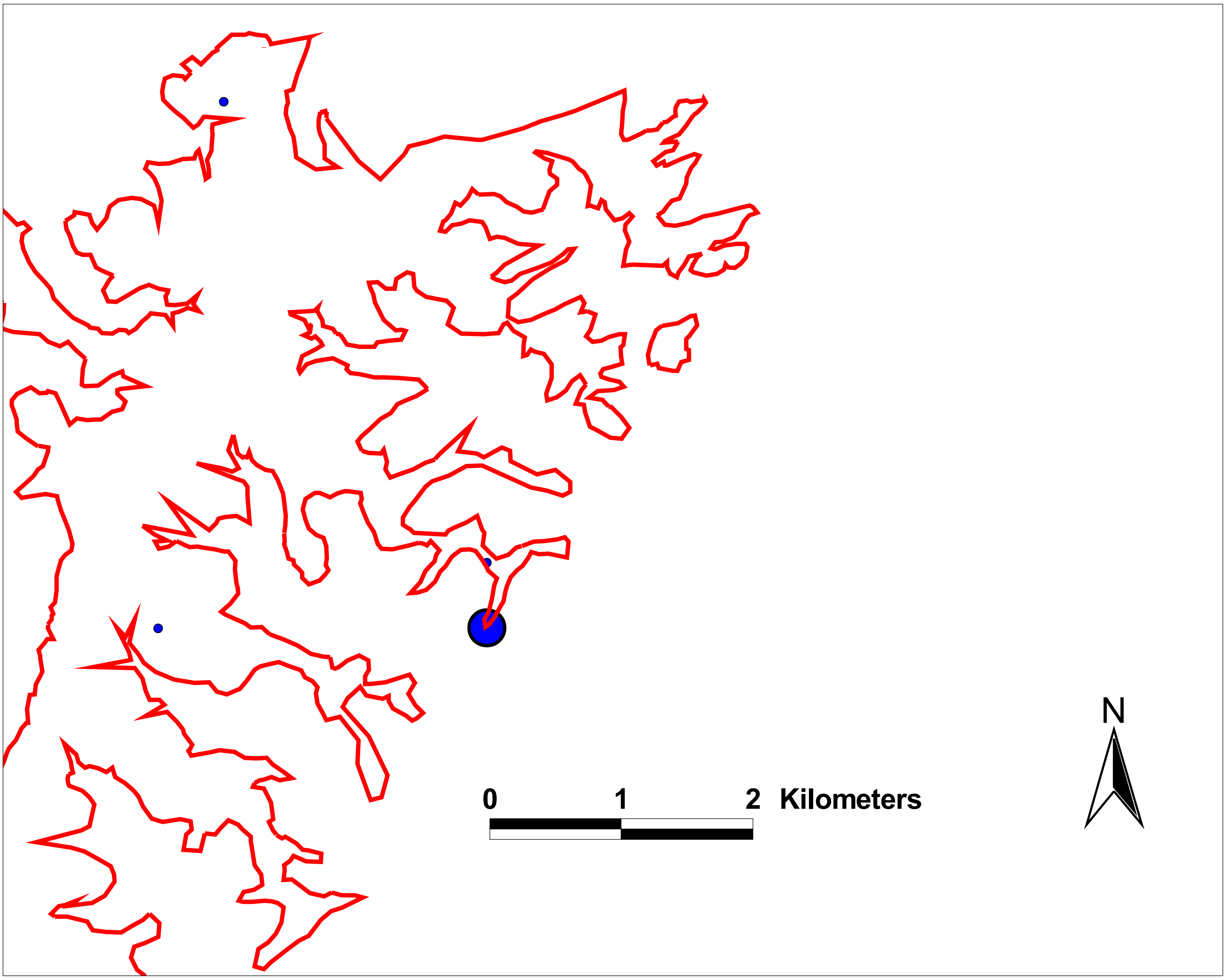

Figure 5.4.4. Location and proportion of stands belonging to NVC U1

Category details as for Figure 5.4.1

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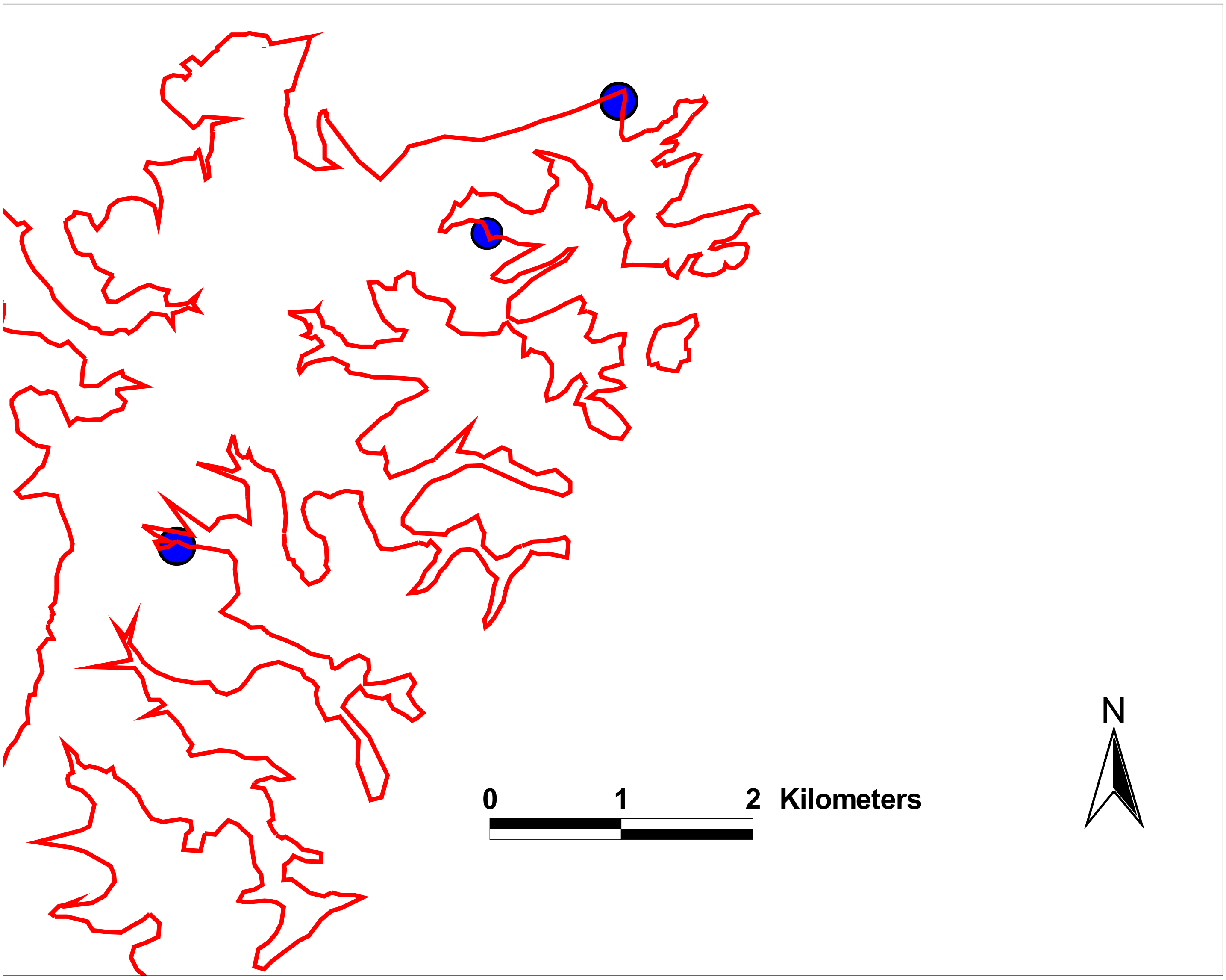

Figure 5.4.6. Location and proportion of stands belonging to NVC U1

Category details as for Figure 5.4.1

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5.5 CANOCO analyses

As stated in section 5.2, WinTWINS analyses were undertaken on three quadrat data sets so these were divided into coherent communities and vegetation types based on the their species composition.

The ‘all species’ WinTWINS analysis [Figure 5.2.2] shows an holistic overview of the community distribution. However there was a possibility that the dynamics of the separation could be blurred by the use of both vascular and bryophyte species in the divisions. Were the dispositions of the two taxonomic groups controlled by similar external environmental factors and to what extent was the presence of one group influencing or controlling the presence of the other?

CANOCO analyses [see section 4.4.2] were undertaken to investigate relationships between the species and quadrats and measured environmental variables. In addition analyses were also carried out on the derived ‘bryophyte and lichen’ data in order to separate the influence of the vascular vegetation from the environmental variables in controlling the distribution of bryophytes.

5.5.1 ‘All species’ analyses

The initial analysis was undertaken using Detrended Correspondence Analysis [DCA] with the options set to: detrending by [26] segments, non linear rescaling of axes [rescaling threshold 0.00].

Figure 5.5.1 shows the positions of the quadrats with two clusters readily discernible in the plot; Group 1 holds the principal wetland quadrats from the first WinTWINS dichotomy and the remaining groups are aggregated into one, or possibly, two further scatters.

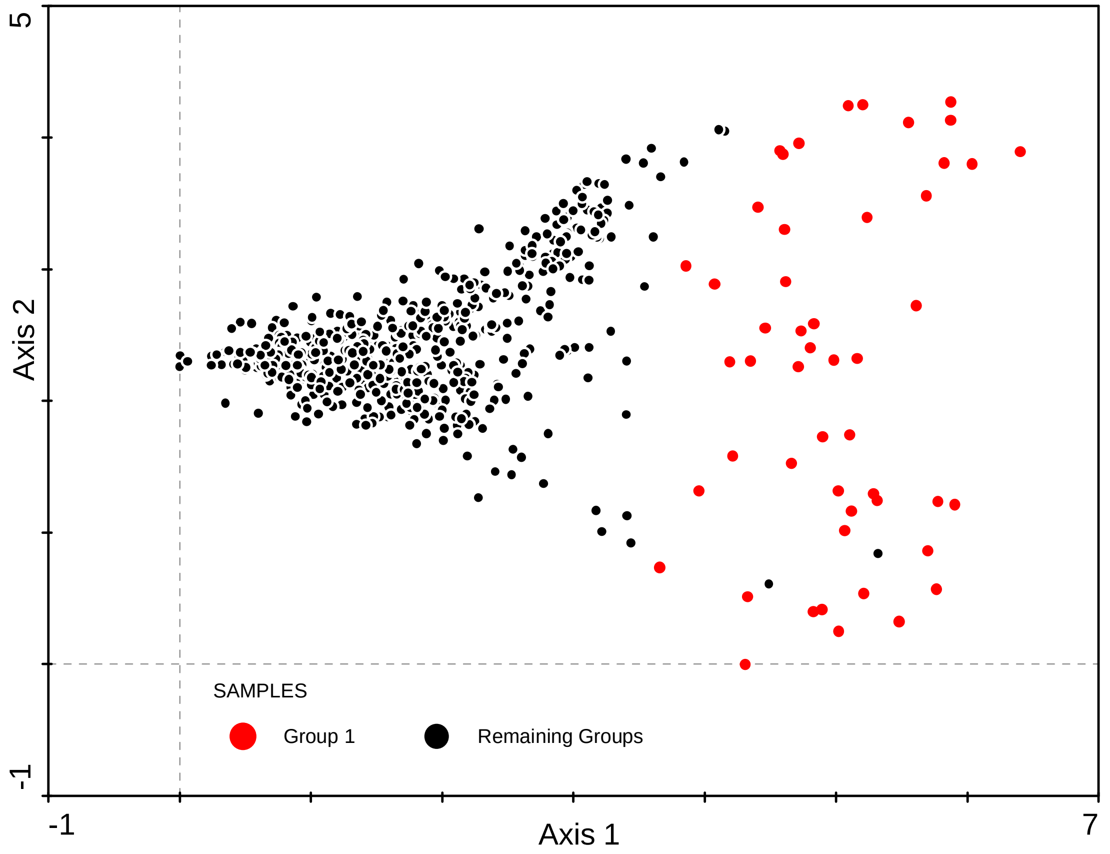

Figure 5.5.1. DCA analysis of ‘all species’ data set, quadrat ordination.
The wetland Group 1, a principal Endgroup in the first dichotomy of the WinTWINS analysis, can easily be differentiated from the remaining groups.

Figures 5.5.2a and 5.5.2b show the species distribution in the same ordination. There appears to be three basic clusters; an upper right group bounded by *Montia fontanum, Sagina procumbens* and *Bellis perennis* with *Mnium hornum, Plagiomnium undulatum, Palustriella commutata* and *Philonotis fontanum.*

A lower right hand group is defined by *Eriophorum vaginatum, Narthecium ossifragum, Carex viridula, Juncus acutifolia* and *J. bulbosus* together with *Polytrichum commune, Aulacomnium palustre* and the sphagna *S. recurvum, S. palustre, S.capilaris and S.subnitens.*

A central group is delineated by *Pteridium aquilinum, Agrostis canina, Rumex acetosella, Cirsium* sp., *Sorbus aucuparia* as well as *Rhytidiadelphus squarrosus, Hypnum jutlandicum, Campylopus introflexus* and *Eurhynchium praelongum.* The separation of the two clusters of ‘wetland’ vegetation is easily seen.

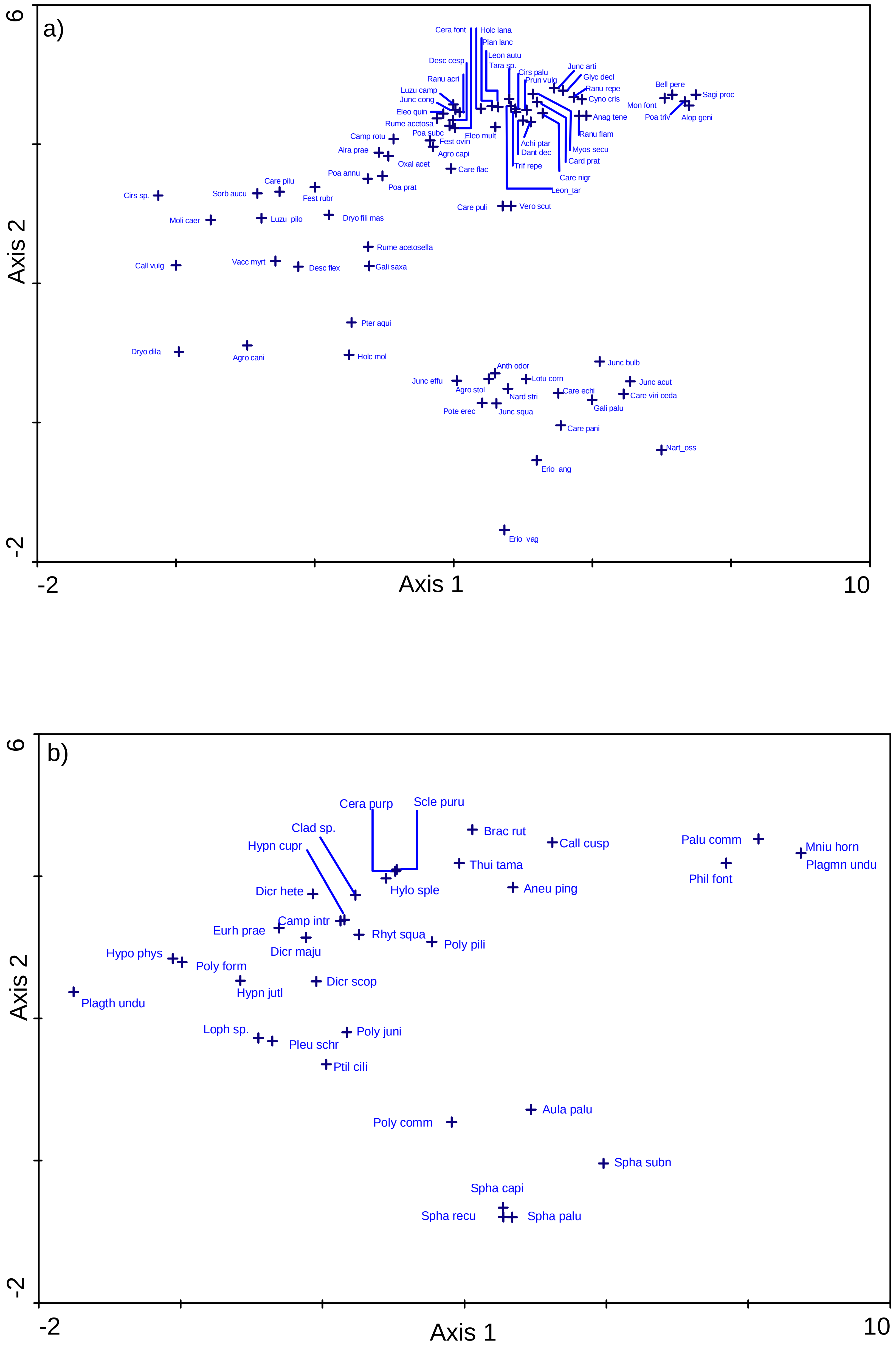

Figure 5.5.2 (a & b.) DCA of ‘all species’ data. Species ordination of 1st and 2nd axes shown as two plots for clarity: a) vascular species, b) bryophyte and lichen species.

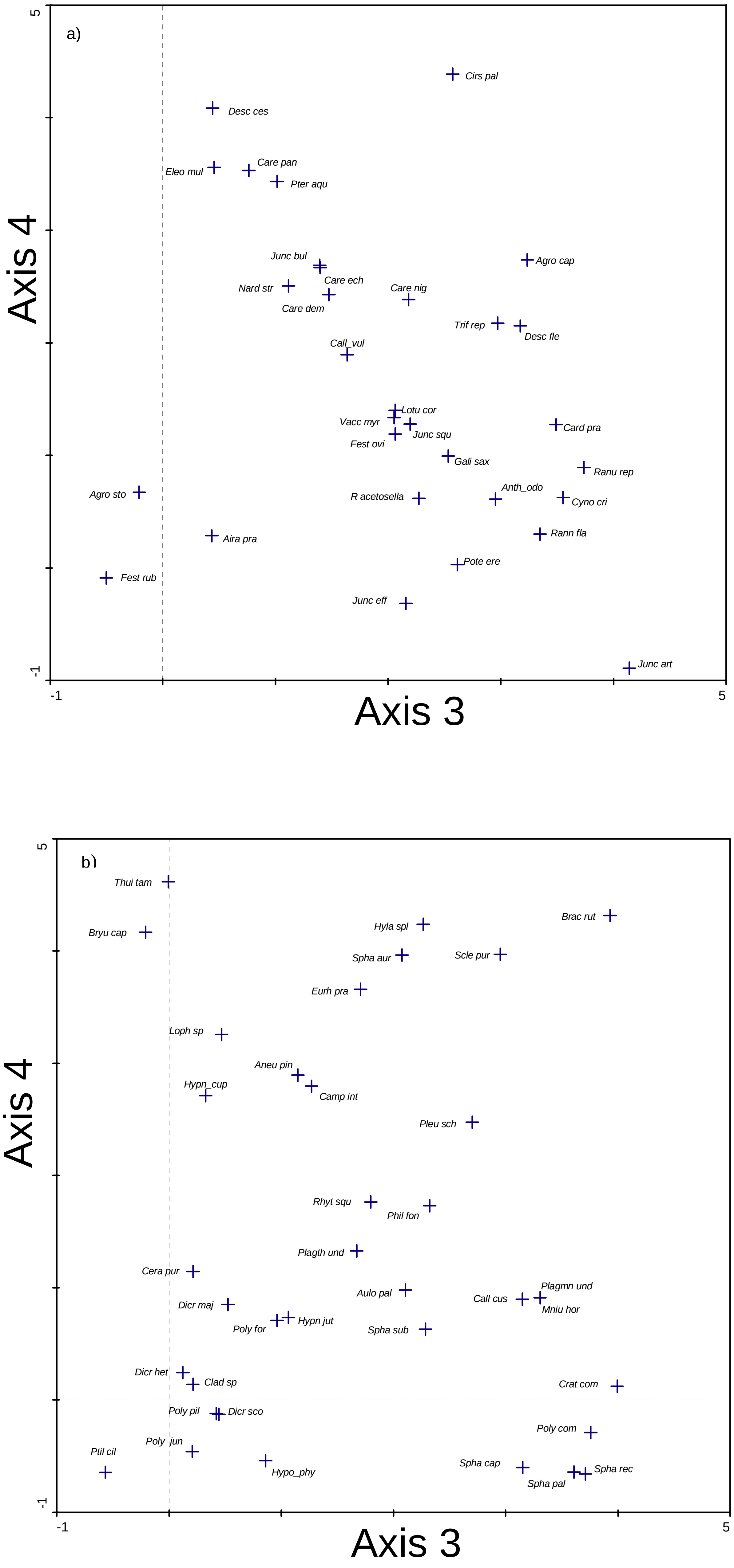

Figure 5.5.3 (a & b) DCA of ‘all species’ data. Species ordination of 3rd and 4th axes shown as two plots for clarity: a) vascular species, b) bryophyte and lichen species.

Figures 5.5.3a and 5.5.3b show the third and fourth axes species ordination of the DCA from the all species analysis.

Looking at the key vascular species [5.5.3a], *Agrostis stolonifera* and *Festuca rubra,* lying at the lower end of axis 3, suggest richer, possibly disturbed soils which are marginal to the heath. *Agrostis capillaris* and *Deschampsia flexuosa,* at the upper end of the axis suggest poorer soils or overgrazed impoverished heath. There is little difference in position between the major species, *Vaccinium myrtillus, Calluna vulgaris* and *Pteridium aquilinum* on this axis.

On axis four there is a separation between *Pteridium aquilinum* in the upper reaches, *Calluna vulgaris* and *Deschampsia flexuosa* in the upper middle zone and *Vaccinium myrtillus* in the lower middle zone.

The ‘central groups’ identified in Figure 5.5.2 are no longer evident on axes 3 and 4, and these axes appear to show some factors associated with the difference between a small number of disturbed and marginal situations and the remainder.

These relationships are not strong and are difficult to interpret and provide little information to that provided by axes one and two, therefore subsequent analyses concentrated on axes one and two

Centroids [means ± standard deviations] for each stand were calculated from the 1st and 2nd axis quadrat scores and plotted as Figure 5.5.4. This shows the distinct separation of the three ‘wetland’ stands, both from the main body of heathland stands, and from each other, as well as suggesting possible clusters amongst the other stands. An equivalent plot (not shown) for the 3rd and 4th axes does not show the same separation.

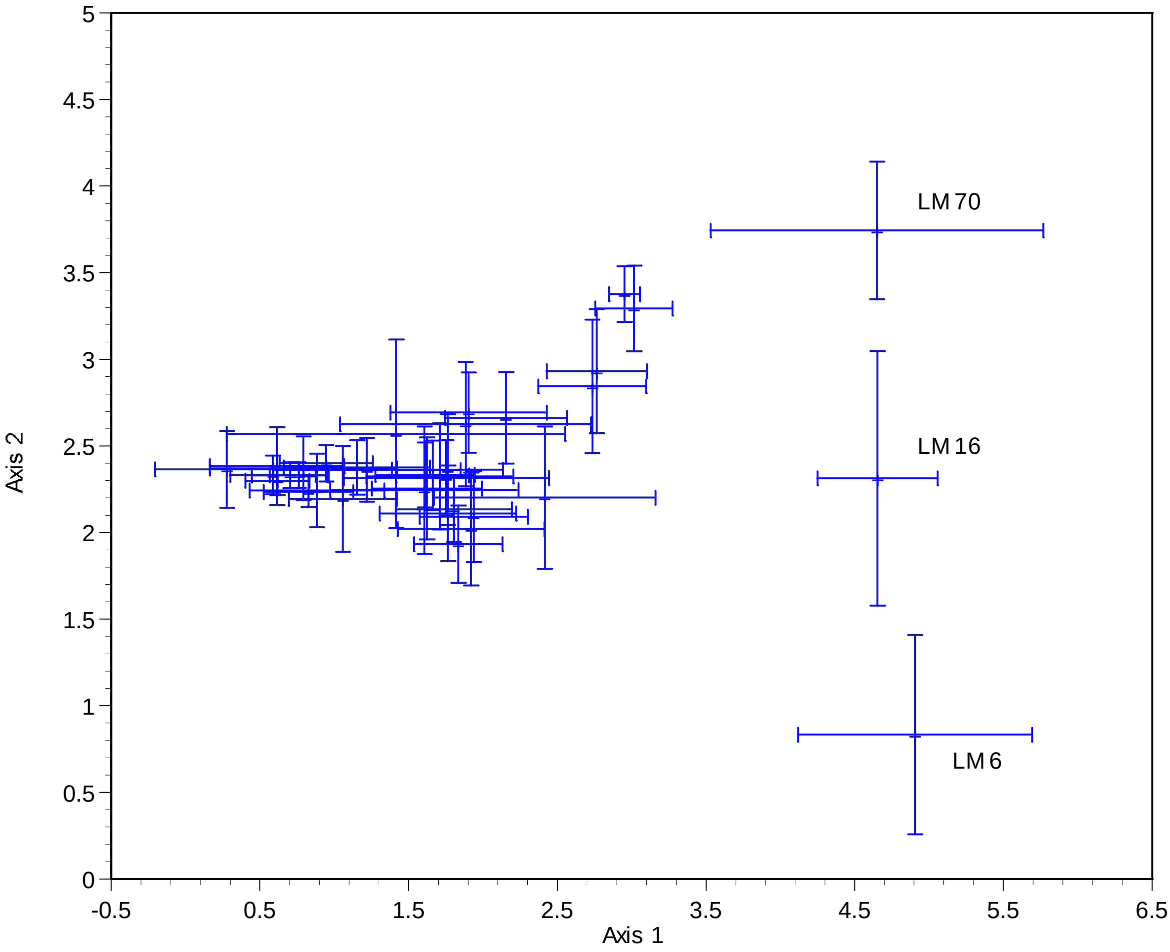

Figure 5.5.4. Centroids [means ± SD] of the stands from the 'all species' DCA showing the separation of the three 'wetland' stands from the bulk of the heathland.

The separation of the wetland stands from the remaining stands seems well established [Figures 5.2.1, 5.4.1 and 5.5.4] and in order to concentrate on the principal point of interest, the heathland, these wetland stands were removed from subsequent analyses.

An exploratory DCA of this modified data set produced gradient lengths [1.850, 4.259, 3.231 and 3.737] which suggested that Principal Component Analysis [PCA] was an appropriate route. ter Braak and Smilauer (2002b) note that gradients do not necessarily decrease in value, and here only the gradient length for axis 2 gave any suggestion of a unimodal response.

The initial PCA is plotted as Figure 5.5.5 with the individual quadrats colour coded according to their WinTWINS end group and their subsequent NVC category.

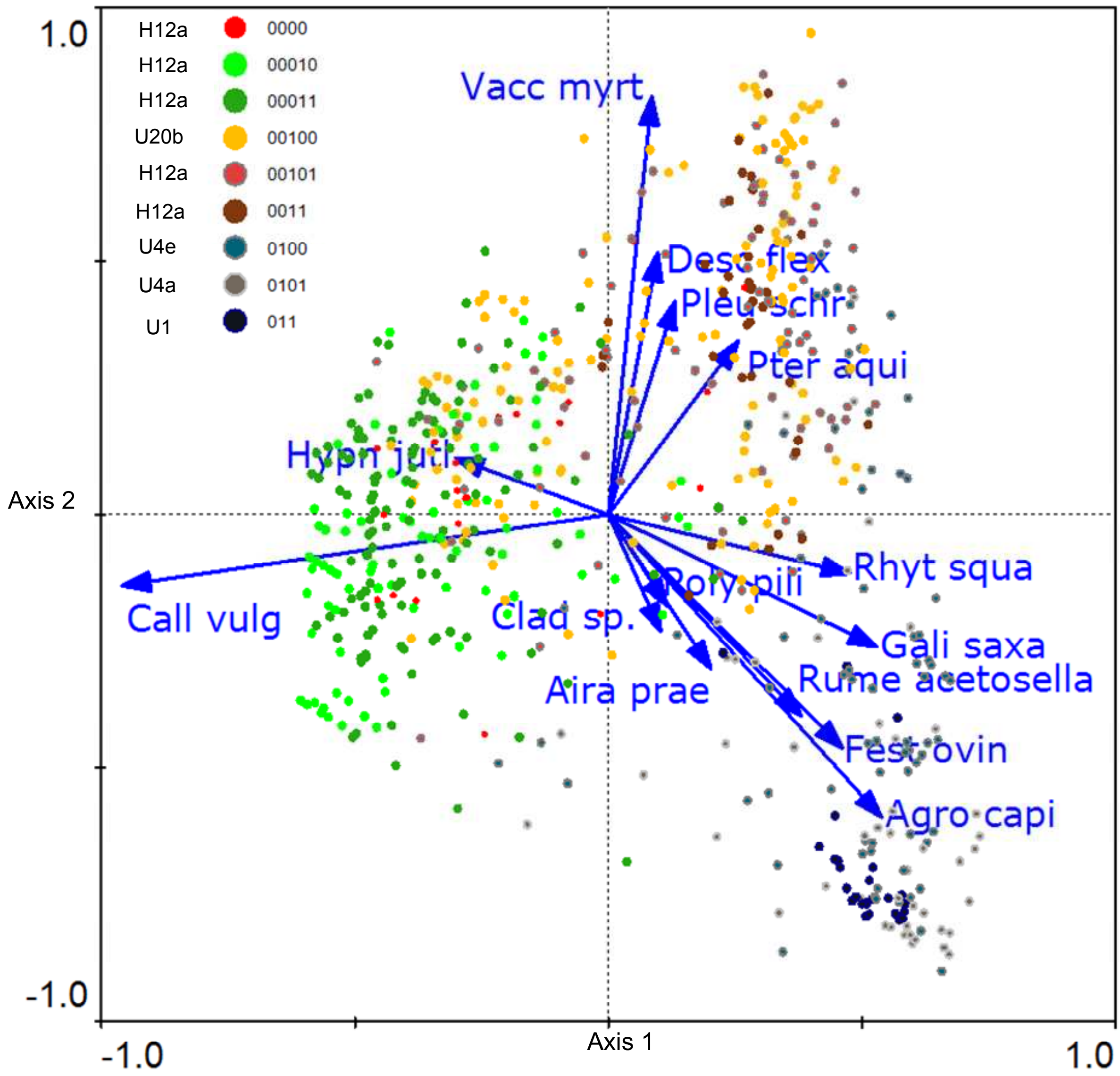

Figure 5.5.5. PCA analysis of the amended ‘all species’ data [i.e. wetland stands removed] showing species, and samples [quadrats] coded according to their WinTwins end group [*vide* Figure 5.2.1]. To simplify the plot only species with a constancy level greater than IV in any WinTwins endgroup have been shown. The eigenvalues of axes 1 and 2 are 0.259 and 0.159, respectively.

The clusters of principal species vectors appear to identify the main vegetation Groups. *Calluna vulgaris* and *Hypnum jutlandicum* indicate ‘quality’ heathland, *Vaccinium myrtillus* and *Deschampsia flexuosa* point to degraded heath communities, whereas *Pteridium aquilinum* suggests a U20b or H12a community: *Pleurozium schreberi* is associated with both vegetation groups both ecologically and on the plot.

Polytrichum piliferum, *Rhytidiadelphus squarrosus, Galium saxatile, Festuca ovina, Agrostis capillaris, Rumex acetosella* and *Aira praecox* indicate a grassland [U1 and U4a & U4e] or possibly the bare heath end of the continuum.

There is a juxtaposition of the *Vaccinium, Deschampsia, Pleurozium* and *Pteridium* vectors. The aggregation of quadrats from different groups [U20, U4 and H12] associated with this, together with the amorphous scatter of those quadrats, suggests that this may be a genuine and quite frequent association on the Long Mynd and not simply the feature of a single stand.

A further analysis using RDA [redundancy analysis, a technique where the analysis is constrained by explanatory, usually environmental, variables] was undertaken on these data.

Manual forward selection using Monte Carlo permutation tests [499 permutations, p = 0.0020] was employed to determine those environmental variables which had a non-random relationship with the ordination and thus which should be used or discarded. It was not possible to show that bare soil and bare rock had non-random relationships with the ordination so they were excluded from the analysis.

Northing and easting were used as supplementary variables; as components of grid references they recorded position and any ecological significance was likely to reflect other variables already considered such as altitude, slope and possibly soil depth at a given position. Canopy height was also used as a supplementary variable; the greatest canopy heights were recorded for *Pteridium* or *Calluna* quadrats and it was considered that such quadrats would be autocorrelated with canopy height if this was used as an environmental variable.

The results of this RDA are shown in Figure 5.5.5; to aid clarity the species displayed have been limited as in Figure 5.5.4, *viz.* only those with a constancy level greater than IV in any WinTwins end group have been shown.

There is a strong positive association between *Calluna vulgaris* and altitude and a corresponding negative association with slope which is perhaps not unexpected given the prevalence of *Calluna* on the flatter areas of the plateau.

Agrostis capillaris has a strong positive association with increasing pH and a negative association with soil depth, as have *Festuca ovina* and *Galium saxatile,* albeit to lesser degrees, suggesting bare heath or grassland areas.

The first axis separation appears to produce three basic zones: heathland zone in the lower part of the axis, a transition zone in the centre of the axis and a grassy or bare heath area in the high end of the axis.

Pteridium aquilinum has a positive relationship with ‘litter’ as does *Pleurozium schreberi* although in the case of the former, this relationship may represent an element of autocorrelation. *Vaccinium myrtillus, Hypnum jutlandicum* and *Deschampsia flexuosa* show a negative relationship with litter

The second axis separation appears to represent differences between those areas of heath and grassland subject to bracken incursions and areas where bracken is not prevalent.

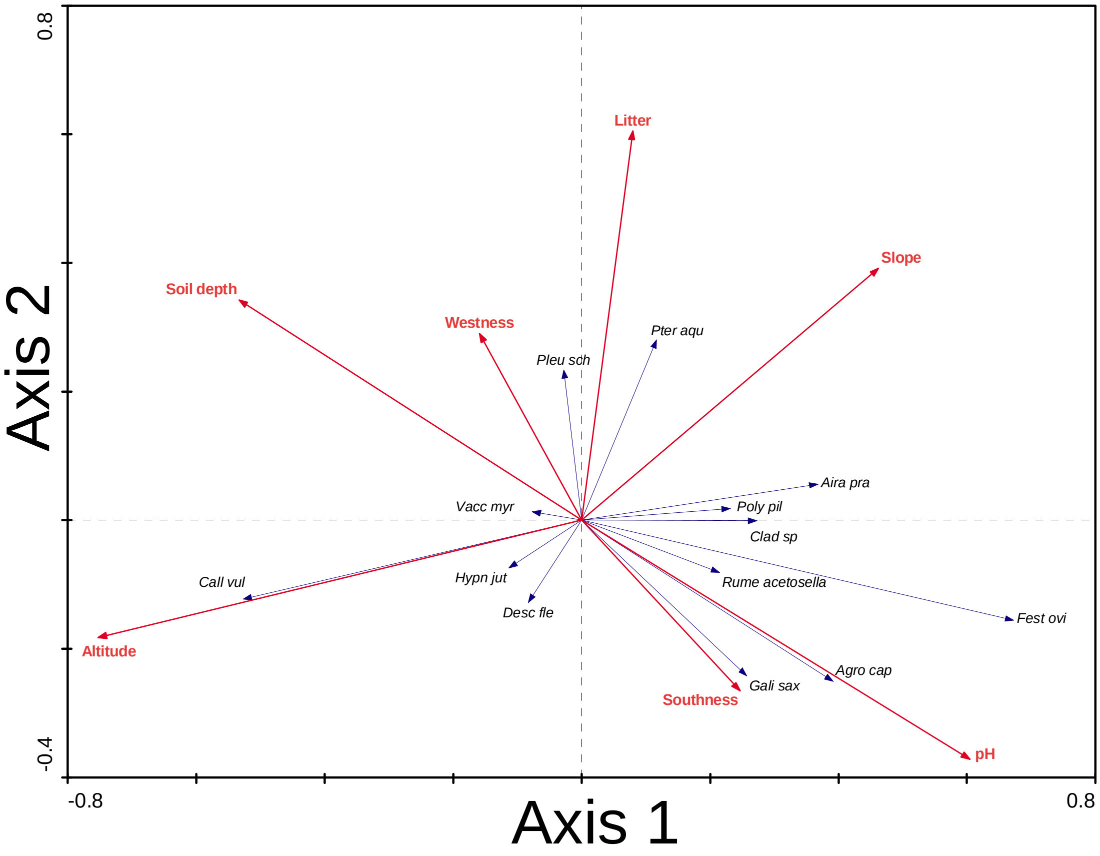

Figure 5.5.6. RDA analysis of the amended ‘all species’ data; species ordination. The species displayed are restricted as in Figure 5.5.4. The eigenvalues are 0.101 and 0.025, respectively. The blue arrows represent the species vectors and the red arrows show the vectors for the environmental variables.

5.5.2 Bryophyte and lichens species analyses

The general procedure used in Section 5.5.1 was repeated with the 'bryophyte and lichens' data set; an initial analysis was undertaken using DCA and Figure 5.5.6 shows the samples [quadrat] ordination with two major clusters visible; the 'wetland species', Groups 1 and 00 (*vide* Figure 5.2.3), are separated from the rest of the 'heathland quadrats.'

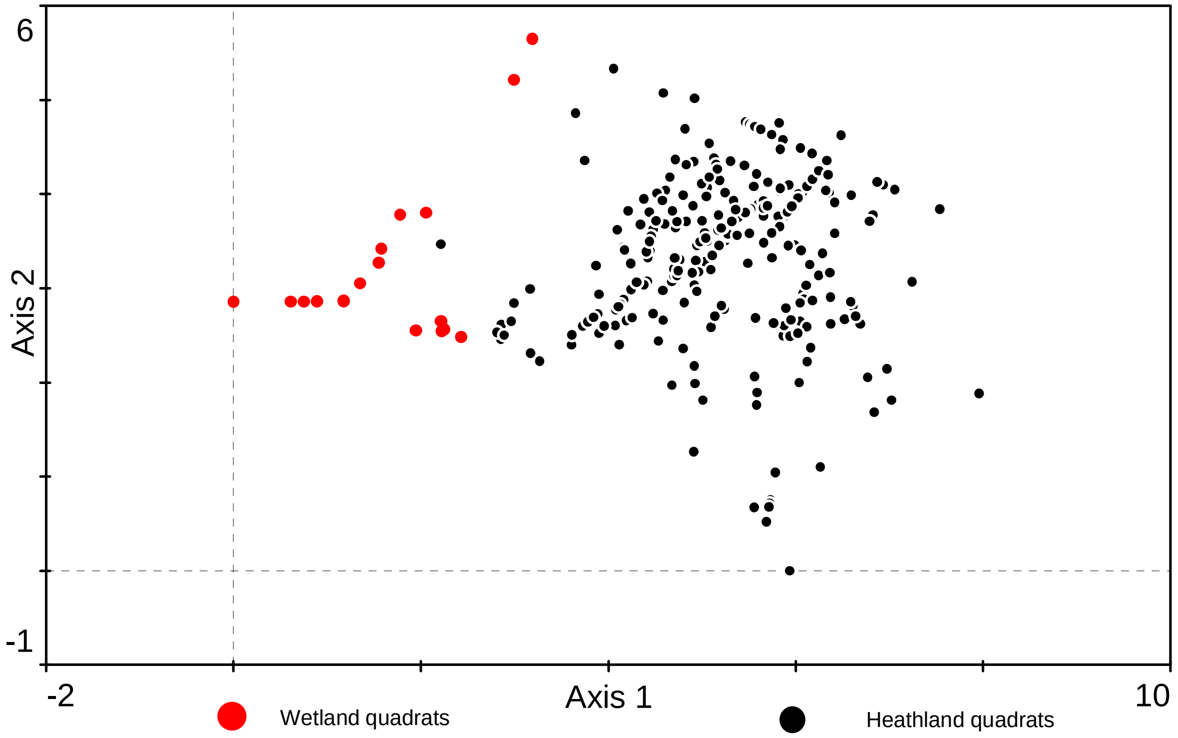

Figure 5.5.7. DCA analysis of the bryophyte and lichen data: sample [quadrat] ordination
The 'wetland quadrats' identified in the WinTWINS analysis can be seen on the edge of the main body of 'heathland' quadrats. The eigenvalues for axis 1 and 2 are 0.877 and 0.734, respectively.

The species ordination [Figure 5.5.8] shows some element of clustering with perhaps three groups in evidence. A separation along a line defined by *Hylocomium splendens*, *Dicranum scoparium* and *Ceratodon purpureus* identifies a group [*Plagiothecium undulatum, Hypnum cupressiforme, Hypogymnia physodes, Hypnum jutlandicum, Polytrichum formosum, Dicranum majus, Dicranella heteromalla, Pleurozium schreberi,* and *Thuidium tamariscinum*] which can be associated with shrubby heath.

A parallel zone holds species associated with grassy heath or bare and burnt heath; *Rhytidiadelphus squarrosus, Scleropodium purum, Polytrichum piliferum, Ptilidium ciliare, Campylopus introflexus, Ceratodon purpureus* and *Cladonia* species.

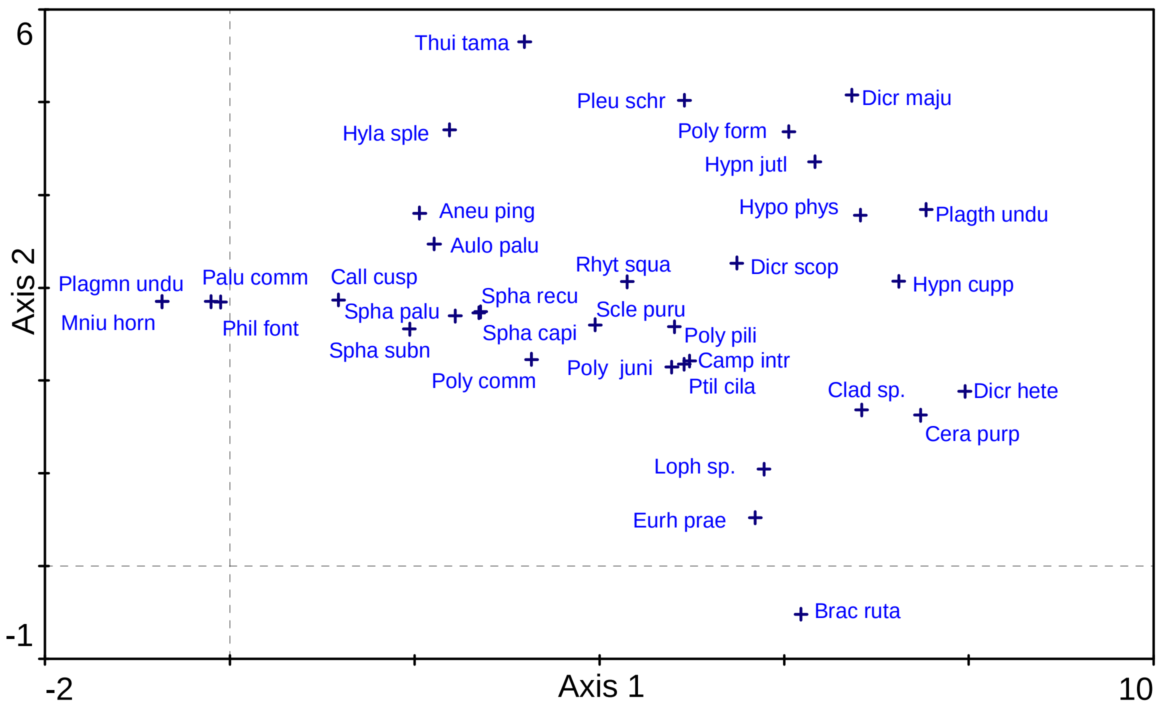

Figure 5.5.8. DCA of the bryophyte and lichen data: species ordination.

The final group holds species which tend to the ‘wet’ end of the continuum - wet heath and flushes; sphagna (*S. subnitens, S. palustre, S. recurvum, S. capillifolium*), *Polytrichum commune, P. juniperinum, Aulacomnium palustre, Calliergonella cuspidata, Philonotis fontana, Palustriella commutata* and *Aneura pinguis.*

CCA was subsequently applied to this data set and environmental variables were again chosen using forward selection and the Monte Carlo Permutation test. The same factors were found to be significant as in the all species analyses [Section 5.5.1] but with the addition of ‘open water’. As then, northing and easting were discarded but canopy height was included to see if the structure of the vegetation was an influence. The resulting biplot is given as Figure 5.5.9.

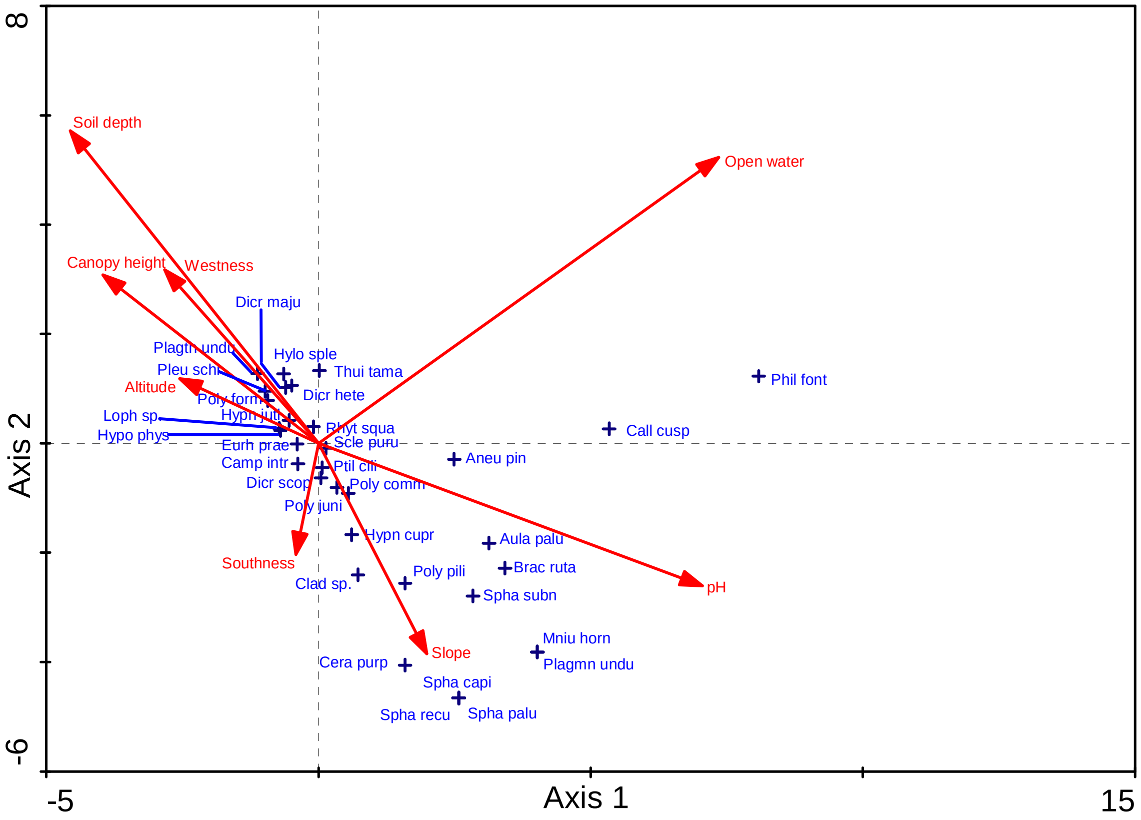

Figure 5.5.9. CCA of bryophyte and lichen data: species ordination. An extreme outlier, [*Palustriella commuta*] which was associated with the open water vector, was causing compression of the axes and ‘crowding’ of the main group of species and was suppressed to rescale the plot and aid clarity.The environmental variables vectors were also exaggerated. Eigenvalues for the axes are 0.479 and 0.311, respectively.

The majority of the outlying species are associated with substrata whose moisture levels range from moist through constantly moist to waterlogged [6-9 on the Ellenberg moisture scale] in semi-shaded to well lit areas [5-7 on Ellenberg light scale]. Their position on the slope vector is in keeping with the hydrology of the study area where flushes resulting from seepage and surface run off are generally associated with slopes.

Their position is in ‘receiving sites’ for flushed nutrients which would drive the increase in pH although, given the potential for variation between surface water and groundwater flushes, this sometimes appears at odds with the indicated preferences of the species.

The environmental variables, soil depth, westness, canopy height and altitude, are all associated with the plateau and therefore it is likely that there is some degree of autocorrelation. It is difficult to establish which of the variables is controlling the relationship.

5.5.3 Combined analysis

Direct influence of the environmental factors on the bryophytes is difficult to establish but there is possibility that these species are associated with vascular communities influenced by these parameters rather than the parameters *per se.*

In order to investigate this possibility, the WinTWINS 'vascular' were used as explanatory variables in a 'bryophyte and lichens' analysis. The groups shown in Figure 5.2.2 together with a quasi end group, designated as 'no vasculars'[36], were used as environmental variables, in the CCA shown in Figure 5.5.10.

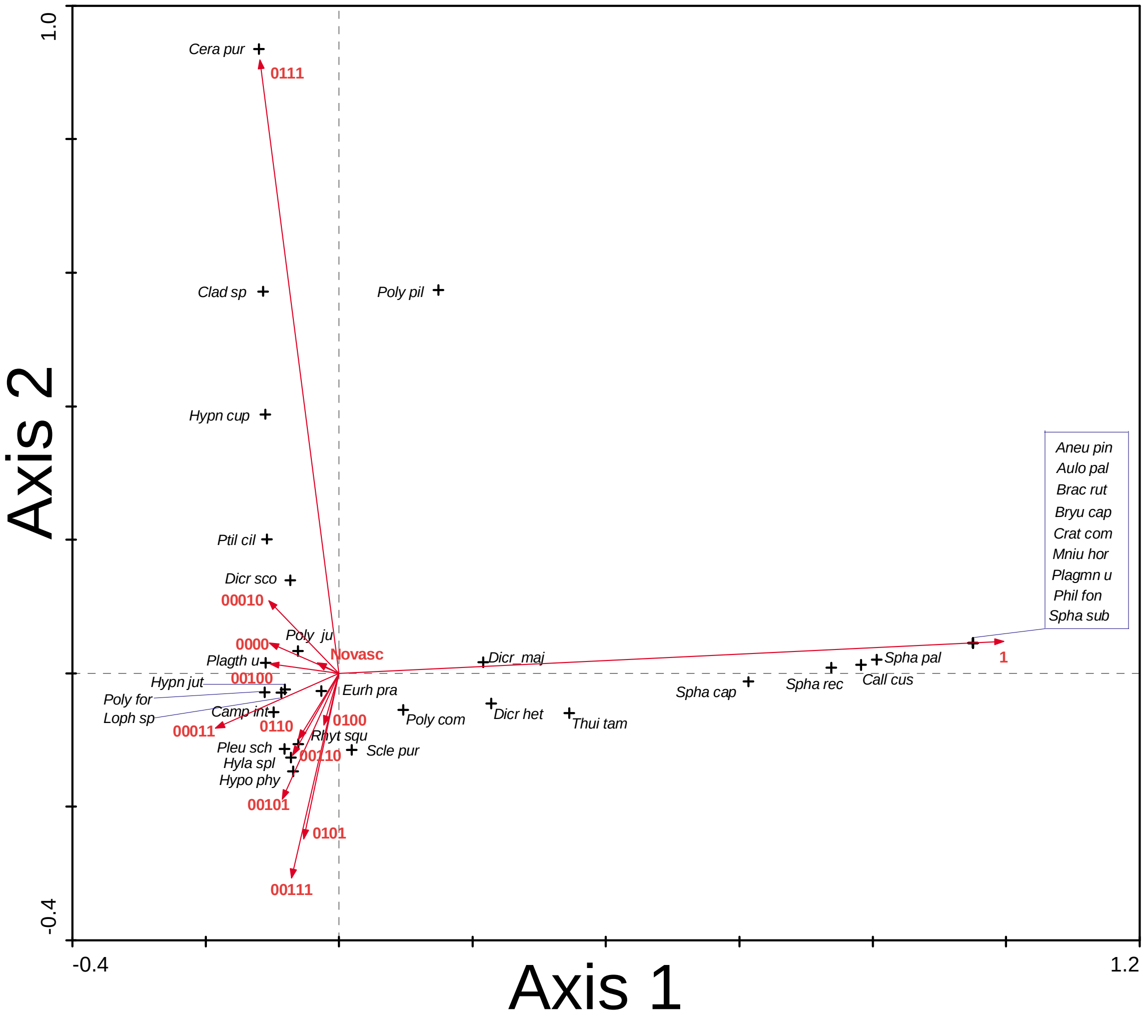

Fig. 5.5.10. CCA analysis of 'bryophyte and lichen' species constrained by the 'vascular species' end groups. Eigenvalues for axis 1 and axis 2 are 0.562 and 0.294, respectively.

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[36] Those quadrats which were excluded as they contained no vascular species.

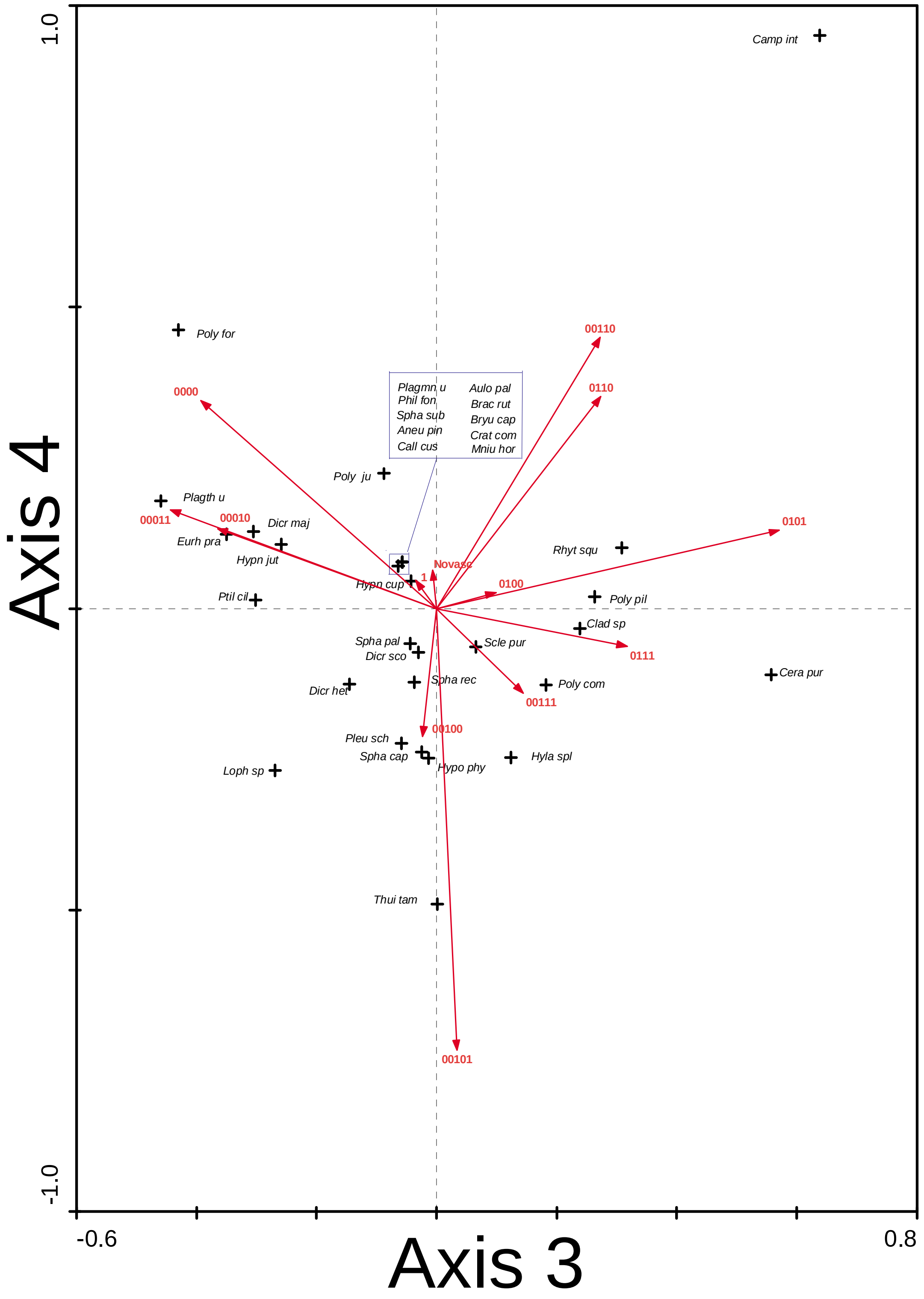

Fig. 5.5.11. CCA analysis of 'bryophyte and lichen' species constrained by the 'vascular species' end groups. Eigenvalues for axis 3 and axis 4 are 0.187 and 0.076, respectively.

The major separation of the first axis is between the species associated with the main body of heath and grasslands in the lower regions and those species associated with the wetland areas in the upper regions. The separation on the second axis is between the heathland and wetland species in the lower quartile and those of the upper quartiles associated with thin droughty soils.

Figure 5.5.11 shows the third and fourth axis plot of this analysis; the principal division on the third axis is between the ‘true heath’ communities and associated variants of the lower quartiles and the ‘grassland and grassy heath’ groups in the upper regions

The fourth axis separation is less easy to interpret but there is a possibility that grazing pressure may be involved

Given the association of these end groups with particular heath communities, the niche widths of the bryophyte species used above were examined to determine the extent to which these associations were governed by the communities.

5.6 Niche width of bryophyte species.

The concept of the niche originated in 1957 with Hutchinson’s view, cited by Crawley (1986), that the niche was a ‘multidimensional description of a species’ resource needs’. He drew a distinction between the ‘fundamental niche’[37] i.e. the ‘space’ occupied by a species in the ‘multi-environmental gradient complex affecting it, irrespective of competitor plants’, and the ‘realised niche’ i.e. the ‘niche of the species as it is constrained by the competitive influences of neighbouring species’.

Økland (1990) considers the major niche dimensions to be the ‘habitat’ niche, i.e. the environmental conditions required by a plant, and the ‘functional’ niche that which encompasses other influences, e.g. competition from other species or from predators, grazers etc. He defines niche width (Økland, *ibid*) as an expression of how large a part of one or more niche dimensions is occupied by an organism.

Lawesson and Oksanen (2002) recommend the use of DCA sample scores in calculating niche properties since these encompass both habitat and functional aspects.

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[37] Sometimes termed the ecological amplitude of the species.

The niche widths of the species in the ‘bryophyte and lichens’ data set were established by determining which quadrats [samples] held a particular bryophyte species and then calculating the means and standard deviations of the scores of those quadrats on the two principal axes produced by a DCA ordination of those data. Niche widths of species which only occurred in a single quadrat were not considered.

The centroids [means and standard deviations] of the first and second axis scores are displayed in Figure 5.6.1. The scatter appears to aggregate into two groups, designated as ‘A’ and ‘B’, but the considerable overlap between some of the species is producing confusion; to reduce this, species were divided into two sets: the low occurrence species which occurred in fewer than ten quadrats and the commoner species which occurred in more than ten quadrats. These are plotted in Figures 5.6.2 and 5.6.3; small clusters of closely associated species have been shown with further enlargement in Figures 5.6.2a and 5.6.3a, respectively.

Examination of the attributes and preferences of the species (Hill *et al.*, 2007) in Figure 5.6.2 points to an aggregation of ‘wetland’ species in group A, viz. species that prefer sites which are more or less waterlogged or moist, and of ‘drier’ species in Group B, i.e. species which prefer moderately moist to well drained or dry sites.

The first axis[38] of Group A is bounded[39] at its lower end by *Philonotis fontana* [e][40], and *Calliergonella cuspidata* [3]*; P. fontana* appears to be occupying a more restricted niche than *C. cuspidata* whilst *Aneura pinguis* [c]*,* a species with similar moisture preferences, appears to be occupying a considerably wider niche ~one which overlaps those of some of the species in the Group B aggregation. The upper limit of this group is bounded by *Polytrichum commune* [5] whose niche, albeit not as extensive as that of *A. pinguis,* also appear to overlap those of some Group B species.

Of the *Sphagnum* group, perhaps the classic indicators of moisture, *S. palustre* [p] and *S. recurvum* [r] seem to be occupying niches of similar magnitude to that of *Philonotis fontana* [e] although *S. capillaris* [q]*,* associated with these species exhibits a considerably narrower niche width along Axis 1.

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[38] The description is based on the details shown in Figures 5.6.2 and 5.6.3.
[39] Based on the position of the mean score.
[40] The letter or number in square brackets is the label used in Figures 5.6.2 and 5.6.3.

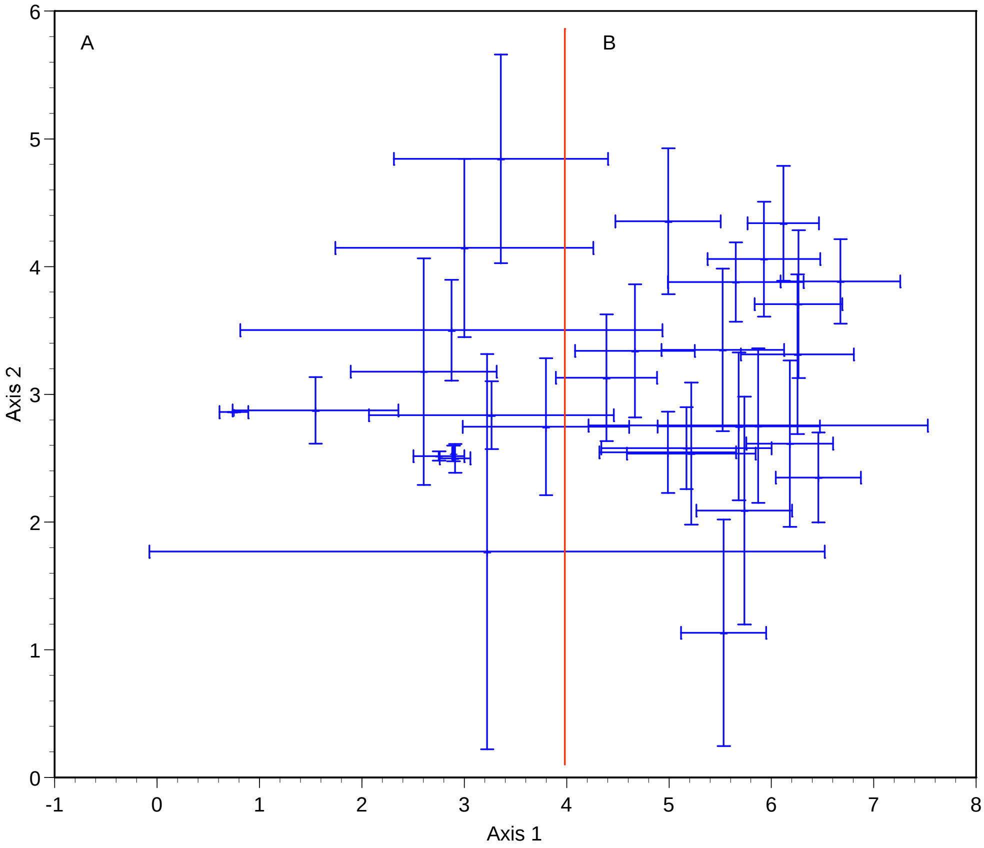


Figure 5.6.1.Centroids [Means ± SD] of the first and second axis species ordination scores from the DCA of the bryophyte and lichen data set showing two apparent species aggregations, Groups 'A' and 'B'.

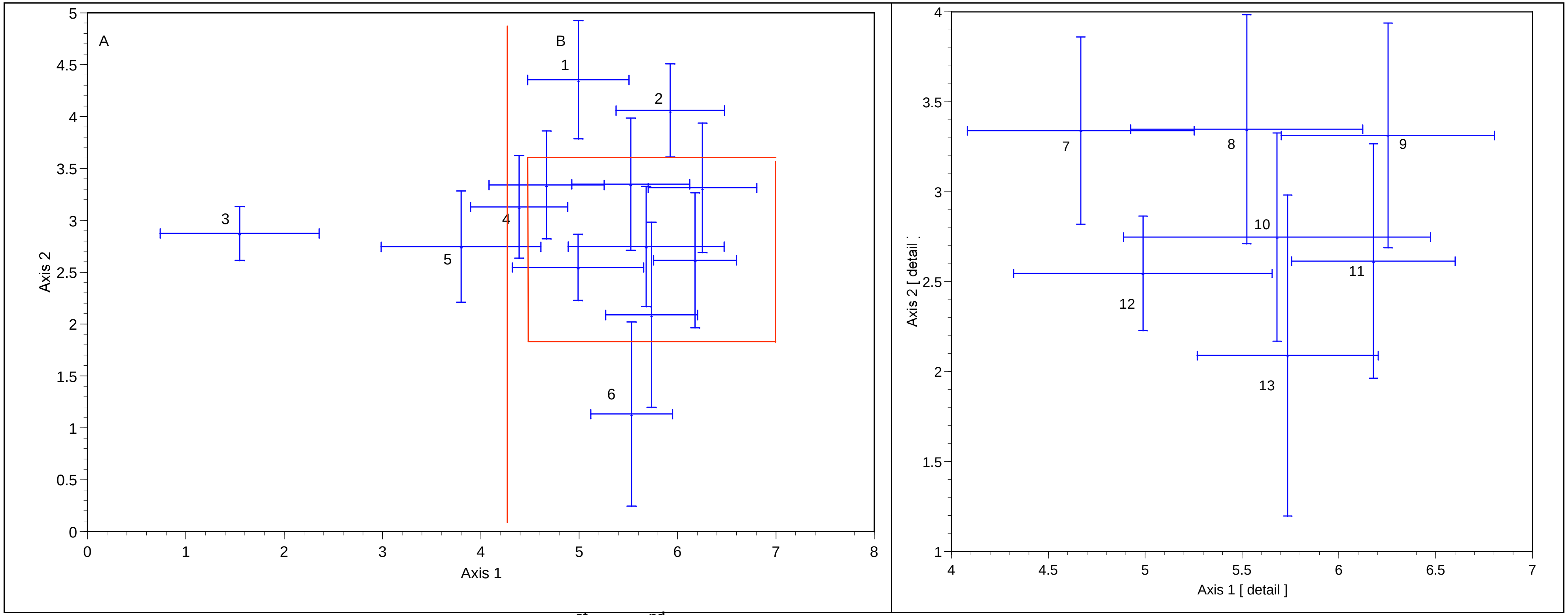
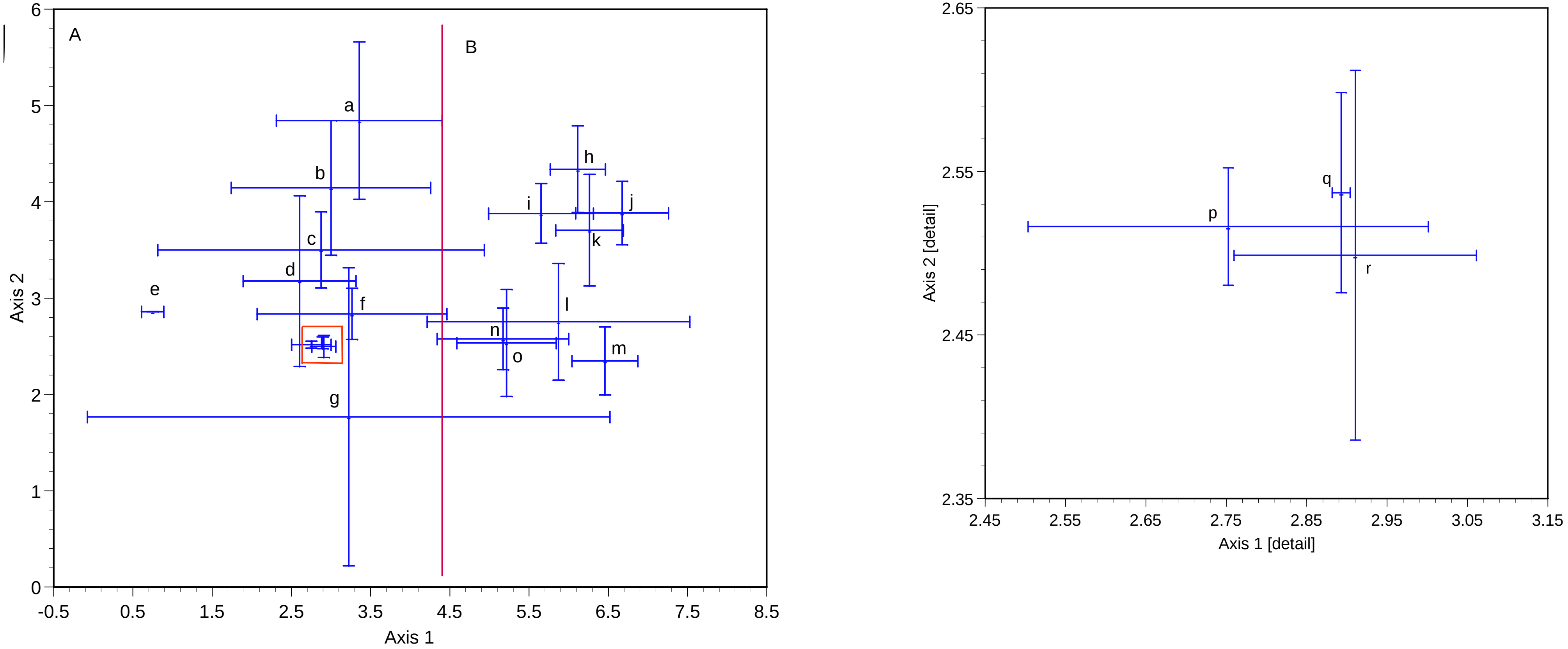


Figure 5.6.2 and 5.6.2a. Centroids [Means ± SD] of the 1st and 2nd axis species ordination scores from the DCA of the 'high occurrence' species of the bryophyte and lichen data. The group bounded by the red rectangles is shown at larger scale in the right hand figure [5.6.3a] The labelling convention as below (the figures in parentheses show the number of quadrats [samples] and the number of stands holding the species).

1 *Pleurozium schreberi* [140:18]
2 *Hypnum jutlandicum* [31:3]
3 *Calliergonella cuspidata* [31:4]
4 *Scleropodium purum* [34:9]
5 *Polytrichum commune* [65:15]
6 *Eurhynchium praelongum* [25:9]
7 *Rhytidiadelphus squarrosus* [232:25]
8 *Dicranum scoparium* [138:26]
9 *Hypnum cupressiforme* [31:3]
10 *Polytrichum piliferum* [11:14]
11 *Cladonia* species [32:8]
12 *Polytrichum juniperinum* [14:6]
13 *Lophocolea* species. [18:6]



Figures 5.6.3 and 5.6.3a. Centroids [means ± SD] of the 1st and 2nd axis ordination scores of the low occurrence species. The group bounded by the red rectangles is shown at larger scale in the right hand figure [5.6.4a]. The labelling convention is given below (the figures in parentheses show the number of quadrats [samples] and the number of stands holding the species).

a	*Thuidium tamariscinum* [6:3]	b	*Hylocomium splendens* [5:3]	c	*Aneura pinguis* [3:2]	d	*Aulacomnium palustre*	e	*Philonotis fontana* [3:2]
f	*Sphagnum subnitens* [4:2]	G	*Brachythecium rutabulum* [2:1]	h	*Dicranum majus* [4:3]	i	*Polytrichum formosum* [3:3]	j	*Plagiothecium undulatum* [7:1]
k	*Hypogymnia physodes* [4:2]	L	*Dicranella heteromalla* [5:5]	m	*Ceratodon purpureus* [7:1]	n	*Campylopus introflexus* [3:2]	o	*Ptilidium ciliare* [9:4]
p	*Sphagnum palustre* [6:1]	Q	*Sphagnum capillaris* [3:1}	r	*Sphagnum recurvum* [5:1]				

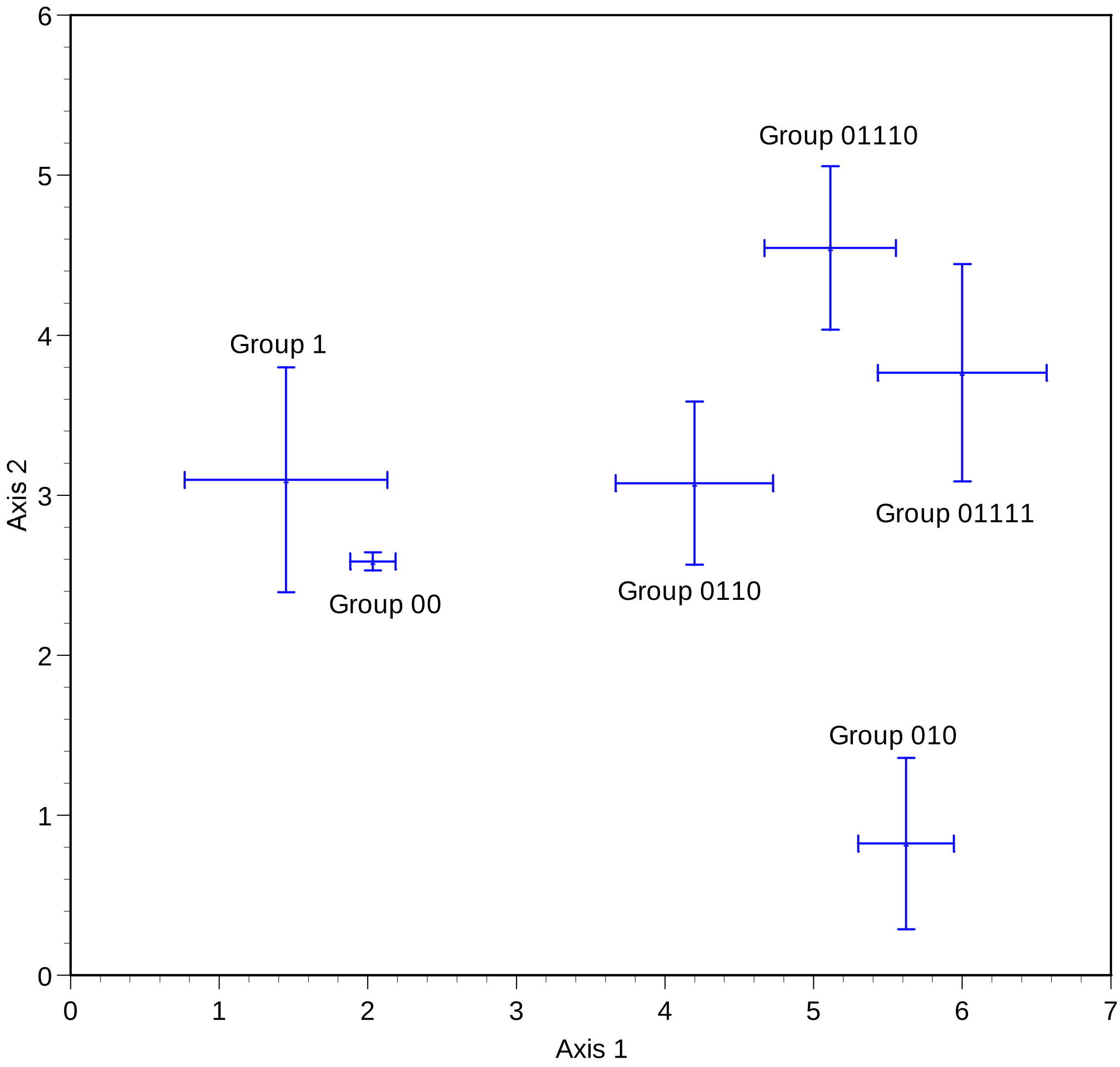


Figure 5.6.4. Centroids [means ± SD] of the first and second axis sample ordination scores from the DCA of the bryophyte and lichen data set grouped according to their WinTWINS end groups.

The lower limits of axis 1 in the B aggregation are represented by *Scleropodium purum* [4] and *Rhytidiadelphus squarrosus* [7] which exhibit generally similar and overlapping niche widths; its upper limits are defined by *Ceratodon purpureus* [m] and *Plagiothecium undulatum* [j] again with similar and overlapping niche spread.

In looking at the second axis niche widths there is no obvious aggregation or separation of groups. The lower limits are bounded by *Eurhynchium praelongum* [6], *Brachythecium rutabulum* [g] and the *Lophocolea* species [13] whilst the upper limits are defined by *Thuidium tamariscinum* [a], *Pleurozium schreberi* [1], *Dicranum majus* [h] and *Hylocomium splendens* [b].

In general terms, the group A species tend to have more extensive niche widths than the Group B species, the obvious exceptions being *Philonotis fontana, Sphagnum palustre, S. capillaris* and *S. recurvum*

This suggests that on the first axis the high occurrence species of the A group, tolerate a wide range of conditions whereas those of the B group tend to have more restricted niche requirements.

Whilst the A Group high occurrence species appear to have similar niche dimensions to those of the B Group species in the middle and upper reaches of the second axis, they are generally narrower than those in the lower end. This suggests that as the A Group have similar niche widths to many species in the B Group as well as similar positions on the second axis, they can be said to be subject to the same influences.

In examining the niche widths of the end groups, bryophyte and lichen species DCA sample [quadrat] 1^{st} and 2^{nd} axis scores of the quadrats in each of the bryophyte end groups [Fig 5.3.3] were taken and centroids [means ± SD] calculated. These are displayed in Figure 5.6.4. A similar procedure was undertaken for the 3^{rd} and 4^{th} axis scores which are displayed as Figure 5.6.5.

With the exception of Group 00, the groups have broadly similar niche widths on both axis 1 and axis 2 and are well segregated, although there is some overlap at the periphery of the ranges.

The factors influencing the distribution of the bryophyte groups are not easy to establish. Group 1 holds a group of wetland quadrats where the presence of a wet or moist substrate is a *sine qua non*. *Palustriella commutata* is the defining [indicator] species and its preferences (Hill *et al.*, 2007) suggest well lit [L7][41], streams and flushes [F9] on more basic [R7] infertile substrates [N2].Ground water flushing could raise the base level of the quadrats, but the lack of nutrients is not untypical of the study area.

Group 00 is a small group isolated by the presence of *Sphagnum subnitens* in its constituent quadrats; *S.subnitens* exhibits preferences (Hill *et al. ibid)* for well lit [L7], constantly damp to waterlogged soils [F8] on acid [R3] and infertile [N2] sites. The base

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[41] Ellenberg values for appropriate factor.

status of this group may reflect surface water flushing as opposed to the groundwater flushing suggested in Group 1.

It has been recognised that sheep will concentrate in the wetter and flushed areas of the hill during summer drought conditions (Jenkins and Anderson, 1999) therefore the lack of shade in both Group 1 and group 00 may be a function of a vegetation structure 'imposed' by grazing as opposed to innate growth forms of the vascular plants in those communities.

Group 010, is a small group isolated from the main body of heathland quadrats through *Eurhynchium praelongum*, often considered a 'woodland' species, with the capacity to exploit more shaded [L5] habitats, this suggests shady areas with taller vegetation. Group 0110 is characterised by *Rhytidiadelphus squarrosus, Polytrichum commune* and *Scleropodium purum.* These favour lightly shaded to full light conditions [L7, L6 and L7 respectively] on moderately moist to constantly damp substrates [F5, F7 and F5] with acid to more basic status [R5,R2 and R6] and various generally low fertilities [N4,N2,N3].

The variation in base and nutrient requirements of these three species suggests that the overriding factors are light and moisture levels; moisture levels are largely dependent on rainfall, soil depth and slope, whereas light availability is dependent on aspect and on the associated species and vegetation structure. This supports the characterisation from the WinTWINS analysis that this group is a more open damper and probably grassy community and its position in Figure 5.6.5, midway between the 'wetland' and the 'heathland' groups, would also tend to support this.

Groups 01110 and 01111 result from the division of a group characterised by *Hypnum jutlandicum, Dicranum scoparium* and *Pleurozium schreberi.* The principal characteristics of these species are similar, semi-shade plants [L6, L6, L6] on moderately moist [F5, F5, F5] acid [R2, R3, R2] low fertility [N2, N2, N2] substrates. The subsequent separation of the two groups was made through *Pleurozium schreberi* which points to Group 01110 as being the more shaded, possibly due to canopy height and species differences.

The niche widths of these two groups overlap on both axis 1 and axis 2 [Figure 5.6.4] confirming their overall similarity.

Figure 5.6.5 shows the axis 3 and axis 4 positions for these endgroups.

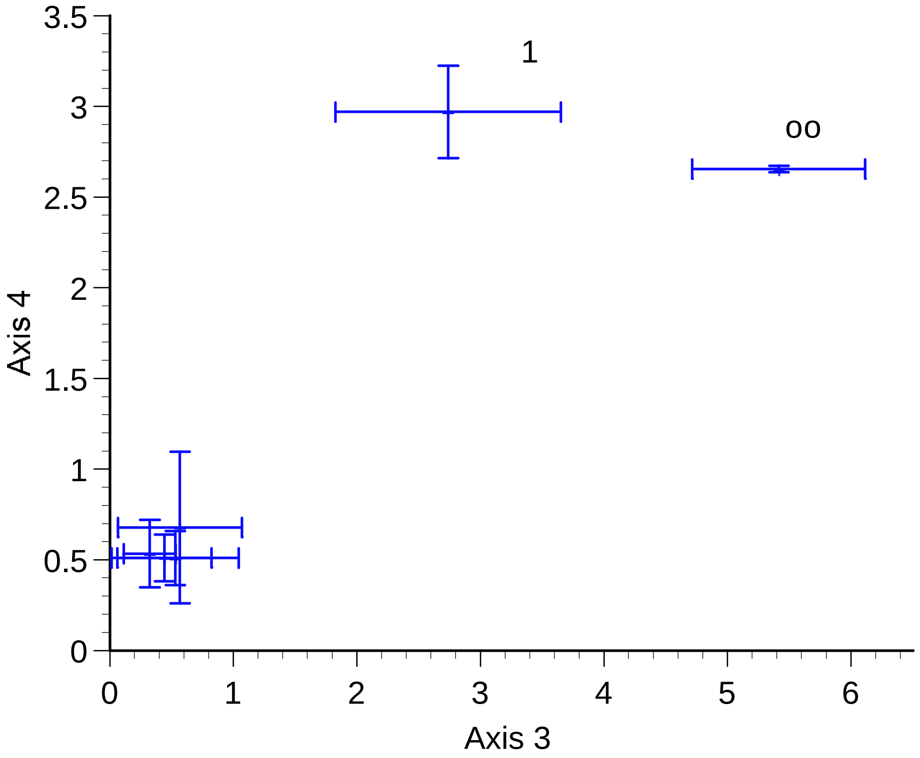

Figure 5.6.5. Centroids [means ± SD] of the third and fourth axis sample ordination scores from the DCA of the bryophyte and lichen data set grouped according to their WinTWINS end groups.

The two ‘wetland’ groups [00 and 1] are well separated on both axes 3 and 4 with the remaining four groups [010,01110,0110 and 01111] clustered with overlapping niches on both the axes.

Overall, apart from those bryophytes which occupy extreme or specialist , typically wetland, habitats, the distribution of most of the bryophyte species on the heathland plateau appears to be controlled by the structure of the vascular vegetation.

6 Discussion

The aims of the present investigation (Section 1.9) were to describe the vegetation at different scales and to investigate the relationship between the different vegetation types in terms of environment and community development. The first of these was achieved through consideration of historic mapping surveys and the classification of quadrat data collected at two spatial scales; the second through the ordination of the vegetation data and environmental data. The outcomes of these analyses are considered in this discussion together with their implications for future vegetation change and management on the Long Mynd, i.e to aid conservation of the plateau heathland, maintain and encourage biological diversity and to ameliorate the spread of bracken. The evaluation of the vegetation has shown that, without doubt, vegetation on the Long Mynd is changing. The important questions are from what, to what and what will it become in the future?

It has been established that the extent of heath and moorland within the Western Atlantic Heathland zone has declined considerably within the last century or so, and whilst estimates of the area remaining vary [*cf.* Noirfalaisie and Vanesse (1988), Farrell (1989) and Webb (1998)], it is probably only of the order of 350,000 ha, with around 60,000 ha remaining in the UK.

This UK component not only forms an important proportion of the total area but also holds unique habitats which have been recognised as of ‘international conservation importance’ and as such, included in Annex 1 of the Habitats Directive 92/42/EEC as ‘natural habitat type of community interest whose conservation requires designation of special conservation areas.’

With the exception of a few montane communities, most UK heathlands are anthropogenic in origin and it is the continued exploitation over the centuries which have maintained them.

The traditional exploitation of heathlands has followed broadly similar practices across Europe (Gimingham, 1994; Webb, 1998) with cutting of gorse, heather, bracken or turves for fodder or bedding, grazing of sheep or cattle, and burning to clear the ground for subsequent cropping or to encourage regeneration of the vegetation.

The cessation of these activities, often through the abandoning of traditional 'marginal ' farming methods' is largely responsible for the loss of many European heathlands although increases in nutrients through aerial deposition (Niemeyer *et al.*, 2005; Hardtle *et al.*, 2006) may be playing a part. In an attempt to combat this trend and to restore these 'semi-natural' communities (Marrs *et al.*, 2007) an increasing amount of UK heath and moorland is managed, actively for conservation purposes, or its exploitation is restricted to meet conservation objectives through various initiatives e.g. National or Regional Biodiversity Action Plans.

In the context of the present study; grazing on the Long Mynd common is controlled in terms of numbers, species and duration, by the involvement of the graziers, the 'Commoners', in the E.S.A scheme initiated in 1999 [*cf.* Uff (2001)] to avoid overstressing areas of heather newly managed by burning, or increasingly by cutting, [*cf.* Uff (2001, 2002, 2003, 2004, 2005, 2006a)]. Control measures to curtail the expansion or the dominance of bracken are undertaken on selected areas, using aerial spraying with Asulam or cutting (Uff, *ibid*)

Such management requires knowledge of the types and extents of the component vegetation and various mapping exercises have attempted to provide descriptions of these for the Long Mynd [*cf.* Leach (1931), Sinclair (1965), Greenhall (1975), Owen and Tapper (1983), Ellett (1984) and FRCA (1995b)]. These descriptions have been used to try to characterise the vegetation, and to define and quantify the changes that have taken place over the last 75 years or so.

As is explained in Chapter 3 comparing these surveys is not a simple process. Leach's (1931) map [Figure 3.1] appears to demonstrate a simple delineation; the plateau area (above some 429 m) is essentially *Calluna* heathland, and bracken is generally confined by the lower enclosed fields or to the steep south facing slopes of the Batches. However the transition zone of grazed *Festuca–Agrostis* and *Vaccinium* below the *Calluna* of the plateau on the northern edges and the understorey of the bracken; suggest the 'grassy heath with bracken' and 'shrubby heath with bracken' subsequently identified by Sinclair (1965) *et seq*. were present in the 1930s.

There is some indication from the Sinclair (1965) and Owen and Tapper (1983) maps [Figures 3.2 and 3.3] that the increase in bracken on the plateau represents an expansion from outside the boundaries of the common, particularly on the western side, although in some cases this came from within some of the batches [*c.f.* Leach (1931)].

Ellett's (1984) map [Figure 3.4] and data suggests both a serious incursion of bracken into the heathland areas as well as a further increase in the area of other bracken influenced communities

The FRCA survey confirmed that bracken was still a problem in 1995 although apparently to a lesser extent than shown by Ellett (1984). Nevertheless evidence from later bracken control maps [Figure 2.2.8] suggests there has been an expansion since, 2003 particularly in the north–eastern limits of the plateau in the High Park area.

More detailed information on community variation and heterogeneity was provided by the stand sampling and quadrat analyses in Chapter 5.

The principal WinTWINS classification was undertaken on the 'all species' data set [Figure 5.2.2] and the resultant 'Endgroups' were referred to NVC communities.

Overall WinTWINS has isolated a small wetland group, U5b, from the remainder, reflecting the diverse edaphic conditions, principally hydrology, separating these two groups. The division of the remaining large 'grass and heathland' group separated 'heathland' from 'grassland' quadrats. The grassland separation isolated the U1 group, the shallow soils group from an aggregation of generic U4 *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland, which subsequently divides into two disparate U4 sub-communities, U4e and U4a.

The U4a community is the group nearest to the U1 group in this dendrogram. U4a is the species-poor sub community which Rodwell (1992) describes as typically of dense and close turf. U1, by way of contrast, is typically an open sward of small tussocky grasses (Rodwell, 1992); its proximity to U4a in this analysis suggests the two communities have a degree of floristic similarity. Whilst high levels of grazing can exert similar pressures on both, it is likely that differences in edaphic preference and possibly topography and aspect separate the two species aggregations; Thorne (2007) notes that U1 is generally found on shallow soils on south facing slopes on the Long Mynd.

U4a typically holds some *Calluna,* albeit at low frequencies and often 'grazed hard back' and *Vaccinium myrtillus* is uncommon (Rodwell, 1992). U4e, the parallel group in the grassland separation, tends towards the adjacent H12a groups on the dendrogram. U4e is the *Vaccinium myrtillus-Deschampsia flexuosa* sub-community, with frequent *Calluna* and constant *Vaccinium,* so this proximity is perhaps not surprising. This group probably represents quadrats where burning and grazing have depressed the *Calluna,* degrading the H12 heath, and heavy grazing continues to drive it towards the U4e species assemblage. Quadrats from some of the stands in the U4e group are also present in various H12a groups, e.g. LM 4 has 65% of its quadrats in U4E and the remainder in H12a which would tend to confirm the suggestion that management pressures are the principal drivers. It also points to a variation within stands that may indicate stages in the transition between 'grassy heath' and 'shrubby heath.'

It is probably intermediate stages of this transition from H12 to or from U4, which have given rise to the various reports of H9 *Calluna vulgaris-Deschampsia flexuosa* heath on the Long Mynd. Rodwell's (1992) description of its species-poor sub-community – "*Calluna* and *D. flexuosa* are the only constants and under……..frequently-burned canopies of heather even the latter……..can be much attenuated " could equally apply to burned areas of H12a that had been subject to the grazing pressure common in the last century. Averis *et al.* (2004) point out that the vegetation beneath the *Calluna* varies according to how recently burning has taken place and the five H9 sub-communities reflects this variation and hence 'age' of the stands. However Rodwell (1992) also considers this community to be the product of pollution which impoverished bryophyte and lichen communities, although Averis *et al.* (2004) point out that in Scotland, where pollution levels are low, H9 is a successional stage following recovery from burning. In this sense we may be dealing with vegetation semantics and not communities

The majority of the Long Mynd heathland quadrats fell within various groups categorised as NVC H12a– *Calluna vulgaris-Vaccinium myrtillus* heath, *Calluna vulgaris* sub-community. Rodwell (1991) notes that *Pteridium* is quite common in this sub-community and it was a feature of all these Long Mynd groups except one. H12a floristics table shows a constancy for *Pteridium* of II and abundance as 1-6[42]; those Long Mynd WinTWINS groups with *Pteridium* showed constancies between I and III with abundances between 5 and 10.

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[42] These follow the usual 'Rodwell' conventions.

This suggests the predominant vegetation of the plateau is *Calluna* heath associated with varying amounts of *Pteridium,* although generally at levels towards the upper end or even beyond those that Rodwell considers typical of H12a, and demonstrates the extent of the modification of the Long Mynd vegetation.

Some of the quadrats categorised as U20b *Pteridium aquilinum-Galium saxatile* community*,* originated in the same stands, (14 in all) , as quadrats that fell within an H12a group whereas only 7 stands held U20b together with U4a and U4e. Whilst this appears to indicate greater expansion of U20b occurring on the heathland areas than in the grassland areas, it may only reflect the relative proportions of heathland to grassland stands. It does however indicate the mixture of communities which can co-exist, albeit temporarily, on the Long Mynd where one stand, LM 64, held quadrats referable to U1, U4a, H12a and U20b communities within an area of 200 m^2.

Whilst not necessarily typical, this latter stand does indicate potential difficulties in placing areas of vegetation into meaningful categories when carrying out habitat surveys, particularly if community boundaries are initially designated using aerial photographs.

Ordinations were undertaken on the same data to investigate further species groupings established through the WinTwins classification and to test them against the measured environmental variables. However, there was a lack of detailed records of the nature and dates of management operations undertaken on the sample sites, none of which were located in areas covered by the recent burning, cutting or spraying maps [Figures 2.2.1, 2.2.2, 2.2.7 and 2.2.8]. This inability to allocate a treatment type and treatment date to a stand, precluded their use as environmental variables in these analyses; management influences could therefore only be inferred by considering differences between unconstrained and constrained analyses.

The major trend in the unconstrained stand ordination is the separation of the various heathland and grassland stands from the ‘wetland’ stands, as in the associated species ordination where aggregations of ‘heathland’ species and ‘wetland’ species were easily distinguished.

The distribution of the stand centroids shows wetland stands are not only segregated from the heathland stands, but are also well separated from each other on the major axes, perhaps indicating variation in habitat, for example, differences in hydrological input although this separation was not in evidence on the third and fourth axes. This figure shows the general coherence of the non-wetland vegetation of the plateau and suggests a disparate species aggregation in the wetland communities.

A subsequent ordination, a PCA, was run on the modified data set, i.e. the non wetland stands. The resultant species-quadrat plot [Figure 5.5.5] shows the major trend as the separation of heathland from grassland communities.

The second strongest trend is associated with increases in *Deschampsia*, *Pteridium* and *Vaccinium*; the trend, which links these species, is found in a number of stands and there appears to be a genuine association between them in particular quadrats. This association and its separation from *Calluna* suggests management factors, burning or grazing, affecting the *Calluna* are not affecting *Deschampsia, Vaccinium* and *Pteridium* in the same way or to the same extent.

A further analysis (RDA) was carried out on this data set with and used to investigate the relationships between species and the measured environmental variables.

Comparison between the first axes in the unconstrained [PCA, Figure 5.5.5] and the constrained [RDA, Figure 5.5.6] analyses show relatively minor differences. The second axes comparison is less clear-cut; the *Vaccinium-Deschampsia-Pteridium* concurrence shown by the PCA is not evident in the RDA suggesting factors other than those used as explanatory variables, perhaps the ‘unknown’ management history, may be influencing the concurrence of these species.

Notwithstanding the difficulties in establishing treatment factors and their use as environmental variables stated above, even using such variables can be problematical. Sheep tend to congregate in particular areas and their use of newly regenerating ‘burns’ or ‘cutovers’ on the Long Mynd is well documented (Uff, 2001). Hester *et al* (1999) point to sheep creating paths through heather which can subsequently increase in width through grazing of the trackside heather [*cf.* Oom and Hester (1999)] or even change to linear grassy communities. A high, albeit subsequently reducing, stock level prior to and during the current investigation, together with variations in the home ranges of the various flocks as well as in range utilisation, made it almost impossible to quantify the grazing pressure on a given area.

Excessive grazing on these regenerating areas could add an undetermined ‘lag’ time to the normal temporal process of regeneration which can allow other vascular plants to achieve dominance (Barclay-Estrup and Gimingham, 1969), whilst selective grazing or nutrient enrichment through urine and faeces deposition could further alter the species composition (Davis *et al.*, 2000) and attenuate or divert the developing communities. Grazing load can hold *Calluna* at the ‘pioneer’ stage whilst the ‘building phase’ can be similarly extended thereby introducing an unknown temporal distortion to the usual assumptions about age and structure in a Callunetum.

If we exclude the specialist habitats, e.g. flush and streamside wetlands and the bare rock areas not encountered in this investigation and ignoring for a moment the bracken expansion, there are two principal community types, acid grasslands and shrubby heathland, although arguably, there is a third type, grassy heathland, which is perhaps an inter-grade between the other two groups.

The expansion of *Pteridium* has introduced a modifying factor to this basic pattern; as well as the development of a full blown bracken community [U20] on the plateau.

The mechanisms of some intercommunity changes are not difficult to postulate; an unmanaged increase in *Pteridium* will drive many of the heath communities towards the U20 bracken community. Some communities, such as U1 grassland which exists on very shallow droughty soils, may well have some protection from such incursions, but, as Thorne (2007) points out, they may still be affected by shading from adjacent bracken stands.

There are other factors affecting the relationship between the vegetation, its utilisation and the direction of change. Field observations suggest sheep do not usually enter dense stands of bracken or heather other than to follow established paths. They prefer a patchwork, a grass-*Calluna* mosaic (Hester and Baillie, 1998) and tend to graze the ‘edges’ of the heather patches . Since ‘utilisation’ tends to diminish with distance from these edges (Oom and Hester, 1999), dense areas of *Calluna* or *Pteridium* can act as a ‘nurse crop’ to protect emerging tree seedlings from grazing, *Sorbus aucuparia* saplings are present in several areas, and could, in the absence of grazing or other intervention, mature and begin to change the character of the heath.

Quadrat analysis was also used to investigate the role of bryophytes on the Long Mynd plateau communities; DCA and RDA analyses were carried out on the ‘bryophyte and lichen’ data to try to elucidate the relationships between them and the ‘vascular plants.’
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A stand ordination (DCA) of these bryophyte and lichen data [Figure 5.5.6] segregated the wetland quadrats from the heathland, with three, possibly four, disparate clusters visible within this wetland group; the associated species ordination [Figure 5.5.7] identified three cognate groups of species, identifiable as associated with shrubby heath, grassy or bare and burnt heath and wet heath or flushes.

A further constrained [CCA, Figure 5.5.9] analysis showed two distinct aggregations; outlying species associated with open water, increasing pH and slope, and a central scatter identified as associated with altitude, soil depth and canopy height. Those linked to slope are associated with hydrological factors, either drainage or input of bases whereas the associations of the central scatter are somewhat more indirect, possibly even auto-correlated since the factors involved, altitude, canopy height and deeper soils, are all associated with the plateau. Direct influence of soil depth and altitude are therefore difficult to determine, it is thought likely that these bryophytes are influenced by the vascular communities dependent on these factors rather than on the actual factors.

Species ordination of the bryophyte and lichen species data using the vascular endgroups[43] as ‘explanatory variables’ [Figures 5.5.10 and 5.5.11] confirmed the association of bryophytes with particular vascular communities on the Long Mynd and raised the possibility of the bryophyte assemblages being used as indicators of vascular community ages i.e. time since burning, when determining management strategy [*cf.* Burch (2008)].

As the principal influence on the distribution of the non-wetland bryophytes on the Long Mynd was found to be the nature and structure of their host communities, management of these communities will effect the bryophyte communities.

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[43] As defined in Figure 5.2.3.

Associations between bryophyte species and communities and management has been established elsewhere, e.g. Piessens *et al.* (2008) stated that in Belgian heathlands 'management turned out to be an important factor explaining community composition of bryophytes.'

Thomas *et al*. (1994) noted the colonisation of 'ashed' peat by *Ceratodon purpureus* and *Polytrichum piliferum* with *P. commune* becoming dominant later*.* Burch (2008) found *Campylopus introflexus* dominated the early regeneration on dry heath with *Ceratodon purpureus* also prominent. *Plagiothecium undulatum* and *Rhytidiadelphus squarrosus* were generally restricted to older plots and *Dicranum scoparium* and *Hypnum jutlandicum* were most abundant on older stands of heather but were also present on younger stands where they appeared to have survived burning. The use of cutting or flailing to manage *Calluna* may also have a similar influence as it removes the heather canopy leaves the ground layer undisturbed althoughy exposed to subsequent grazing, or in the case of bryophytes, to subsequent dehydration.

The other major management technique, bracken control through spraying with Asulox, may also influence bryophyte communities. Måren *et al.* (2008) found *Pleurozium schreberi, Polytrichum commune* and *Scleropodium purum* were negatively affected by Asulox.

Whilst this survey identifies a limited number of NVC communities, this should not be equated with a lack of diversity. Diversity is not merely a reflection of an aggregation of plant species into communities, but also of the structure of those communities and the way in which that structure influences their suitability as habitats for other species. The various pressures and their impact on the vegetation have been both well explored and documented and while the excessive grazing and burning of much the last century unquestionably damaged the classic heathland, it has left behind important and often unique habitats. It is, therefore, necessary to consider the positive features of the fragmentation or degradation of communities described in these analyses before seeking to halt or reverse these trends.

Smith (2004, 2007) has established the importance of what might be seen as degraded habitats, for various species of birds on the Long Mynds. Whinchat (*Saxicola rubetra*) occupies some 'heath with scattered bracken'[44] and 'acid flushes' on the plateau

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[44] Smith used the FRCA maps and habitat categories.

although it has its stronghold in the bracken communities [heath with scattered bracken, bracken with heath understorey, and bracken with heath and grass understorey] and acid flushes of the batches. Red grouse (*Lagapogus lagapogus scoticus*) are generally restricted to the plateau on areas of heath and heath with scattered bracken, and bracken with heath understorey. The skylark (*Alauda arvensis*) is generally restricted to the plateau, where it utilises both short grass and short dwarf shrub cover (Pearce-Higgins and Grant, 2006). Where species are occupying obviously disparate habitat types, e.g. the whinchat with both bracken communities and acid flushes, this represents partitioning of habitats between those where feeding takes place and those providing nesting sites.

Cheeseborough (2007) draws attention of the importance of areas of short grazed grassland, bare ground and flushes within the heath as foraging areas for *Aculeate hymenoptera* whilst track edges, bare ground, sheep scrapes and grass tussocks are important in providing nesting sites.

In a similar vein, Uff (2007a) also noted the importance of a mosaic for other invertebrate species, particularly the need to reduce the dominance of even aged stands of old and degenerate *Calluna* on the plateau, whilst at the same time still preserving some of this important habitat.

In addition to catering for the disparate needs of the fauna of the Long Mynd when devising management strategies, new factors may also need to be addressed. The role of management in maintaining heath and moorlands is well established, and whilst in many ways practices have not altered for centuries, new situations are now presenting new challenges. The principal challenges are not unique to the Long Mynd and fall within three interconnected areas: climate change, eutrophication and carbon sequestration.

Werkman and Callaghan (1999) note the view (Mitchell *et al.*, 1990) that atmospheric carbon dioxide and other greenhouse gases will continue to rise in the near future and that surface temperatures will almost certainly follow the same trend, whilst Terry *et al.* (2004) point out that global emissions of reactive nitrogen have increased substantially over the last century which has lead to increased availability within terrestrial ecosystems.

The effects of these on plants is likely to be vary between species, with consequences for community structure and interactions between different communities (Werkman and Callaghan, 2002).

Lee (1998) concluded that heather can remain dominant in moorland under high nutrient conditions provided the canopy was maintained and suppressed faster growing understorey species. However Power *et al* (1998b) found larval growth rates and weights of adult heather beetles were significantly higher when insects were reared on plants that had received additional nitrogen. This had implications for insect survival and reproductive success and obviously, for future infestation and the connection between *Lochmaea* infestation and transition from heather dominated to grass dominated heathland is well established [e.g. Berdowski (1987)].

Gordon *et al.* (1999) suggest *Calluna* is more sensitive to drought when receiving increased nitrogen and more prone to frost damage where this follows a summer drought event. Bannister and Polwart (2001) suggest that warming may result in increased frost sensitivity to *Calluna* and *Erica tetralix* and *E. cinerea.*

Increased nitrogen is also having an effect on bryophytes, Pitcairn *et al.* (1995) noted the findings of Press *et al.* (1986) that growth of *Sphagnum cuspidatum* was reduced by very small increases in nitrogen, as was that growth of *Hylocomium splendens* and *Pleurozium schreberi* (Dirkse and Martakis, 1992). Atmospheric inputs were also thought to affect the health of *Sphagnum* communities in the southern Pennines and areas of mid and north Wales. The deterioration in *Racomitrium* heath in areas south of the Scottish Highlands has also been attributed to nitrogen deposition (Thompson and Baddeley, 1991).

At a community level attempts have been made to model the effects of temperature increases; Berry *et al.* (2002; 2003) predicted that lowland heath, wet heath, and blanket/raised bogs would gain increases in suitable climate space.

Changes in climatic conditions can influence carbon release or sequestration. In their work at Moor House NNR, Garnett *et al.* (2001) found vegetation was less important for carbon storage than soil, with peat soils, particularly blanket bog, holding the greatest amounts of carbon. Milne and Brown (1997) determined that some 46% of UK soil carbon is held by Scottish peat soils. Dawson and Smith (2007) reported that in

England and Wales, stagnogleys, brown earth and raw peat soils, typical soils of the Long Mynd [*cf*. Mackney and Burnham (1966)], hold the majority of carbon.

Carbon release can take various forms. Burning vegetation releases CO_2 directly to the atmosphere and may alter hydrological conditions (Garnett *et al.*, 2000). Severe burns on moorland may ignite plant litter or even the underlying peat (Maltby *et al.*, 1990) and draining or droughting of peat deposits leaves themopen to carbon loss through gaseous decomposition. Rain and subsequent surface run off can produce erosion and also institute loss of carbon as ‘dissolved organic carbon’ or as ‘particulate organic carbon’ (Evans *et al.*, 2006b). Particulate organic carbon can also be mobilised by wind, either ‘dry blow’ or ‘wind-splash’ (Warburton, 2003).

Domisch *et al.* (2006) point out that soil temperature is a major factor affecting organic matter decomposition and thus, global warming may accelerate decomposition. in material accumulated under higher levels of atmospheric nitrogen resulting in higher CO_2 emissions and dissolved organic carbon release.

Metzger *et al.* (2005) developed a model of climate stratification of the environment in Europe which produced 13 environmental zones. Britain is divided into two zones: Atlantic North: [southern Pennies, Pennines and North York Moors northwards, the Welsh Massif and Marches] and Atlantic Central [Midland Plain, Devon & Cornwall, and the southern and eastern lowlands]. The Atlantic North zone encompasses the areas where Rodwell (1991) considers H12 communities are extant.

Climatic factors used in the model include ‘minimum’ and ‘maximum’ temperatures[45] precipitation[46] and percentage sunshine and environmental factors included altitude, northing (latitude), slope and oceanicity[47]. Following Mitchell *et al.’s* (1990) prediction for temperature increases it is likely that the temperature component of the model will become greater and possibly the precipitation smaller, which would have the effect of ‘shrinking’ the area of the Atlantic North zone.

Whilst Usher (2007) accepts the general assumption that in a warming environment the geographical range of a community will move northwards and uphill, he points out that

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[45] January, April, July and October.

[46] January, April, July,October and November.

[47] Measured as the June-January temperature range divided by the sine of the latitude.

this ignores differences between communities and that the component species in the community will react to a changing climate in an individual way.

Given Rodwell's (1991) view that H12 heath is concentrated in those areas where the climate, particularly the winter climate is severe, increasing temperatures alone may modify the community without taking in to account, eutrophication, drought or bracken incursions. This is also another complication when assessing the effects of management.

These factors suggest that vegetation and hydrology management will play an increasingly important role in carbon management on the Long Mynd. Control of aerial nitrogen deposition is more problematical, only national, or even international, initiatives are likely to have any long term effects, however mitigation of localised sources may be possible.

Angold (1997) showed there was an increase in the abundance of grasses in a zone bordering roads up to 200 metres either side of the carriageway, and that this change could be attributed in part, to nitrogen from exhaust gases. The restricted road network on the Long Mynd limits traffic to two basic routes on the plateau and whilst it is difficult to attribute the development of the grassy ‘verges‘ to enrichment through vehicle exhaust emissions as opposed to ‘grazing’ or ‘trampling and compaction’ by vehicle encroachment, their existence is not in dispute. Since the removal of traffic from these roads is not a realistic option it may be appropriate to maintain such ‘grassy’ areas as part of the general mosaic, albeit excluding traffic from the verges themselves.

Debate is also emerging about the direction of conservation management on the Long Mynd. There are two basic options: return the area to its classic communities, or maintain the current mosaic of disparate communities albeit with limits to bracken expansion. This, of course, poses the question; what are the classic communities of the Long Mynd plateau?

The principal heather communities found in this investigation were identified as NVC H12a. Rodwell (1991) records this as being common throughout the ‘less oceanic parts of the sub-montane zone,’ and Trueman *et al.* (1995) report it as common on the hills to the west in Montgomeryshire. Trueman (2007) suggests that the Long Mynd may be close to its south-eastern extent in England as well as being at the limit of its extension into the lowlands.

NVC H9 has variously been determined or rejected as a community extant on the plateau. Rodwell (1991) describes it as a species poor community whose character is derived from frequent burning and grazing, a view shared by Averis *et al.* (2004), but Rodwell (1991) also associated it with the atmospheric pollution attendant on heavy industry. Whatever the mechanism the potential for NVC H12 to degrade to an NVC H9 type remains.

Four 'grassland' communities/sub-communities were recorded in this investigation, NVC U1, NVC U4a, NVC U4e and NVC U5, together with the bracken dominated NVC U20C. The two NVC U4 sub-communities, occurred both as disparate communities and as part of a mosaic containing both communities in the same stands.

Thorne (2007) pointed out the sensitivity of these communities to changes in grazing levels; under-grazing can allow a reversion to heathland, whilst overgrazing can result in the loss of grassland species. Carty and Uff (2007) reported that following the ESA reduction in grazing there was a marked improvement in the grasslands; some severely cropped turf reverted to a tussocks structure and overwintering stems of *Nardus stricta* appeared again. There was also an increase in the frequency of flowering, especially in *Poa annua* and *Deschampsia flexuosa.*

NVC U1 is a species rich assemblage characteristic of base poor, summer parched soils where grazing and disturbance are important factors (Rodwell, 1992). On the Long Mynd it is generally associated with south facing slopes in the valleys or, particularly on the eastern side, on the steeper sides of the hills at plateau height. This was confirmed at two stands, but there is some evidence of small pockets of U1 persisting on the main body of the plateau itself.

NVC U20 is often the result of bracken expansion in grassland and heathland areas, in this case to produce the 'b' variant - *Vaccinium myrtillus- Dicranum scoparium* sub-community. In some stands it was the dominant community whereas in others it was only present within the mosaic suggesting it was expanding into other communities.

Lockton and Whild (1999) postulate a degradation sequence to explain a progression from core heathland, H12 to bracken dominated U20: H12, subjected to burning and [or] overgrazing results in the loss of dwarf shrub cover which alters the character of the community to NVC U2 *Deschampsia flexuosa* grassland. Subsequent grazing pressure diminishes *Vaccinium* and the community moves to U4 *Festuca-Agrostis* grassland. Both U2 and U4 are prone to 'take over' by bracken, where they change into U20.

Whilst no full blown U2 was encountered in this investigation, two of the H12a groups exhibited some affinities with it in the MATCH output; these dual affinities were taken as suggesting areas recovering from management, burning or cutting, where *Deschampsia* had recovered better in the short term.

The NVC U5 grassland was present at three well-separated stands. U5 may be restricted by its habitat requirements, but these seem to be widely spread on the plateau. Lockton and Whild (1999) cast doubt as to the existence of U5 on the Long Mynd, but these results, together with U5 affinities found in other groups, at least support the need for further investigation.

The plateau holds a limited number of habitats when described simply in terms of their species assemblage, but when age and structural variations and the mosaic effect are included, the effective number is greatly increased.

Watt's (1955) *Calluna* regeneration cycle with its four growth stages, pioneer, building, mature and degenerate, suggests there can be four different structural variations in the H12a community, at the landscape level these facies form a continuum. *Calluna* in these mature and degenerate stages is generally considered of little use for grazing hence it is the normal target for management, [*cf.* Backshall *et al.* (2001)] but it does have considerable value in terms of structural diversity and niche provision.

In national or, even regional terms the U4 grasslands of the Long Mynd may not seem worthy of conservation; Lockton and Whild (*ibid*) suggest that only the U1 [and the U5 if they exist] are the 'good quality' grasslands that management should seek to maintain on the Long Mynd. However, the greatest importance of all these U4 areas lies, not in their botanical status, but as habitats - foraging and nesting areas for invertebrate and vertebrate species.

Although wet areas are not a major feature in this investigation, those sampled appear to hold the disputed U5 communities and overall, mires and flushes are an important feature of the Long Mynd. Lockton and Whild (*ibid*) suggest there are some five wetland communities, seven if the two pool communities are included. As with the grasslands, these have importance greater than their simple NVC classification might indicate and would benefit from further investigation of their floristics and of their role as habitats for other species.

The extent to which management pressures have depleted species on the Long Mynd is largely speculative, but comparison with other sites may provide indications, particularly where such species feature in management initiatives.

As an example Lockton and Whild (1999) describe *Erica cinerea* as ‘not at all common’ on the Long Mynd and its current distribution is thought to be in small isolated pockets, (P. Carty, *pers. comm*.) although its actual extent is not well defined. There are populations on Cannock Chase to the east, and perhaps more significantly, on the nearby Stiperstones, which could indicate that its low representation on the hill is not geographical in origin but may be anthropogenic.

Evidence for this is indirect and somewhat tenuous. Hobbs and Gimingham (1984) found that the age of stands prior to burning influenced the subsequent regeneration of both *Calluna* and *E. cinerea*. In pioneer and building phase stands, regeneration through vegetative growth predominated whereas in mature and degenerate stands re-growth was mainly from seed. Gimingham (1949) established that, regardless of the source of regrowth in regenerating stands, *Calluna* withstood heavy grazing pressure better than *E. cinerea*. This combination, burning and high stocking levels, was a persistent feature in the management of the plateau for much of the latter half of the last century and could well account for a decline in *Erica cinerea.*

If this process drove *Erica* to its current levels, removal of these pressures may permit the population to recover, although given the small and highly fragmented nature of the population this could take an extremely long time. Particular efforts should be made to monitor these ‘isolated pockets’ of *Erica* to establish if it is recovering and to make estimations of direction and rate of spread.

There are, however, dangers in adopting an ‘analogous site comparison’ approach. *Vaccinium vitis-idaea,* a major feature of the Stiperstones ridge and also present on Cannock Chase, is not found on the Long Mynd. Trueman (2007) suggests this absence could be connected with geology, the soils of the Long Mynd may not be sufficiently acid to support this strongly calcifuge species. Conversely, Lockton and Whild (*ibid*) merely list the species as extinct, i.e. one for which they have no reliable record for at least a century.

The interaction between the basic vegetation communities, their structural complexity and position in the mosaic means drawing up management schemes for the upland area of the Long Mynd is not a simple task.

Given the varying and often conflicting habitat requirements of the different invertebrate and vertebrate species, management processes will probably become even more localised. There is even the prospect of specific areas needing to be isolated by temporary fencing, not an easy process under a ‘common’ grazing system, so that stock can be excluded or conversely, concentrated, i.e. maintained at levels which would be well in excess of normal stocking levels, in order to maintain the extremes of structural simplicity which may be needed by some species groups. A policy of active ‘rutting’ or ‘turf stripping’ may become necessary if natural or managed revegetation removes these features.

Removal of ‘old growth’ *Calluna* will remain the mainstay of management on the Long Mynd plateau however this may need to be reviewed in the future when local effects of climate change and eutrophication have been quantified. Cutting is likely to play the dominant role where the topography is appropriate but burning will continue to be required on slopes where cutting is not possible. Cutting *Calluna* has some ‘ecological’ advantages but there are additional advantages; old growth stems can be used in biofiltration and ‘brash’ also has the potential for use as biofuel. Burning can have well established disadvantages in terms of erosion, destruction of ground flora etc. but even these may be necessary if the mosaic of disparate habitats is to be maintained

Bracken control will still depend on cutting and spraying, however as areas suitable for cutting are again limited by topography, use of cutting may decrease as cut areas stabilise at acceptable levels. Aerial spraying is topography independent but is limited by the need for buffer zones around sensitive areas, typically wetlands, however evidence of sensitivity of both vascular plants and bryophytes to Asulox is increasingly being published which may impose further restraint on the use of this technique.

Suggestions for approaches to further work.

The consequences of climate change are perhaps emerging as the principal long term challenge to the Long Mynd although eutrophication, grazing and other anthropogenic pressures are still important factors which need to be addressed in future research, as will the need to manage carbon sequestration.

Monitoring of species and community changes in both vascular and non vascular species will continue to play an important part in gathering management information as well as monitoring the effects of management and using the stand and sub-quadrat approach adopted in this survey would provide such information.

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A systematic 'permanent stand ' design based on appropriate sub grids of the National Grid should be established to form the base on which annual or bi-annual surveys would be undertaken. The reduction in cost and the increasing precision of GPS devices makes location of stand positions relatively easy and reduces, if not eliminates, the need for permanent markers.

The position for each stand (as northing and easting) would be designated by the scheme design but aspect (as southness and westness), angle of slope and altitude would be established during the initial survey. These factors are unlikely to change although 'quality' checks made through the life of the scheme may be desirable. Variables such as litter depth, soil depth and pH should be measured during each annual survey.

Measures of soil moisture and soil nutrients should also be made during each survey; these could be determined using 'probe' technology[48] thus avoiding 'destructive' sampling, i.e. removal of substrate. Soill pH should also be determined using this methodology. Nitrogen levels within key species, defined as either target species or dominant species in a sub-quadrat, could also be made through sampling shoots or other biomass for subsequent determination.

These factors, together with data on management methods used and the date of application, together with levels of grazing and areas utilised, would provide additional environmental variables for use in analyses but also be available as 'inputs' for various predictive models e.g. bracken (Werkman and Callaghan, 2002), or levels of carbon accumulation (Evans *et al.*, 2006a).

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[48] E.g. Hanna Instruments ~pH and soil temperature, soil moisture, ammonia and nitrate.

Detail studies of particular locations could be made using the the same approach but using a reduced stand interval and the timing of surveys can be changed e.g, to bi-annual or even more frequently to detect changes in phenology.

7 Conclusions

- There is evidence from the Sinclair (1965) and Owen and Tapper (1983) maps that the bracken invasion represents an expansion of its range from outside the boundaries of the common and that its major incursions on to the plateau occurred in the late 1970s.

- The area of bracken encroachment appeared stable in the 1960s and 1970s (Sinclair, 1965; Owen and Tapper, 1983) but experienced a major increase by the 1980s (Ellett, 1984) however this area appeared to decreased by the mid 1990s (Farming and Rural Conservation Agency, 1995b). New areas have been colonised since then but whether this represents an overall increase is not known.

- The areas within the ‘shrubby heath’ groups appears to be relatively constant at around 1000 ha but the proportions of that infiltrated by bracken has varied, peaking at around 855 ha in the 1980s (Owen and Tapper, 1983) before falling back to some 526 ha in the mid 1990s (Farming and Rural Conservation Agency, 1995b).

- Acid grassland categories were fairly stable during the 1970s and 1980s at around 630 ha (Owen and Tapper, 1983; Ellett, 1984) but appeared to experience an overall decline in the 1990s (Farming and Rural Conservation Agency, 1995b).

- Classification of the quadrat data gathered during this investigation identified a small number of communities extant on the plateau and an interrelation between different facies of those communities. The core heathland, H12a, can be segregated into five disparate facies whilst the U4 grassland can be divided into two sub-communities, often within the same stands.

  This supports the argument that the different facies, possibly dependent on the structure and by implication the age of that community, can give indications as to the direction and rate of ‘movement’ within that community and perhaps inform more localised management efforts.

- Ordination of these data suggests:
    - Abiotic environmental parameters have a limited influence on the distribution of vascular species and that other factors, probably management effects, have a greater influence.

    - Distribution of bryophytes is more influenced by the structure of their associated vascular communities than by the abiotic parameters. Further work is required with regard to the scarcer or more specialised species, particularly those not associated with wetlands, to determine these relationships and the extent to which managing the vascular communities impacts on the bryophytes. The role of bracken as ‘pseudo-woodland’ and its effect on bryophyte assemblages may merit further study.

- A major, possibly the principal, management influence on the Long Mynd is grazing pressure (Jenkins and Anderson, 1999). The decrease in numbers following the implementation of the ESA Scheme in 2000 and the additional fall following the 2001 FMD cull has changed the overall grazing pressure to the extent that Uff (2007b) states “ reduced stocking is by far the most important factor in achieving the significant ecological improvements seen ……… over the past seven years.”

- New challenges for management

    - The projected effects of climate change on the UK; warmer drier summers on one hand and cold wetter winters on the other, will have major impacts on the species and the communities of the Long Mynd; impacts which can be compounded by the effects of nutrient enrichment. Surveying to monitor such impacts will become increasingly important.
    - The need to reduce the carbon footprint will change the management priorities for the Long Mynd: the possibility of managing communities to increase carbon lockup, for example, by keeping a greater proportion of old heather, or by restoring or expanding wetland areas, provides new opportunities for conservation.
    - The current expansion of *Pteridium* will probably not abate with the expected amelioration of climate attendant on global warming. Although bracken control will continue to be needed in particular areas, the importance of bracken to the composition and structure of the overall

mosaic particularly at the local level for vertebrate and invertebrate species, may well need further elucidation.

- The increasing public access to the Long Mynd, and the public's expectations of facilities will increasingly impinge on management. The wish for wilderness and isolation does not sit well with demands for car parks or the grazing sheep and ponies with poorly controlled dogs.

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Appendix 1.

Choice of methods for scoring vegetation cover: Domin or Presence/absence.

Musgrove (2001) compared the results of using both Domin and Presence-absence scoring in TWINSPAN and *DECORANA* analyses of the initial quadrat data. The Domin scored data was converted to simple Presence-absence form and analyses undertaken using both data sets. Figure 9.1.1 shows the dendrograms from these analyses

The initial separation of the ‘Domin scored’ analysis is resolved through the positive indicator, *Nardus stricta*, allocating 18 samples to the first level positive Group 1 with the remaining 182 samples being allocated to the negative Group 0.

With a single exception [408], all sub-quadrats in Group 1 fall within the same stand, LM 6, so no further divisions were undertaken. These sub-quadrats (85% of those in this stand) fall in a 'wet flush area' and whilst *Nardus stricta*, is not considered a 'wet' species it tolerates dampness and is acting as the indicator for the positive group as it is not recorded elsewhere in this data set.

The negative preferentials are *Calluna vulgaris, Vaccinium myrtillus* and *Deschampsia flexuosa* therefore it is no surprise that the negative group 0 is predominantly heathland vegetation.

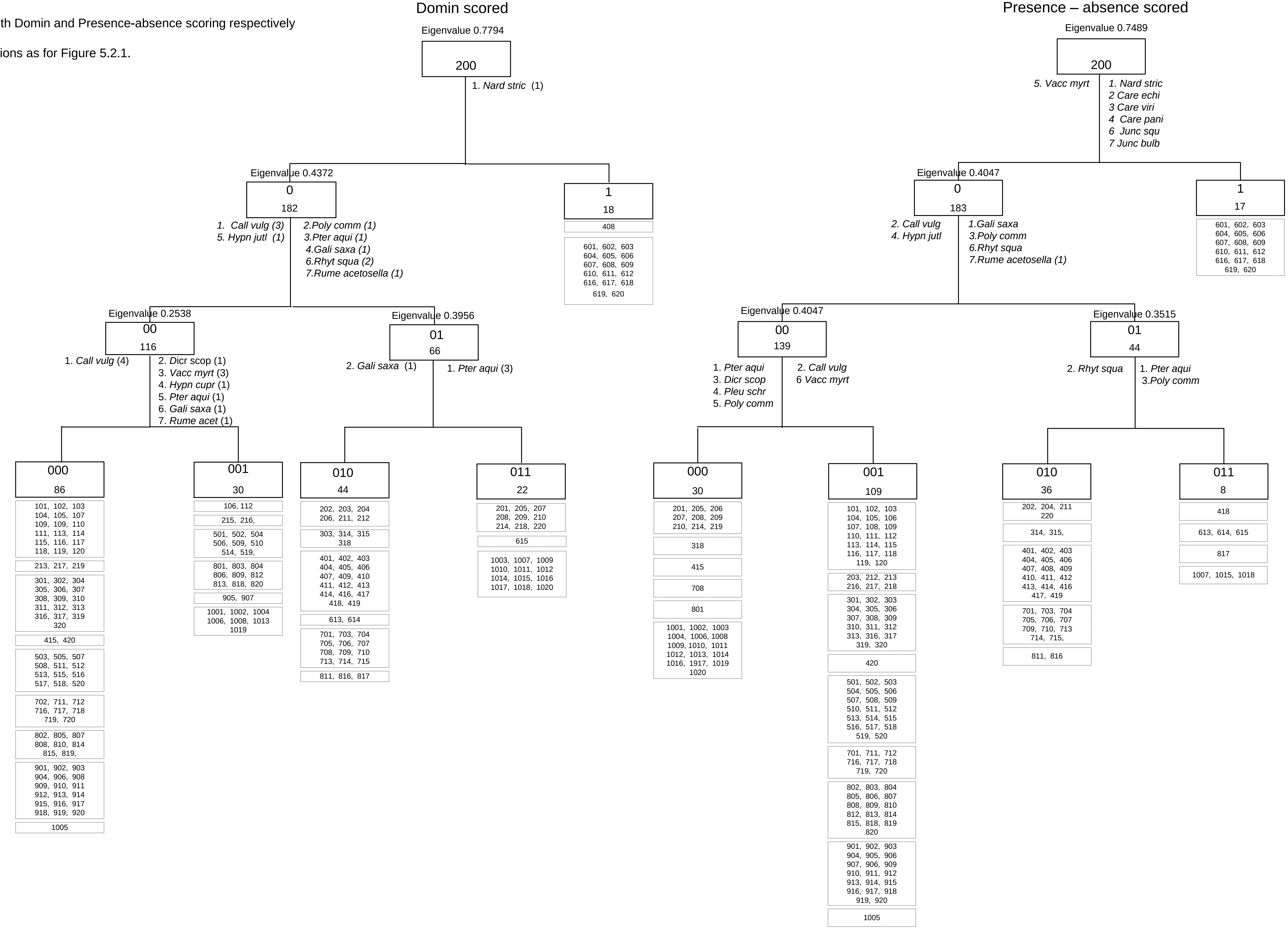
The division of this negative Group 0 is based on the negative indicators, *Calluna vulgaris* and *Hypnum jutlandicum* allocating 116 sub-quadrats to negative Group 00, and the positive indicators *Polytrichum commune, Pteridium aquilinum, Galium saxatile, Rhytidiadelphus squarrosus* and *Rumex acetosella*, allocating the balance (86) to the positive Group 01.

This division is segregating those sub-quadrats with *Calluna* dominated communities, from the remaining 'dry' communities which contain lower levels of *Calluna* and is based on the dominance of the indicator species in the 116 negative group stands (negative preferentials *Calluna* (1):108, (2):108, (3):106, (4):84 and *Hypnum* (1): 62, (2):62, (3):45). Two species, *Vaccinium myrtillus* and *Deschampsia flexuosa* are non-preferentials in this division and are probably the true characteristics of Group 0.

Figure 9.1.1: dendrogram of WinTWINS analysis of the initial ‘all species’ data set

using both Domin and Presence-absence scoring respectively

Conventions as for Figure 5.2.1.


Domin scored

Presence – absence scored

The positive group 01 can be considered a 'catch all' group which holds those stands where *Calluna* is not the dominant, and which subsequently divides into two disparate groups.

The segregation of Group 00 is made through the negative indicator *Calluna vulgaris* and positive indicators *Dicranum scoparium, Vaccinium myrtillus, Hypnum jutlandicum, Pteridium aquilinum, Galium saxatile* and *Rumex acetosella*; this segregation sends 86 samples to the negative group 000 and 30 samples to the positive group 001.

The non preferential species in Group 00, *Calluna, D. flexuosa, V. myrtillus and D. scoparium* are again defining the basic characteristics of these sub-quadrats and the separation is based on the increased dominance of *Calluna* [negative preferential (4)] in 80 sub-quadrats in the negative group.

Division of the positive group 01 is made by the negative indicator *Galium saxatile* (44 stands to Group 010) and the positive indicator *Pteridium aquilinum* (22 samples to Group 011). These end groups are considered to represent the maximum level of sensible separation and no further iterations were employed.

The end groups 000 and 1 are perhaps the most convincing in terms of site classification: between them they hold 5 stands with a minimum sample representation of 65%. Groups 010 and 011, hold three stands with a minimum representation of 60%.

Only one stand, LM 2, is represented in all four negative end groups (at a maximum stand representation of 45%). This is a diverse 'mosaic' stand with *Pteridium* as a canopy species at cover levels ranging from 20%-100% , *Calluna* as the principal 'understorey' species at cover levels from nil to 100%, and with varying but significant levels of *Vaccinium myrtillus* and *Deschampsia flexuosa.*

By way of contrast, the initial separation of the' presence-absence' scored analysis is resolved through a range of indicator species: the positive indicators, *Nardus stricta*, *Carex echinata*, *Carex viridula*, *Carex panicea*, *Juncus squarrosus* and *Juncus bulbosus*, allocating 17 samples to the positive Group 1 and the negative indicator, *Vaccinium myrtillus*, allocating the remaining 183 samples to the negative Group 0.

All the samples in the positive Group 1 fall within a single 'wet flush' stand and represent 85% of the samples in that stand; the negative preferentials are *Vaccinium myrtillus* and *Calluna vulgaris* so the previous characterisation of these Group 0 stands as essentially upland ericaceous vegetation is still valid.

The subsequent division of this group is made through the positive indicators *Galium saxatile*, *Polytrichum commune, Rhytidiadelphus squarrosus* and *Rumex acetosella* diverting 44 samples to the positive Group 01 and the negative indicators, *Calluna vulgaris* and *Hypnum jutlandicum* sending 139 samples to Group 00. This separation appears to be segregating the more open and diverse stands,(as indicated by the positive preferentials, *Rumex acetosella, Galium saxatile* and *Agrostis capillaris*) from the *Calluna* dominated ericaceous stands. Two stands, LM 4 (90%) and LM 7 (55%) are represented in the positive Group 01.

The division of Group 00 is made through the positive indicators, *Calluna vulgaris* and *Vaccinium myrtillus,* allocating 109 samples to Group 001 with the negative indicators *Pteridium aquilinum*, *Dicranum scoparium*, *Pleurozium schreberi* and *Polytrichum commune* allocating the remainder (30) to Group 000. This dichotomy is essentially segregating the *Pteridium* dominated samples in the negative Group (000) from the ericaceous stands in the positive Group (001). Two stands, LM 2 and LM 10, are represented in Group 000 (minimum presence 50%) with stands LM 1, LM 3, LM 5, LM 8 and LM 9 represented in Group 001 with a minimum presence of 75%.

Comparison of the analyses of these samples using the two scoring systems suggests that ‘presence-absence data’ are the appropriate choice when classifying the communities for mapping purposes, allocating all 10 stands to end groups with minimum sub-sample presence of 50% and the majority at 65% or greater.

On the other hand, the analysis using Domin values is superior in giving a fuller picture of the dynamics which are driving the classification by removing what might be considered the oversimplification introduced by the basic presence/absence analysis. Whilst this 'Domin' analysis only allocated 8 stands to end groups, at a minimum level of presence of 60%, it demonstrates some of the subtle differences in within-stand composition which produce associations between sub samples and the 'wrong' stand types.

Appendix 2.

Validation of quadrat numbers:

Following the suggestion that the number of quadrats scored in each stand could be reduced , the Domin scored data set was divided into two subsets, based on the ‘odd numbered’ and ‘even numbered’ quadrats, which were analysed using Twinspan. The resultant dendrograms are shown in s shown as Figure 9.2.2.

The first level division of both analyses diverted quadrats from the same stand, LM 6 to the respective positive Endgroups 1 through the same indicator, *Nardus stricta* although in the even number set an isolated quadrat from another stand [LM 4] was also identified. Once again the principal separation is between the ‘wetlands’ and the ‘heath and grassland’ areas of the negative Endgroup 0.

The division of these latter groups allocates the predominantly shrubby heath areas to the negative Endgroups 00, and the more open heath or grassland areas to the positive Groups 01. This separation is made through the positive indicators *Calluna vulgaris* [both] and *Hypnum jutlandicum* [‘odds’] and the negative indicators *Galium saxatile and Polytrichum commune* [both] although *Pteridium aquilinum* was the principal indicator on the ‘even’ division.

Subsequent division tended to lose their symmetry both in terms of indicator species and numbers of quadrats and their source stands. This perhaps indicates that the diversity of both species presence and their abundance is coming in to play pointing to real distinctions within the stands and suggesting that given the scale of mosaic present in the stands information would be lost if the number of quadrats per stand were reduced.

Figure 9.2.1: dendrogram of WinTWINS analysis of the initial ‘all species’ data set separated into the ‘odd’ numbered and ‘even’ numbered quadrats. Conventions as for Figure 5.2.1.