A comparison between primary grasslands and abandoned quarries of the magnesian limestone, county Durham, with special reference to scrub invasion

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A COMPARISON BETWEEN PRIMARY GRASSLANDS AND ABANDONED QUARRIES OF THE MAGNESIAN LIMESTONE, COUNTY DURHAM, WITH SPECIAL REFERENCE TO SCRUB INVASION

by Elizabeth Allchin

A dissertation submitted in part fulfillment of the requirements for the degree of Master of Science in Ecology by advanced course.

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Epipactis atrorubens

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Abstract

Seven grassland Sites of Special Scientific Interest on the Magnesian Limestone of County Durham were botanically surveyed using the methodology of the National Vegetation Classification. Both primary grasslands and grassland developed in abandoned quarries were included, but the sampling was limited to open calcicolous grassland and scrub-invaded grassland, with areas of impenetrable scrub and woodland being avoided. Characteristic of these grasslands is blue moor grass, *Sesleria albicans*, which reaches its southern lowland limit in County Durham.

The results were analysed using multivariate techniques to reveal patterns in community composition and possible environmental factors causing this variation. Six main communities are described, comprising both grassland and scrub vegetation. A successional sequence linking these communities and their sub-communities is postulated. It is suggested that abandoned quarries are floristically different from primary grasslands, but may achieve similarity in time if there is a nearby seed source of *S. albicans*.

Scrub invasion, mainly by hawthorn, *Crataegus monogyna*, is ubiquitous in both the primary and secondary grasslands and presents the major threat to the integrity of the limestone flora. The botanical survey reveals a significant change to the flora under scrub, with some of the low-growing calcicoles being partially replaced by tall nutrient-demanding grasses and herbaceous species. However, the invasion of willow (*Salix* spp.) at one of the abandoned quarries has had negligible impact on the ground flora. The two most common scrub species, hawthorn and dog rose (*Rosa canina* agg.) appear to have more influence on the ground flora than any other species. It is suggested that the age of these species is more important than density in altering the ground flora.

The results of this investigation have been used to make tentative suggestions for management of the sites.

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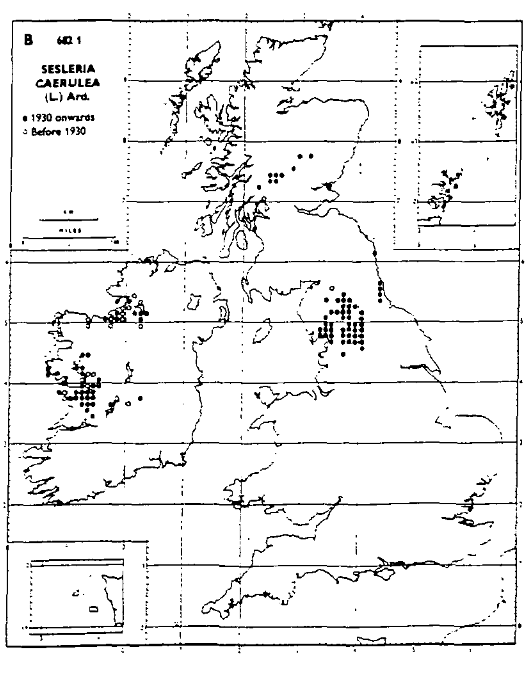
CHAPTER ONE
INTRODUCTION

1.1 Magnesian Limestone Grasslands

The total national resource of Magnesian Limestone grassland constitutes 270 ha, of which 177 ha are in County Durham and Tyne and Wear (English Nature, 1992). There are small pockets of grassland remaining in Derbyshire, Nottinghamshire and Yorkshire, but County Durham supports the largest remnants (Ratcliffe, 1977). These remnants comprise both 'primary' (unquarried) grasslands as well as secondary grasslands developed in abandonded quarries. Most of the original area of natural vegetation has been turned over to agriculture, so there are few areas of primary grassland remaining, most of which are on steep slopes which cannot be cultivated. These are subject to many pressures such as quarrying, agriculture, over-grazing, eutrophication, scrub invasion and recreation (Spencer, 1976). In 1975 Marren described the plight of the Magnesian Limestone as "critical, with many former sites reduced in interest, and others threatened with tipping, quarrying and scrub encroachment". In County Durham 430 ha, including woodlands, wetlands, grasslands and old quarries, retain wildlife habitat worthy of conservation. Of this, 70 ha (16%) have been destroyed since the end of the Second World War (Doody, 1977). For example, 10 of the original 24 ha in Bishop Middleham SSSI have been lost due to tipping and reworking. Scrub encroachment is perhaps the most widespread threat to the limestone flora. Pritchard (1989) suggests that approximately 60% of sites suffer from scrub invasion and that clearance of scrub could increase the amount of grassland by 15%. Not only does scrub shade out the ground flora, but the establishment of woody species can alter soil chemistry and pH (McCulloch, 1974). This has implications for the re-establishment of the grassland flora following scrub clearance.

Figure 1.1 Distribution map of *Sesleria albicans* (from Perring and Walters, 1962)



Blue moor grass (*Sesleria albicans*) is dominant or co-dominant in much of the grassland in County Durham. It has a distribution that is both restricted and disjunct (Pigott and Walters, 1954). It is locally abundant in western Ireland and on the limestone uplands of northern England and is a rare occurrence on cliff ledges of basic mountains in Scotland. In Europe the grass occurs in "dealpine" grass heath. These habitats suggest a wide tolerance of water and soil parameters, but *Sesleria* seems to prefer open vegetation, being an efficient coloniser of limestone scree and pavements.

The Magnesian Limestone Grasslands in County Durham have been characterised phytosociologically by Shimwell (1968) as being of the association *Seslerio-Helictotrichetum* (sub-alliance *Seslerio-Mesobromion,* Class *Festuco-Brometea*). This association has since been recognised as Community CG8 (*Sesleria albicans - Scabiosa columbaria* grassland) by the National Vegetation Classification (Rodwell, 1992). Shimwell also identified sub-associations within these associations and smaller-scale variants of the sub-associations. The NVC has divided community CG8 into 4 sub-communities, which have affinities with some of Shimwell's vegetation types.

Grasslands of this association are botanically interesting because they represent a link between arctic-alpine grasslands (Class *Elyno-Seslerietea*, Shimwell, 1968) and the southern lowland calcicolous grasslands (Class *Festuco-Brometea*). Representatives of both the northern and the southern flora coexist in the grasslands of County Durham.

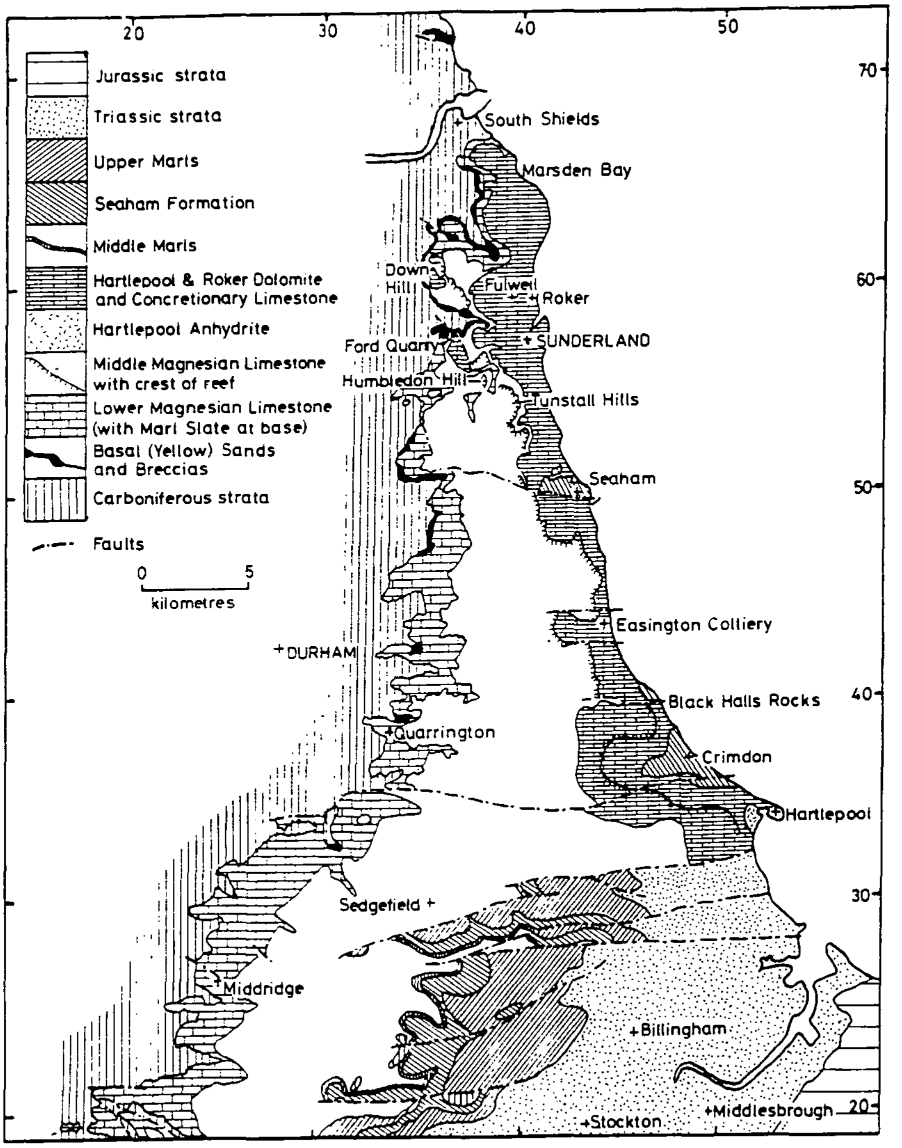
Table 1.1 Some species at the edge of their range in County Durham

Absolute Northern Limit	Near the Northern Limit	Southern Lowland Limits
Linum anglicum	*Aquilegia vulgaris*	*Epipactis atrorubens*
Bromus erectus	*Orchis ustulata*	*Antennaria dioica*
Ophrys apifera	*Blackstonia perfoliata*	*Trollius europaeus*
Hypericum montanum	*Erigeron acer*	*Pinguicula vulgaris*
Serratula tinctoria	*Anacamptis pyramidalis*	*Primula farinosa*

Thrislington Plantation and Cassop Vale are primary grasslands of national importance and are mentioned in the Nature Conservation Review (Ratcliffe, 1977). Grasslands such as these tend to be valued for conservation more than the re-colonised abandoned quarries by virtue of their antiquity. Bartley *et al.* (1976) suggest that some areas of the Magnesian Limestone escarpment have not supported woodland for over 3000 years (section 1.7). It has been suggested that steeper parts of the escarpment may never have been forested (Tansley, 1939). Furthermore, secondary grasslands may exhibit slightly different plant communities to the unquarried grasslands. Dalby (1991) suggests that secondary grasslands tend to have more species of a southern distribution, possibly due to the sun-trapping effects of quarries and the speed with which bare soil heats up. However, old quarries, many of which were abandoned earlier this century, have partially compensated for the loss of semi-natural grasslands because many of these quarries were abandoned at the same time as the expansion of agriculture in the region and so provided an important "refuge" for the calcicolous species. However, these secondary habitats are also under threat from reworking, tipping and recreation (Spencer, 1976; Doody, 1977).

1.2 Geology

Figure 1.2 Geological map of Eastern County Durham (from Pettigrew, 1980)



Magnesian Limestone forms an irregular discontinuous strip from Tyne and Wear south to Nottingham. The largest area of outcrop is in Tyne and Wear and Durham, where the rock also attains its maximum thickness (Pettigrew, 1980). It was laid down in the Permian, 290-250 million years ago. It differs from other limestones in containing a large proportion of magnesium carbonate, as well as calcium carbonate. If it contains more than 15% magnesium carbonate it is known as dolomite.

During the Permian, desert conditions prevailed in Britain. The desert phase of the Permian was halted by the transgression of the hypersaline Zechstein Sea, which covered much of the present North Sea basin and parts of East England, Denmark and North Germany (Johnson, 1970). The western coastline is thought to have been formed by the precursors of the Pennines (Pettigrew, 1980) and most of East Durham lay on the marginal shelf. The Magnesian and dolomitic limestones were deposited under this sea. There are 3 divisions in the Magnesian Limestone, the lower, middle and upper, each of which had different modes of origin and a different structure and composition.

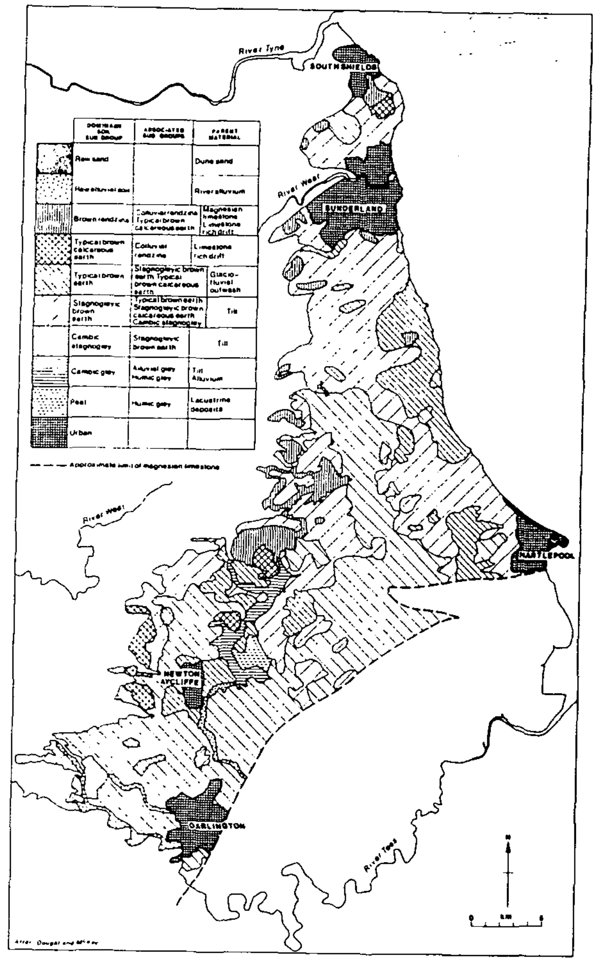
The Lower Magnesian Limestone consists of fine-grained dolomites and limestones which have been extensively quarried (Booy, 1975). The Middle Magnesian Limestone formed either side of a barrier reef which developed on the shelf of the Zechstein Sea, about 235 million years ago (Johnson, 1970; Pettigrew, 1980). The Upper Magnesian Limestone is retricted to a narrow belt on the coast (Pettigrew, 1980)

1.3 Geomorphology

The major outcrop of the Magnesian Limestone is in County Durham in an approximately triangular shape of area 596 km^2 (Booy, 1975). Apart from some very small exposures south of the River Tees, the rock does not reach the surface again until it forms a narrow strip along the eastern flanks of the Pennines near Ripon (Spencer, 1976). A steep escarpment is formed on the western side, approximately 166 - 200m high, extending between South Shields in the north and Bishop Auckland in the south. The southern boundary with the Tees lowland is much less distinct (Stevens & Atkinson, 1970). The East Durham plateau is covered by thin glacial deposits and slopes gently eastwards to the coast, where it forms a cliff approximately 15m high. The plateau is dissected by denes up to 60 m deep, probably formed in the last glaciation.

1.4 Soils

Figure 1.3. Distribution of soil types on the Magnesian Limestone (from Alexander, 1980)



The soils of the Magnesian Limestone are very heterogeneous in composition and texture. Two types of soil (**brown rendzinas** and **calcareous earths**) support all the important species (Spencer, 1976), but they are quite limited in extent (Alexander, 1980). More than three quarters of the remaining area is strongly affected by glacial drift deposits, reducing the influence of the limestone and poorly drained soils predominate. The thickness of soil varies, depending on topography and the nature of the limestone.

Brown rendzinas formed directly on the limestone only occur on the higher parts of the escarpment and on the steep slopes where down slope creep and erosion have removed drift cover (Alexander, 1980). These soils are shallow (20 - 40 cm), with a dark brown loamy "A" horizon directly overlying the weathered limestone (Stevens & Atkinson, 1970). The surface horizon is calcareous throughout (pH 7.5 - 8.0) and has a freely draining strong crumb or granular structure. Soil analyses by Booy (1975) and Richardson & Evans (1986) found that these soils are deficient in nitrogen, phosphorus and potassium, but magnesium and calcium are abundant. These shallow rendzinas form the **Cornforth Series** of McKee (1965).

Brown Calcareous soils are found on parent material rich in limestone debris or where the limestone is only covered by a thin mantle of till. These soils are deeper than the rendzinas (50 - 100 cm) and have a clearly defined B horizon. because they are deep, nutrient-rich and are freely-draining (Alexander, 1980). These soils represent McKee's **Middleham Series.**

1.5 Climate

Most of the climatic information for the area comes from the Durham University Observatory record which is 6 - 10 km away from the escarpment and 60 m closer to sea level, so the temperatures on the escarpment are probably slightly lower. Spring comes to the plateau on average 2 - 3 weeks later than the surrounding area (Spencer, 1976). The escarpment is subject to frost between the months October and May. The mean monthly soil temperatures at Trimdon Quarry are 2.5^{o}C in January and 15.3^{o}C in August (Durham Wildlife Trust, 1988). The growing season commences at the beginning of April and extends to mid-November (Smith, 1970). The escarpment receives 650 - 700 mm of rain per year. Spring is the driest season, whereas late summer and autumn experience the most rain. The plateau as a whole has approximately 170 days of rain per year (Spencer, 1976). There is a snow cover of up to 50 days per year. During late spring and early summer sunshine can be reduced by the inshore movement of the North Sea "haar", which extends inland due to the preponderance of light easterly air.

1.6 Quarrying

The Magnesian Limestone grasslands of County Durham are valued for quarrying because the absence of a deep layer of drift makes the rock below readily accessible. There is evidence of quarrying in the area since Roman times (Percy, 1980). By the 18th century there were many pits and kilns for burning limestone, the residue to be used for building or agriculture. In the late 18th and 19th century limestone was extensively quarried to use as flux in iron blast furnaces and later as a refractory lining for steel blast furnaces.

There was a major increase in quarrying in World War I when dolomite could no longer be obtained from Austria (Spencer, 1976). In the 19th and 20th centuries magnesia has been extracted from dolomite and magnesian limestone for the pharmaceutical and rubber industries.

This century, the production of magnesite from dolomite and sea water has been a major use of quarrried dolomite. Magnesite is used as a high grade refractory and facilitated the production of magnesia, magnesium metal, magnesium chloride and sulphate (Percy, 1980).

Since World War II there has been a growing demand for both agricultural lime and materials for the construction industry. For example, the large quarry at Raisby provides roadstone, aggregates and fill. This increase in demand has prompted the re-opening of a number of workings such as Bishop Middleham in 1976. However, the quarries are now being worked down to the underlying sands so are unlikely to support a typical limestone flora when they are abandoned (Spencer, 1976).

Today, this demand from the construction industry has declined somewhat, but this has been accompanied by an escalating demand for flux, magnesite and agricultural lime for export. There has been a huge increase in the production of lime since the War (Spencer, 1976). In 1949 1.4 million tonnes were being produced per year, and in 1971, this figure rose to 6 million tonnes, 50% of which came from County Durham.

Table 1.2 Uses of Magnesian Limestone (1975 figures)

Civil Engineering and construction	50%
Iron and steel	15 - 20%
Magnesia production	10 - 15%
Agriculture, chemicals and pharmaceuticals	20%

(from Spencer, 1976)

1.7 Vegetational History

The evidence of past vegetation on the Magnesian Limestone is relatively scarce, due to the lack of peat or lacustrine deposits. However, early this century, pyritized seeds, probably dating from the mid-late Pliocene, were found at Castle Eden. At this time the Magnesian Limestone is thought to have been mainly wooded, with areas of open herbaceous vegetation (Reid, 1920, cited in Turner, 1970). Over 60% of the species present then are now extinct in this country, many having Far Eastern or North American distributions.

The layer of boulder clay on the Magnesian Limestone indicates that the area was covered by ice during the Pleistocene glaciations, although thermophilous arboreal taxa dominated during the Ipswichian interglacial (Turner, 1970). Herbaceous species colonised during the warm phases of the Devensian from areas south of the ice sheet. When trees began to dominate approximately 10 000 yr BP herbaceous species may have survived in places where trees could not grow successfully, such as on very shallow soils or on cliffs and steep banks (Richardson, 1956). These species extended their distribution when the forest cover declined due to clearance by man.

Bartley *et al.* (1976) investigated the vegetation history of 6 sites in County Durham, one of which was at Bishop Middleham, just south of the Magnesian Limestone outcrop, where pollen was preserved in a small peat deposit. Around 7 000 yr BP the site was forested, dominated by *Pinus* and *Corylus*, later to be replaced by *Alnus, Quercus, Ulmus* and *Tilia.* Both Mesolithic and Neolithic man appear to have had little impact on the forested landscape, although it is proposed that Neolithic man instigated the elm decline. Indicators of forest clearance such as *Plantago lanceolata* and *Rumex acetosella* did not appear until 5180 yr BP, when small and temporary forest clearance appears to have been practised.

All tree pollen except *Betula* declines sharply around 3660 yr BP (the beginning of the Bronze Age), accompanied by an increases in Gramineae, Cyperaceae, Compositae, *Plantago lanceolata* and *Potentilla* pollen, indicating forest clearance and pasturing, possibly permanent. The presence of *Plantago major-media, Artemisia* and Chenopodiaceae pollen suggest some arable cultivation. Bishop Middleham shows the greatest extent of clearing of any of the sites studied by Bartley *et al.* (1976). This extensive clearing is similar to that which occurred at the same time on the southern chalk. It seems that the Magnesian Limestone and probably the adjacent sands and gravels were completely cleared and used for grassland and arable. Bartley *et al.* (1976) suggest that there may have been a settlement at Bishop Middleham, although shifting agriculture was more widespread at that time (Turner, 1970).

The upper part of the pollen diagram for Bishop Middleham indicates a decline in *Plantago* pollen but little forest recovery. This contrasts with the other sites in eastern County Durham which show a rise in colonising trees such as *Betula* and *Fraxinus.* It is suggested that this is due to differences in edaphic factors, and that the shallow soils of the magnesian limestone were never recolonised by forest. Land for pasture was increased with the arrival of the Romans (Shimwell, 1968), only to be left derelict by the Saxons. Since then, there has been an overall upward trend in the area of grassland, except during the Black Death.

The Enclosure Acts of the late 18th century contributed to the demise of natural vegetation, with most of the Magnesian Limestone plateau becoming arable land or permanent pasture where the soils were too shallow or the topography too undulating for arable farming. Because the plateau was subject to fertiliser applications, it is only on the steep slopes, which were used for rough grazing, that vegetation approaching a 'natural' state remains.

1.8. Aims of this investigation

The primary grasslands of the Magnesian Limestone in Durham have already been studied from a phytosociological viewpoint by Shimwell (1968) and were sampled during the compilation of the National Vegetation Classification (Rodwell, 1992). The plant communities of the re-colonised quarries, however, have not received so much attention. One of the aims of this study, therefore, is to compare the plant communites of old quarries with semi-natural grasslands. If there are differences, this prompts the question: are old quarries likely to emulate semi-natural grasslands in time? A process of classification (TWINSPAN) will be used to characterise plant communites and it is hoped that a successional sequence may be inferred.

The second principal aim is to discover the extent to which limestone grassland communities are affected by scrub encroachment. Is scrub invasion more of a problem on semi-natural or on secondary grasslands? Do the different scrub species affect the ground flora in different ways? It is proposed to answer these questions by identifying the gradients in floristic composition (Detrended Correspondence Analysis) as well as the environmental variables that correlate with the floristic variation (Canonical Correspondence Analysis).

CHAPTER TWO
SITE DESCRIPTIONS

The sites were selected to include both primary and secondary grasslands developed in abandoned quarries. Bishop Middleham and Trimdon are abandoned quarries, as are Pittington Hill and Raisby, but the latter two sites also support areas of primary grassland. Thrislington and Cassop Vale are primary grasslands. All the sites are situated on the western escarpment of the Magnesian Limestone. Maps of the sites are found in appendix 1.

2.1 Trimdon (NZ 362353)

2.1.1 Description

Trimdon Quarry was designated an SSSI in 1992. Although only 0.8 hectares in extent, it forms part of a larger reserve managed by Durham Wildlife Trust, which was acquired on a lease from Durham County Council in 1975. The quarry was designated primarily for its geological interest, but also on account of the diverse grassland that has colonised the quarry floor. The quarry walls are almost vertical, ascending to a height of approximately 3 - 4m. Only the area within the SSSI boundary, i.e. the quarry floor was sampled in this study, but the Wildlife Trust Reserve incorporates an area west of the quarry of mature hawthorn (*Crataegus monogyna*) scrub, grading into ash (*Fraxinus excelsior*) woodland on a boulder clay substrate. The reserve is surrounded by arable land on three sides and a disused railway line on the fourth. Although the entrance to the quarry is quite concealed, it seems to receive quite heavy recreation pressure in the form of dog-walking, children playing and even motor cyclists. There is evidence of camping and bonfires and litter is a problem.

2.1.2 History

It is not clear when quarrying at Trimdon began, although it is likely to be the mid-late 18th century (Durham Wildlife Trust, 1988). Quarrying operations ceased in 1926 (Spencer, 1976), only to be recommenced during the War, when the quarry was extended to its present size. There has been no further quarrying since the War.

2.1.3 Management

Management of the quarry aims to prevent the invasion of ruderal and scrub species, chiefly rosebay willowherb (*Epilobium angustifolium*), *Crataegus monogyna,* bramble (*Rubus fruticosus* agg.) and gorse (*Ulex europaeus*) in order to maintain the diversity of the short limestone grassland. These species were last removed from the quarry floor in May 1993 by the Durham Wildlife Trust Task Force, although the shrubs of *Rosa* spp. (mostly *R. canina* agg. and *R. rubiginosa*) were left on account of their botanical interest. Bee orchids (*Ophrys apifera*) were transplanted on to the quarry floor from Aycliffe Quarry in 1974.

2.2 Bishop Middleham (NZ 332327)

2.2.1 Description

Bishop Middleham Nature Reserve was first designated as an SSSI in 1968. The reserve was then considerably larger than its present extent, incorporating a disused quarry to the south. The new SSSI (4.5 ha) was renotified in 1982 because the interest of the southernmost quarry had been destroyed by tipping and extended quarrying (Durham Wildlife Trust, 1984). Within the reserve there are sparsely colonised spoil heaps, open grassland on the quarry floor being invaded by willow scrub, rank grassland, (thought to have been encouraged by eutrophication due to tipping), scrub and woodland (photographs 1 and 2). The dense scrub and woodland areas of the reserve were not surveyed in this investigation. The grassland on the quarry floor and the remnants of "primary" grassland on the northern quarry edge support the most interesting flora, including a population of the rare dark red helleborine (*Epipactis atrorubens*). The reserve is surrounded by arable land (mostly barley) on 3 sides and the active quarry lies on the southern side.

2.2.2 History

Quarrying at Bishop Middleham began around the mid 19th century (Spencer, 1976). The lower level was opened in 1918 and limestone extracted northwards until 1934. The southern quarry was re-opened in 1976 and is active today. The works have extended down to the Permian Sands, so a typical limestone flora is not expected to develop when the quarry is abandoned (Spencer, 1976). Tipping has also been a problem. In 1966 tipping was confined to the part which is now the active quarry (Bellamy *et al.*, 1966). By 1971 tipping had occurred in the centre of the quarry, and in 1972 building rubble was dumped along the eastern side of the quarry. One third of the SSSI had been destroyed by 1974 (Spencer, 1976).

2.2.3 Management

The quarry floor has been invaded by various species of willow, mostly *Salix caprea* and *S. cinerea*. The main objective of management is to control this scrub and encourage open grassland. The willow has been cut many times by the Durham Wildlife Trust Task Force and the stumps treated with the herbicide "Amcide" (ammonium sulphamate). This treatment has had mixed success, and regeneration is still occurring. Bee orchids were transplanted from Aycliffe Quarry in 1982 (photograph 3).

Photograph 1 Sparsely colonised spoil heap at Bishop Middleham

Photograph 2 *Sesleria albicans* grassland at the rim of Bishop Middleham quarry (foreground), with *Salix* spp. scrub colonising the quarry floor

Photograph 3 Bee orchid (*Ophrys apifera*) at Bishop Middleham

2.3 Raisby Hill Grassland (NZ 335354)

2.3.1 Description

Raisby Hill Grassland SSSI covers 10.01 hectares, incorporating a small abandoned quarry, an expanse of semi-natural magnesian limestone grassland, limestone spoil heaps, a small wetland, and scrubby areas with developing woodland. It was first designated an SSSI as Raisby Hill Quarry in 1957, but was renotified with new boundaries as Raisby Hill Grassland in 1984. The SSSI has been managed by Durham Wildlife Trust since 1978. The reserve is surrounded by pasture on the north-west side, the active quarry extends the length of the south-east side and there is a disused mineral railway to the south. Several footpaths lead from the disused railway into the reserve, so it tends to be used by local children and walkers.

The semi-natural grassland is undergoing scrub encroachment in places (photograph 4), and there is quite dense scrub developing into woodland at the bottom of the hill. There are small localised flushed areas on the hillside, which are characterised by purple moor grass (*Molinia caerulea*). The floor of the abandoned quarry is still quite sparsely colonised (photograph 5), although the slope of the spoil heap supports woody species, such as *Crataegus monogyna, Fraxinus excelsior, Acer pseudoplatanus* and *Viburnum lantana.*

2.3.2 History

Raisby Quarry first opened in 1830 and has been worked continuously since 1847 (Booy, 1975). Quarrying began at the south-west end of the escarpment and continued in a north-easterly direction. The oldest area of quarrying was abandoned in the 1940s, and some tipping of quarry waste occurred in this area (Durham Wildlife Trust, 1991).

2.3.3 Management

Management aims to clear scrub from 4 areas: the abandoned quarry, a small area immediately north-east of the quarry and 2 parts to the east. The large sparsely-colonised spoil heap was regraded in 1987 to fit the contours of the original hillside, although the lack of vegetation means that this area is easily eroded (Durham Wildlife Trust, 1991).

2.4 Wingate (NZ 372378)

2.4.1 Description

Wingate Quarry has been managed by Durham County Council as a Local Nature Reserve since 1980 and was given SSSI status in 1984. It is a large site of 19.7 hectares, with a variety of habitats, including recently disturbed open vegetation, established grassland (calcicolous and semi-improved), scrub, ponds and damp grassland. The reserve is surrounded by arable land and there may be some spray drift and run off (Durham County Council, 1992). Other pressures on the reserve are recreational, e.g. heavy use by scrambling motor bikes. One area of the reserve (not in the SSSI) was set aside for use by motorbikes, but this was banned due to erosion and damage caused to the vegetation. However, illegal scrambling still occurs.

2.4.2 History

The quarries were worked for dolomite from the mid 18th century through to the mid 1930s. The presence of rigg and furrow in the semi-improved pasture within the reserve suggests at least part of the reserve has a long history of agricultural management. In 1840 the area was predominately grassland and arable. The northern-most quarry has been used as a waste disposal site and part of the southern quarry has been used by the National Coal Board for slurry disposal, followed by inert waste. This area has now been reclaimed (although not sampled in this study).

2.4.3 Management

The area of calcicolous grassland within the reserve constitutes 9.5 ha, but this is hopefully being increased by cutting the improved grassland for hay in order to reduce fertility (this area was not sampled in this project). The semi-improved grassland has been grazed in the past, although there was no grazing in 1991 (Durham County Council, 1992). Other parts of the quarry have also been grazed by cattle (in 1985-87), but there has been no recent grazing. It has been recommended that the most effective method of prevention of invasion by *Crataegus monogyna* and *Rosa* spp. is grazing by sheep, but the heavy use of the area for dog-walking and the steep unfenced quarry walls have made this form of management impractical. Instead, scrub has been cut and the stumps treated with Amcide (photographs 6 and 7).

2.5 <u>Pittington Hill</u> (NZ 331447)

2.5.1 Description

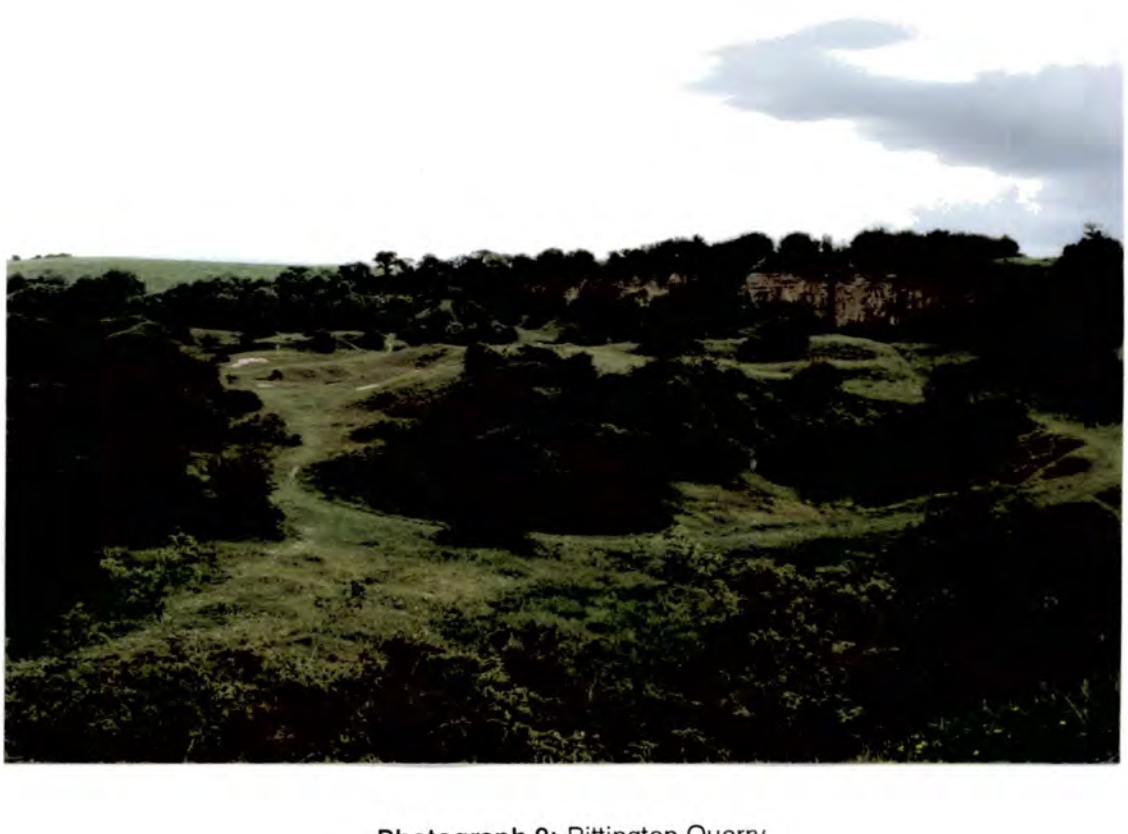
Pittington Hill was designated an SSSI in 1987. It occupies a total area of 6.4 hectares, of which 3.1. hectares is unimproved calcareous grassland on the hill and the edges of the quarry. It is surrounded by pasture and arable fields. The hillside especially is subject to scrub invasion by hawthorn, gorse, bramble and rose (photograph 8). The unquarried hillside supports some *Sesleria,* but it is not as abundant as some herbs, notably, *Helianthemum nummularium.* On the south-eastern edge of the reserve there is some unimproved neutral grassland, dominated by *Agrostis capillaris.* On the lower slopes of the hillside, there are areas of semi-improved neutral grassland.

Photograph 4: Scrub encroachment on Raisby Hill Grassland

Photograph 5: Raisby Quarry floor

Photographs 6 and 7: Scrub encroachment at Wingate

Photograph 8: Bramble (*Rubus fruticosus* agg.) invasion on Pittington Hill



Photograph 9: Pittington Quarry

Some areas of the quarry are tightly grazed, but the more inaccessible areas support a dense sward. There are almost impenetrable pockets of scrub, with *Crataegus, Ulex* and *Rosa* present (photograph 9). There are some areas of eutrophication, on the flat areas of deeper soils between the pits and ridges. These areas support herbs such as *Bellis perennis, Plantago lanceolata, Achillea millefolium* and grasses, mostly *Poa* spp. The bare rock of the steep quarry walls has not been colonised.

2.5.2 History

The hillside was used for "gardens" in 1840 (Spencer, 1976), but had reverted to rough grassland by 1900. The hill is too steep for ploughing and so has been used for grazing first by sheep and more recently by cattle. However, the hillside has sufferred from overgrazing and eutrophication has caused a drastic decline in the botanical interest of the site (Doody, 1980). Before the War scrub was removed every winter, but the decline in the agricultural workforce since then means this practice is no longer continued. It is not clear when the quarry was abandoned, but Spencer (1976) suggests it was abandoned at least 100 years ago.

2.5.3 Management

The grassland has been grazed by horses, under a management agreement in 1985 stipulating no application of fertilisers and the continuation of grazing. However, in January 1992 there were no signs of grazing and the grassland was quite rank (English Nature, 1992). Scrub was removed and burnt in 1987 and 1988. The hillside still appears to be dominated by *Rubus* spp. and *Ulex* scrub, but many calcicoles are still present.

2.6 Thrislington Plantation (NZ 315328)

2.6.1 Description

Thrislington Plantation is the finest and largest (25.9 hectares) area of Magnesian Limestone grassland in Great Britain (Ratcliffe, 1977). It was designated an SSSI in 1962 and has since been awarded National Nature Reserve status. There are substantial areas of *Sesleria* grassland and a small area of deciduous woodland, mainly larch. The grassland has one of the only lowland records for the montane species *Antennaria dioica* (photograph 10), and large stands of the rare *Linum anglicum* and *Epipactis atrorubens* (photographs 11-13). As with all the grassland sites, Thrislington is susceptible to scrub encroachment by *Crataegus monogyna, Viburnum opulus, Rosa pimpinellifola, Betula* spp. and *Prunus spinosa* (photographs14 &15).

Photograph 10: Mountain Everlasting (*Antennaria dioica*) at Thrislington

Photograph 11: Perennial flax (*Linum perenne* ssp. *anglicum*) at Thrislington

Photograph 12: Perennial flax and rock rose (*Helianthemum nummularium*) at Thrislington

Photograph 13: Dark red helleborine (*Epipactis atrorubens*) at Thrislington

Photographs 14 and 15: *Sesleria albicans* grassland and scrub invasion at Thrislington

2.6.2 History

Before 1850 Thrislington was rough pasture, probably grazed by cattle, sheep and possibly ponies. In the 1850 the whole of the original site was planted with larch, to be clear felled in World War I. A few larch remain at the southern end of the site. The grassland was used for grazing of cattle and pit ponies up to approximately 1965. Since then, there has been no management until 1982, apart from unofficial grazing by horses, so scrub invasion was quite severe. There was some grazing by rabbits, and the scrub was cut back by frequent fires. The northern part of the grassland, which was of prime importance, was transplanted to a quarried floor on the western edge of the present grassland when Steetley Quarries were granted permission to extend their quarrying operations in 1982.

2.6.3 Management

Scrub is cut annually, and the larger stumps are treated with herbicide. The site is grazed by sheep from April to October, the sheep being moved from compartment to compartment to help prevent scrub regeneration (photograph 16). The transplanted area is being monitored by English Nature to discover if any species were lost during transplantation.

Photograph 16: Sheep grazing at Thrislington

2.7 Cassop Vale (NZ 336386)

2.7.1 Description

Cassop Vale is a large and varied SSSI, supporting calcareous grassland, acidic grassland, scrub, woodland, fen and flush communities, as well as a pond. It was first notified as an SSSI in 1958, with a revision of the site boundaries in 1985. Of a total 40.9 hectares, 5.7 are calcareous grassland (photograph 17). Most of this semi-natural grassland is on the hillside west of the road, but there are also species-rich abandoned quarries. Only the primary areas were surveyed in this investigation. Much of the *Sesleria* grassland on the hillside is being invaded by scrub, principally gorse (*Ulex europaeus*) (photograph 18). Cassop Vale SSSI is regarded as second only to Thrislington in importance for conservation (Ratcliffe, 1977), although there has been a loss in area of the calcicolous grasslands due to the lack of grazing (Nature Conservancy Council, 1984).

2.7.2 History

The upper slopes of the Vale have been grazed for centuries (Spencer, 1976). The grassland has been encroached by agriculture, with the south facing slopes being cleared of scrub and ploughed up in 1975. The quarry on the south slope was abandoned in the 19th century, whereas the quarry on the north slope was worked a little longer.

2.7.3 Management

Cassop Vale is grazed by both cattle and sheep from April to October. Scrub is also cut on a yearly basis, and large stumps are treated with herbicide. There is no treatment of the small stumps, especially gorse because it is hoped that regeneration will be controlled by grazing (J. Barrett, 1993 *pers. comm.*).

Photograph 17: Acid grassland (foreground) and calcareous grassland (background) at Cassop Vale

Photograph 18: Gorse (*Ulex europaeus*) and *Brachypodium sylvaticum* at Cassop Vale

CHAPTER 3
MATERIALS AND METHODS

3.1 Sampling of vegetation

The methodology of the National Vegatation Classification was employed throughout this investigation. Each site was first explored on foot to distinguish the main vegetation types. Stands of a homogeneous vegetation type were selected by eye and the position of the sample to be taken was selected as objectively as possible. If the stand was quite large the sample was taken in the middle, to avoid edge effects, but in a mosaic homogeneous stands could be small and hence nearly all the stand had to be sampled. Ground flora was sampled using 2m x 2m quadrats, an area generally regarded as sufficient to be representative of grassland communites (Shimwell, 1971; Mueller-Dombois & Ellenburg, 1974; Rodwell, 1992). Between early May and early July, 161 such samples were taken, distributed fairly evenly between the 7 sites.

Every vascular plant and bryophyte in the quadrat was identified. Vascular plants were mainly identified in the field using Clapham *et al.* (1981), but bryophytes were brought to the lab for microscopic examination and were identified using Watson (1968) and Smith (1978; 1990). Both vascular plants and bryophytes were identified to species wherever possible, although *Festuca rubra* and *Festuca ovina* could not be reliably distinguished early in the season and sometimes vegetative violets (probably *Viola riviniana* or *V. odorata*) were recorded as *Viola* sp.. Some bryophytes such as *Weissia* spp. and *Bryum* spp. could not be identified to species, due to the lack of capsules. A few liverworts such as *Cephaloziella* sp. were also identified to genus. Apomictic species with numerous microspecies such as *Rosa canina* and *Rubus fruticosus* were identified to the aggregate. *Hieracia* were always recorded as '*Hieracium* indeterminate'. Species abundance was quantified using the Domin Scale.

Table 3.1 The Domin Scale of abundance

1	1 - 2 individuals
2	scattered
3	frequent
4	4 - 10%
5	11 - 25%
6	26 - 33%
7	34 - 50%
8	51 - 75%
9	76 - 90%
10	91 - 100%

Scrub vegetation was surveyed using 10m x 10m quadrats. Each shrub taller than 0.5 m was identified and its height measured. A 2m x 2m ground flora sample was always taken in the middle of the larger quadrat. Nomenclature of higher plants follows Clapham *et al.* 1987 (except *Chamaenerion angustifolium*, which is referred to as *Epilobium angustifolium*). Bryophyte nomenclature follows Smith, 1978 and 1990.

3.2 Environmental measurements

For each quadrat, soil depth was measured with an auger, and its appearance noted, especially the position of any horizons. A sample of the top 5cm of soil was also taken for pH analysis in the laboratory. Other enviromental variables measured were the percentage of bare ground and slope (flat, gentle, steep or vertical).

Soil pH was measured as soon as possible after the sample was taken, although keeping the samples refrigerated limits the extent to which the pH might change. Plant material was removed from each sample before mixing the soil with an approximately equal volume of distilled water. The pH was measured using a portable glass electrode pH meter (Bibby model SMP1)

3.3. Multivariate Analysis

3.3.1 TWINSPAN (Two-way indicator species analysis)

Classification of the species data was carried out using TWINSPAN, a program incorporated in VESPAN (Malloch, 1988). This is a polythetic divisive technique (i.e it divides the samples in a 'top-down' manner, based on overall similarities rather than differences). It works by classifying the samples, the results of which are used to classify the species according to their ecological preferences (Hill, 1979a). The presence or absence of a species is considered more important in classification than slight variatons in quantity (Mueller-Dombois & Ellenburg, 1974), so instead of being truly quantitative, TWINSPAN substitutes species with 'pseudospecies' which denote different abundance values. Pseudospecies cut levels are selected, which divide the Domin scale into segments. Five cut levels were chosen in this investigation - 0, 3, 4, 5 and 7.

Individuals are first ordered along a principal axis by the process of reciprocal averaging. Ordering the data considerably reduces the time taken to classify the data (from thousands of years to a matter of minutes!). Indicator species are those which show a clear preference for one side of the division over the other, although perfect indicators are rare. The best 5 indicators are emphasised to polarise the samples and the division is made near the middle of the principal axis. This process is repeated on each resultant group until no further division is possible. In this way a classificational hierarchy is formed. When the hierarchy is examined, sensible end groups of similar samples can be distinguished. These end groups are then compared with NVC communities using 'Match' (Malloch, 1992)

3.3.2 DECORANA (Detrended correspondence analysis)

DECORANA is an eigenvector ordination technique which extracts the principal axes of variation within the data set (Hill, 1979b). Although based on reciprocal averaging, it has been refined to correct the problems of arch distortion and compression of the ends of the axes (Hill & Gauch, 1980). An ordination diagram is produced, in which similar species or samples are close together and dissimilar ones are apart.

3.3.3. CANOCO (Canonical Correspondence Analysis)

This technique is a combination of ordination and multiple regression (Ter Braak, 1988) It attempts to explain variation in floristic composition by ordination axes that are constrained to be linear combinations of environmental factors. It assumes a response model common to all species and the presence of a single set of environmental gradients to which all the species respond.

The results of the analysis are displayed as an environmental biplot in which the species/samples are ordinated and the environmental variables are represented as arrows, the length and direction of which indicate the degree of contribution to the principal axes.

When used in conjunction with DCA (detrended correspondence analysis) CCA can indicate the importance of the environmental variables that were measured. In other words, the principal axes of variation displayed by DCA may not correspond with the variables chosen. When the solutions of the two analyses are similar, the measured environmental variables must be responsible for the main variation in the species/samples data. When the solutions are different, however, the variables may account for less obvious directions of variation in the data, or perhaps none at all if correlations are small (Ter Braak, 1986).

CHAPTER 4
RESULTS

4.1 Classification of communities

Since the aim of this investigation is to elucidate the effects of scrub and other environmental factors on community composition, as well as differences between primary and secondary grasslands, the communities have been divided down further than they would be if this was a purely phytosociological investigation. In this way, small scale changes in community composition can be seen. Table 4.1 details the main features of the 9 end groups generated by TWINSPAN. Phytosociological tables are presented in appendix 2.

Table 4.1 Summary of communities and sub-communities

Community/sub-community (code used in analyses)	number of releves	mean pH (range)	mean soil depth (cm) (range)	mean scrub density/10 m^2 (N)	mean % bare ground (N)
Sesleria albicans grassland	63	7.76 (7.4-8.0)	13.38 (2 -38)	-	-
a) *Avenula pratensis* sub-community (AP)	37	7.72 (7.4-8.4)	14.42 (4 -32)	-	-
b) *Bromus erectus* sub-community (BE)	11	7.68 (7.6-.7.9)	15.45 (13 -22)	50 (1)	-
c) *Hieracium pilosella* sub-commmunity (HP)	15	7.90 (7.4-8.2)	9.07 (2 -28)	35 (1)	25.33 (3)
Briza media grassland (BM)	54	8.00 (7.0-8.5)	7.39 (2 -16)	61 (1)	20.43 (30)
Crataegus monogyna scrub	32	7.82 (7.5-8.3)	14.03 (4 -33)	41.80 (20)	-
a) *Dactylis glomerata - Briza media* sub-community (DG)	20	7.84 (7.5-8.3)	11.60 (4 -20)	24.33 (9)	-
b) *Brachypodium sylvaticum* sub-community (BS)	12	7.81 (7.5-8.0)	18.08 (4 -33)	56.10 (11)	-
***Holcus lanatus* grassland** (HL)	5	7.76 (7.6-8.0)	14.60 (7 -25)	14 (3)	-
***Rubus fruticosus* scrub** (RF)	4	7.83 (7.7-8.0)	9.75 (7 -14)	62 (1)	5 (1)
***Festuca rubra* grassland** (FR)	3	7.87 (7.8-8.0)	12.00 (10 -14)	-	-

4.1.1 *Sesleria albicans* grassland

Constant species: *Carex flacca, Sesleria albicans, Lotus corniculatus, Briza media, Festuca ovina, Sanguisorba minor, Plantago lanceolata, Centaurea nigra, Helianthemum nummularium, Ctenidium molluscum.*

Indicator species: *Sesleria albicans, Sanguisorba minor, Helianthemum nummularium, Pseudoscleropodium purum.*

Sesleria albicans is usually dominant in the sward, but is frequently accompanied by the grasses *Briza media* and *Festuca ovina*, as well as *Avenula pratensis* and *Bromus erectus. Avenula pubescens* only achieves a constancy of I, as does *Koeleria macrantha*, although the latter is a constant in the equivalent NVC community CG8 (*Sesleria albicans - Scabiosa columbaria grassland*). *Festuca ovina* and *Carex flacca* are sometimes co-dominant with *Sesleria*, although *Sesleria* sometimes becomes so tussocky that it excludes some of the smaller species, especially bryophytes. When *Sesleria* is not so vigorous the herbaceous flora is both abundant and varied, including legumes such as *Lotus corniculatus, Trifolium* spp. and *Medicago lupulina*; chamaephytes such as *Thymus praecox arcticus* and *Helianthemum nummularium* and rosette species including *Plantago lanceolata, P. media, Succisa pratensis* and *Hieracium pilosella*. Rare species other than *Sesleria* found in this community are *Epipactis atrorubens, Linum perenne anglicum* and *Antennaria dioica*. Scrub encroachment seems to be fairly ubiquitous, with *Crataegus monogyna* and *Fraxinus excelsior* seedlings attaining constancies of III and II respectively.

Within the 63 samples classified as *Sesleria albicans* grassland, 3 sub-communities have been distinguished. Table 4.2 summarises the constancies of the component species in the parent community and the sub-communities. This community has a 63% correlation with the NVC community CG8 (*Sesleria albicans- Scabiosa coloumbaria*) and also agrees well with Shimwell's association *Seslerio-Helictotrichetum* of the alliance *Seslerio-Mesobromion.* However, some species which were frequent in CG8 and in *Seslerio-Helictotrichetum* were not found to be constant in this investigation, including *Koeleria macrantha, Centaurea scabiosa, Thymus praecox arcticus, Avenula pubescens, Gentianella amarella, Galium verum* and *Anthyllis vulneraria*. However, *Pseudoscleropodium purum, Ctenidium molluscum, Calliergon cuspidatum* and *Listera ovata* are more constant than recorded by the NVC. Furthermore, some species recorded in this study were not recorded in CG8 at all: *Heracleum sphondylium, Eurynchium praelongum, Fissidens taxifolius, Dactylorhiza fuchsii, Brachythecium rutabulum, Fragaria vesca* and seedlings of *Crataegus monogyna* and *Fraxinus excelsior.* The only constant species in CG8 not to be recorded here is *Carex caryophyllea*. These discrepancies are to be expected due to the subjective nature of vegetation survey and the three vegetation types can be considered synonymous.

4.1.1.1 *Avenula pratensis* sub-community

Constant species: *Carex flacca, Briza media, Lotus corniculatus, Plantago lanceolata, Festuca ovina, Sesleria albicans, Sanguisorba minor, Helianthemum nummularium, Polygala vulgaris, Avenula pratensis, Centaurea nigra, Scabiosa columbaria.*

Indicator species: *Festuca ovina, Avenula pratensis.*

This sub-community has been distinguished on the basis of its indicator *Avenula pratensis* which reaches a constancy of IV, compared to III in the main community. *Polygala vulgaris, Scabiosa columbaria* and *Pseudoscleropodium purum* also become more constant. In addition, *Festuca rubra* is more frequent than in the main community and *Crataegus monogyna* and *Fraxinus excelsior* seedlings are common, although records for shrubs above 0.5 m tall are scarce. Notable in this sub-community is the high percentage cover achieved by *Linum perenne anglicum* in releves 121, 124 and 137. These samples were taken at Thrislington, which is the only site to support a colony of this species. Relevé 138 also comes from Thrislington, and has the only record for *Antennaria dioica* along with other open herbs such as *Epipactis atrorubens, Thymus praecox arcticus* and *Gentianella amarella. Antennaria dioica* reaches its lowland limit in County Durham and is more common in Upper Teesdale. It is an example of one of the northern montane species that are found on the Magnesian Limestone and is confined to the more humid north and west facing slopes (Shimwell, 1968). Shimwelll described an *Antennaria* variant of the sub-association *Caricetosum pulicariae*, where *Carex pulicilaris* is co-dominant with *Sesleria.* This sedge was not found in this relevé, but may well have been present nearby.

Although *Bromus erectus* only has a constancy of II, it reaches very high percentage cover in some of the relevés, for example, 128 and 129. Relevés 112 and 113 are affected by gorse (*Ulex europaeus*) and bramble (*Rubus fruticosus* agg.), but still support most of the herbaceous calcicoles along with *Sesleria.*

This community is developed on fairly shallow soils as well as the slightly deeper soils at Thrislington. The shallow soils are found on the hillsides of Pittington and Cassop Vale, where soils are maintained in an 'immature' state by downslope creep and possibly erosion. The shallowest soil is only 4 cm at Pittington, whereas the deepest of 32 cm is at Thrislington. The soil pH varies between 7.4 and 8.4, with a mean of 7.72.

Table 4.2 Summary of *Sesleria albicans* grassland community and sub-communities

Species	Main	a	b	c
Carex flacca	V	V	V	V
Sesleria albicans	V	V	V	V
Lotus corniculatus	V	V	V	V
Briza media	V	V	IV	IV
Festuca ovina	IV	V	V	III
Sanguisorba minor	IV	V	II	IV
Ctenidium molluscum	IV	III	V	V
Plantago lanceolata	IV	V	III	II
Centaurea nigra	IV	IV	IV	III
Helianthemum nummularium	IV	IV	-	V
Campanula rotundifolia	III	III	V	IV
Succisa pratensis	III	III	IV	III
Pseudoscleropodium purum	III	IV	IV	III
Leontodon hispidus	III	III	IV	III
Polygala vulgaris	III	IV	II	II
Crataegus monogyna (g)	III	III	IV	II
Linum catharticum	III	III	V	II
Pimpinella saxifraga	III	III	IV	II
Avenula pratensis	III	IV	II	I
Scabiosa columbaria	III	IV	-	III
Calliergon cuspidatum	III	III	IV	II
Listera ovata	III	II	V	I
Bromus erectus	II	II	IV	II
Thymus praecox arcticus	II	III	-	III
Trifolium pratense	II	III	I	II
Festuca rubra	II	III	I	I
Plantago media	II	III	-	II
Brachypodium sylvaticum	II	II	III	I
Primula veris	II	II	I	II
Prunella vulgaris	II	II	II	II
Fissidens taxifolius	II	II	III	I
Achillea millefolium	II	III	-	I
Hieracium 'indeterminate'	II	I	III	IV
Fraxinus excelsior (g)	II	III	I	IV
Dactylorhiza fuchsii	II	II	-	IV
Gymnadenia conopsea	II	I	III	III
Campylium chrysophyllum	II	I	II	IV
Plagiomnium undulatum	II	III	I	I
Dactylis glomerata	II	III	I	I
Hieracium pilosella group	II	I	-	V
Viola seedling/sp	II	I	V	I
Viola hirta	II	II	II	-
Galium verum	II	II	I	I
Heracleum sphondylium	II	I	IV	I
Brachythecium rutabulum	II	II	III	I
Fragaria vesca	II	II	II	I
Eurhynchium praelongum	II	II	III	-
Anthyllis vulneraria	I	II	-	I
Stachys officinalis	I	I	IV	-
Koeleria macrantha	I	II	I	I
Trifolium medium	I	II	-	-
Vicia cracca	I	II	-	I
Viola riviniana	I	II	-	I
Centaurea scabiosa	I	II	I	I
Ulex europaeus (g)	I	I	II	-
Taraxacum seedling/sp	I	II	-	I
Avenula pubescens	I	I	III	I
Hypericum pulchrum	I	I	II	I
Rosa canina (g)	I	I	I	I
Rhytidiadelphus squarrosus	I	II	-	-
Rubus fruticosus agg.	I	I	I	-
Danthonia decumbens	I	I	I	I
Cerastium fontanum triviale	I	I	-	-
Epipactis atrorubens	I	I	-	II
Euphrasia officinalis agg	I	I	-	I
Festuca pratensis	I	I	-	I
Lathyrus pratensis	I	I	-	I
Potentilla erecta	I	-	-	-
Ulex europaeus (s)	I	I	I	I
Barbula recurvirostra	I	I	-	-
Fissidens cristatus	I	I	I	I
Plagiomnium rostratum	I	I	I	-
Thuidium tamariscinum	I	I	I	-
Crataegus monogyna (s)	I	I	I	I
Festuca ovina/rubra	I	-	-	-

Knautia arvensis	I	I	-	I
Trifolium repens	I	I	-	-
Corylus avellana (g)	I	I	-	-
Rubus fruticosus agg (g)	I	I	I	-
Cirsium sp	I	I	I	-
Angelica sylvestris	I	I	I	-
Bellis perennis	I	I	-	I
Carlina vulgaris	I	I	-	I
Centaurium erythraea	I	I	-	I
Epilobium angustifolium	I	-	-	I
Equisetum arvense	I	I	-	-
Linum perenne anglicum	I	I	-	-
Medicago lupulina	I	-	-	I
Molinia caerulea	I	-	II	-
Potentilla reptans	I	I	-	I
Senecio jacobaea	I	I	-	-
Barbula fallax	I	I	I	-
Brachythecium velutinum	I	I	-	-
Encalypta streptocarpa	I	-	-	I
Salix caprea (g)	I	-	-	I
Agrimonia eupatoria	I	I	-	-
Agrostis stolonifera	I	I	-	-
Cirsium vulgare	I	I	-	-
Daucus carota	I	I	-	I
Festuca gigantea	I	I	-	-
Gentianella amarella	I	I	-	I
Holcus lanatus	I	I	-	-
Plantago maritima	I	I	-	I
Ranunculus bulbosus	I	I	-	-
Rhinanthus minor	I	I	-	-
Salix caprea (s)	I	-	-	I
Trisetum flavescens	I	I	-	-
Veronica officinalis	I	II	-	-
Barbula hornschuchiana	I	I	I	-
Encalypta vulgaris	I	-	-	I
Eurhynchium striatum	I	-	I	I
Eurhynchium swartzii	I	I	-	-
Fissidens adianthoides	I	I	-	I
Betula pubescens (g)	I	-	-	I
Betula pendula (g)	I	-	-	I
Quercus robur (g)	I	I	-	-
Viburnum lantana (s)	I	-	-	I
Weissia sp	I	I	I	-
Dactylorhiza sp.	I	-	-	-
Elymus repens	I	I	-	-
Agrostis capillaris	I	-	-	I
Antennaria dioica	I	-	-	I
Arabidopsis thaliana	I	I	-	-
Arabis hirsuta	I	I	-	-
Arrhenatherum elatius	I	-	I	-
Leucanthemum vulgare	I	-	-	I
Cirsium arvense	I	-	-	I
Cirsium palustre	I	-	I	-
Conopodium majus	I	I	-	-
Deschampsia cespitosa	I	-	I	-
Epilobium montanum	I	-	I	-
Filipendula ulmaria	I	-	I	-
Hypericum perforatum	I	-	I	I
Hypochoeris radicata	I	-	-	I
Ononis repens	I	-	-	I
Potentilla sterilis	I	I	-	-
Pteridium aquilinum	I	-	I	-
Reseda lutea	I	-	I	-
Rosa canina agg.	I	-	I	-
Rosa pimpinellifolia	I	I	-	I
Salix aurita	I	-	-	-
Tragopogon pratensis	I	I	I	-
Tussilago farfara	I	-	I	-
Veronica chamaedrys	I	I	-	-
Brachythecium glareosum	I	-	-	I
Campylium stellatum	I	-	I	-
Acer pseudoplatanus (s)	I	-	-	I
Acer pseudoplatanus (g)	I	-	I	I
Betula pubescens (s)	I	-	-	I
Betula pendula (s)	I	-	I	I
Fraxinus excelsior (s)	I	-	I	-
Alchemilla vulgaris agg	I	-	-	I
Bryum sp	I	I	-	-
Ulmus minor (s)	I	-	-	I
Seligeria sp.	I	-	I	-

a = *Avenula pratensis* sub-community
b = *Bromus erectus* sub-community
c = *Hieracium pilosella* sub-community

These relevés are all closed swards of primary grassland at Cassop Vale, Pittington Hill and Thrislington. There is a very good correlation with the NVC community CG8 (coefficient = 67.9%), but it does not agree so well with any of the sub-communities described by the NVC. It has similarities with CG2, *Avenula pratensis-Festuca ovina* grassland, but the frequency of Sesleria prevents them being synonymous. This sub-community is most similar to Shimwell's (1968) sub-association Typicum of the association *Seslerio-Helictotrichetum* (alliance *Mesobromion erecti*, sub-alliance *Seslerio-Mesobromion*).

4.1.1.2 *Bromus erectus* sub-community

Constant species: *Sesleria albicans, Ctenidium molluscum, Campanula rotundifolia, Carex flacca, Festuca ovina, Linum catharticum, Listera ovata, Lotus corniculatus, Viola* seedling/sp., *Briza media, Bromus erectus, Centaurea nigra, Succisa pratensis, Crataegus monogyna* seedling, *Stachys officinalis, Heracelum sphondylium Leontodon hispidus, Pimpinella saxifraga, Calliergon cuspidatum, Pseudoscleropodium purum.*

Indicator species: No indicators generated by TWINSPAN.

There are so many constant species in this sub-community because there are only 11 samples, all from the same site (Raisby Hill Grassland), so it is not expected to find a huge amount of variation. Only *Sesleria albicans* and *Ctenidium molluscum* occur in all the samples. This sub-community differs from the main *Sesleria* community by the high constancy of *Bromus erectus*, a coarse grass which is frequently co-dominant with *Sesleria*. It reaches its northern limit of distribution in county Durham and tends to be confined to south-facing slopes, although Raisby Hill has a north-west aspect. There are large populations of *Listera ovata* and *Stachys officinalis* on Raisby Hill grassland, so these species become constant in this sub-community. The therophytes *Linum catharticum* and *Campanula rotundifolia* are also more frequent than in the main community or the neighbouring sub-communities. not a therophyte

It is of note that *Molinia caerulea* achieves high percentage cover in some of the relevés. These are flushed areas towards the the foot of the hill, near the marshy area. The absence of *Helianthemum nummularium* is another obvious difference from the main community and the other sub-communities. These differences highlight the considerable amount of inter-site variation and that all sites have their own peculiarities.

The constancy of IV for *Crataegus mongyna* seedlings indicates the hillside is in the early stages of hawthorn invasion, although the vegetation seems to be maintaining its limestone grassland identity. However, the constancies (III) of *Brachypodium sylvaticum*, a grass usually associated with woodland and *Eurynchium praelongum*, a moss tending to prefer shady habitats under rank grassland or scrub/trees suggest some impact on the open vegetation. Only one of the relevés appeared to be directly influenced by scrub when recording. The 10m^2 quadrat accompanying relevé 68 was occupied by 50 shrubs, mostly *Ulex europaeus* and *Crataegus monogyna. Acer pseudoplatanus* and *Fraxinus excelsior* were also present. This relevé has the only records at this site for *Reseda lutea, Thuidium tamariscinum, Rosa canina* and *Dactylis glomerata.*

The highest correlation that 'Match' generated was 52.5% with CG8. Although *Sesleria* is still constant, the frequency of *Bromus erectus* and the presence of species such as *Molinia caerulea, Angelica sylvestris* and *Potentilla erecta*, among others, mean that this vegetation demonstrates considerable differences from CG8. The abundance of *Bromus erectus* implies similarities with CG3, *Bromus erectus* grassland, although southern species characteristic of this community such as *Cirsium acaule* and *Hippocrepis comosa* were not recorded at all in this survey. This sub-community does not agree closely with any of Shimwell's associations. It appears to be most similar to the *Bromus erectus* variant of the *Helictotrichon pubescens* sub-association (association *Seslerio-Helictotrichetum*), although the characteristic species of this variant, *Avenula pubescens, Dactylis glomerata* and *Daucus carota* do not achieve constancy in the sub-community described here. It also has affinities with association *Helictotricho-Caricetum flaccae* in the sub-alliance *Eu-Mesobromion.* However, one of the outstanding features of this association is the absence of *Sesleria*, so the two cannot be considered identical. Despite this major difference, Shimwell did record this association on the coastal side of the Magnesian Limestone. The *Bromus erectus* sub-community of *Sesleria* grassland could perhaps be the 'interface' of *Helictotricho-Caricetum flaccae* and *Seslerio-Helictotrichetum.*

4.1.1.3 *Hieracium pilosella* sub-community

Constant species: *Hieracium pilosella, Carex flacca, Lotus corniculatus, Sesleria albicans, Helianthemum nummularium, Ctenidium molluscum, Hieracium* sp., *Briza media, Dactylorhiza fuchsii, Sanguisorba minor, Campylium chrysophyllum.*

Indicator species*:* *Hieracium pilosella, Helianthemum nummularium*

This sub-community is generally found on shallow soils with a high pH (see table 4.1). Soils range from a skeletal 2cm at Trimdon to 28 cm at Bishop Middleham. Soil pH is higher than the other *Sesleria* sub-communities, with a mean of 7.90.

Herbaceous species, especially those characteristic of open habitats such as *Hieracium pilosella, Hieracium* sp., *Campanula rotundifolia* and *Dactylorhiza fuchsii* all achieve high constancies. The only grass to achieve a high percentage cover is *Sesleria albicans. Briza* *media* is also constant, althogh not at high cover, often interspersed with *Festuca ovina.* Other calcicoles of open habitats such as *Thymus praecox arcticus* and *Scabiosa columbaria* reach constancies of III. Orchids become very frequent and even abundant in this open vegetation; *Dactylorhiza fuchsii, Gymnadenia conopsea, Epipactis atrorubens* and *Listera ovata* are all represented here. Although no acrocarpous mosses themselves attain constancy, if *Encalypta streptocarpa, E. vulgaris, Barbula recurvirostra,* and *B.fallax* are taken together, an overall constancy of III is achieved.

All the relevés in this sub-community are secondary grasslands, mostly from Bishop Middleham. Relevé 36 was taken from an area of willow scrub (dominated by *Salix caprea*) of a density of 35 shrubs per $10m^2$, but there does not seem to be any invasion of the herbs such as *Heracleum sphondylium* or *Cirsium* spp., or even *Brachpodium sylvaticum* which tend to be associated with scrub invasion. The "typical" limestone grassland community appears to surviving quite well under the willow.

This sub-community has a very high correlation with the *Centaurea nigra* sub-community of the NVC's *Bromus erectus* grassland community CG3 (correlation = 63.5%), but on closer inspection there is very little similarity. Despite the high percentage cover of *Bromus erectus* in some of the relevés (27, 50, 61 and 77), it achieves a constancy of only II, compared to V in the NVC. Moreover, *Sesleria* is completely absent from CG3, yet has a constancy of V in this sub-community. The high constancies of species characteristic of open habitats suggest similarities with the *Hieracium pilosella* sub-community of CG8 and the *Encalypta vulgaris-Plantago maritima* sub-association of Shimwell (1968) and seems to bare little resemblance to rank *Bromus erectus*-dominated grassland. However, *Plantago maritima* only occurs once in this sub-community, in relevé 102, a sample taken at Pittington quarry. It is not found at all at Trimdon or Bishop Middleham.

4.1.2 *Briza media* grassland

Constant species: *Briza media, Carex flacca, Lotus corniculatus, Centaurea nigra, Leontodon hispidus, Hieracium pilosella, Plantago lanceolata*

Indicator species: *Lotus corniculatus, Hieracium pilosella, Briza media*

The remaining 54 samples after the first division represent a communty characterised and often dominated by quaking grass, *Briza media.* Other grasses are not so frequent, but herbaceous species and the sedge *Carex flacca* are common. *Hieracium pilosella* often attains dominance on steep quarrry walls or spoil heaps, where it can grow on the dry infertile substrate. Again, if the acrocarpous mosses are taken as a whole, they attain a constancy of III. This implies that acrocarps are early colonisers, which is to be expected, but the precise species that happens to colonise is more a matter of chance. It is of note that *H. nummularium* is not as frequent as in the *Hieracium pilosella* sub-community of *Sesleria albicans* grassland. Although *Sesleria* does not attain a high constancy in this community, it is not excluded. It occurs in relevés 48, 103, 108 and 109. Relevé 48 is situated on the quarry floor at Bishop Middleham, and the others are from the edge of Pittington quarry. These are examples of where *Sesleria* has colonised the quarry floor from a local seed source. *Epipactis atrorubens* occurs in this community, but is restricted to the quarry floors at Bishop Middleham and Raisby. Near the pond at Wingate are the only occurrences of *Pinguicula vulgaris,* a predominately wetland species with a northern distribution. The only individual of *Ophrys apifera* was found on the quarry floor at Bishop Middleham, very near an area of *Salix* scrub. The pyramidal orchid *Anacamptis pyramidalis* was also observed near here, but it did not occur in any of the relevés.

All the relevés are from abandoned quarries, and this community seems to be characteristic of newly exposed ground, since 30 of the 54 samples have some percentage of bare ground. The most sparsely colonised has 85% bare ground. The soil pH is generally very high, with a mean 8.01, varying between 7.0 and 8.5. The soils tend to be skeletal, the shallowest is only 2cm deep.

Most of the species reaching high constancy in this vegetation type appear to be colonisers of bare ground, such as *Hieracium* sp., *Thymus praecox arcticus, Carlina vulgaris* and *Centaurium erythrea.* It is interesting to note that apart from these small species, there are also tall grasses and herbs, including *Dactylis glomerata* and *Heracleum sphondylium.* Moreover, *Crataegus monogyna* seedlings achieve a constancy of IV, indicating that neither soil development or ground vegetation are essential for the establishment of scrub seedlings. It seems that newly exposed ground provides opportunities for colonisation by many species, including shrubs. Indeed, one of the relevés of this community is in the middle of a moderately dense area of scrub dominated by *Salix caprea.* Bishop Middleham is unusual in that it is being invaded by *Salix* scrub rather than by *Crataegus.* The other sample taken under *Salix* scrub has been classified in the *Hieracium pilosella* sub-community of *Sesleria albicans* grassland. Thus it seems that, at least at these densities, *Salix* has had little influence on the ground flora.

This community does not agree well with any of the communites distinguished either by the NVC or Shimwell (1968). It is most closely correlated (58.9%) with CG2 *Avenula pratensis-Festuca ovina* grassland but *Festuca ovina* and *A. pratensis* only reach constancies of II and I respectively. It has a correlation coefficient of 58.6% with CG3 *Bromus erectus* grassland, but

"..this community comprises all those swards in which *Bromus erectus* makes up more than 10% of the cover" (Rodwell, 1992), so the two communities are really very different.

4.1.3 *Crataegus monogyna* scrub

Constant species: *Crataegus monogyna* sapling, *Plantago lanceolata, Calliergon cuspidatum, Centaurea nigra, Dactylis glomerata, Lotus corniculatus, Heracleum sphondylium, Leontodon hispidus, Primula veris, Briza media, Festuca rubra, Fragaria vesca, Rubus fruticosus* agg.

Indicators: *Leontodon hispidus, Calliergon cuspidatum.*

This scrub community is a transitional stage between grassland and *Fraxinus* woodland, which is the climax vegetation on the Magnesian Limestone (Tansley, 1911; Doody, 1980). Many of the calcicoles remain, but they are accompanied by many species associated with rough grassland or scrub such as *Vicia cracca*, *Dactylis glomerata, Veronica* spp., *Elymus repens, Arrenatherum elatius, Convolvulus arvensis* and *Cruciata laevipes.*

This vegetation type has developed on both deep and shallow soils. Skeletal soils do not prevent the development of some scrub cover, as can be seen at Trimdon, where *Rubus fruticosus* agg. and *Crataegus monogyna* are established on only 4cm of soil. The pH of these soils remains high, with a mean of 7.82. Of the 32 relevés within this community, 20 were recorded with $10m^2$ scrub quadrats, others may not be directly under a cover of scrub, but may be influenced by nearby scrub or the presence of a scrub cover in the past.

"Match" generates a 58.3% correlation with CG3 *Bromus erectus* grassland. However, indicative of this community is a high constancy of *Bromus erectus*, which clearly isn't the case here. This community may be expected to have affinities with the NVC community W21, *Crataegus monogyna-Hedera helix* scrub (Rodwell, 1991), but the calcicoles are still frequent under the scrub, accompanied by shade-tolerant and more mesotrophic species. Shimwell (1968) classified the scrub vegetation of the Magnesian Limestone as *Crataegus-Rosa pimpinellifolia* association of the alliance *Prunion fruticosae* (Order *Prunetalia*). The classification of scrub communities is not an easy task because they are transitional stages and may have been cut or burnt in the past, meaning there is a mixture of species of open habitats and shade tolerant species.

This community has been divided into two subcommunites, the first characterised by a ground layer dominated by the grasses *Dactylis glomerata* and *Briza media* and the second by *Brachypodium sylvaticum*, often accompanied by *Rubus fruticosus* agg. under the hawthorn shrubs. These communities are summarised in table 4.3.

Table 4.3 Summary of *Crataegus monogyna* scrub sub-communities

	Species	Main	a	b
973	Plantago lanceolata	V	V	V
1445	Calliergon cuspidatum	V	V	V
371	Centaurea nigra	IV	V	IV
445	Crataegus monogyna (s)	IV	IV	V
465	Dactylis glomerata	IV	V	IV
800	Lotus corniculatus	IV	V	IV
661	Heracleum sphondylium	IV	IV	IV
769	Leontodon hispidus	IV	IV	IV
1056	Primula veris	IV	IV	IV
251	Briza media	IV	IV	III
576	Festuca rubra	IV	III	IV
587	Fragaria vesca	IV	IV	IV
1136	Rubus fruticosus agg.	IV	III	V
323	Carex flacca	III	III	V
247	Brachypodium sylvaticum	III	II	V
1059	Prunella vulgaris	III	III	III
372	Centaurea scabiosa	III	III	II
2982	Taraxacum seedling/sp	III	III	III
1411	Vicia cracca	III	II	III
1122	Rosa canina agg.	III	II	IV
758	Lathyrus pratensis	II	III	I
104	Achillea millefolium	II	II	II
743	Knautia arvensis	II	II	II
1677	Eurhynchium praelongum	II	I	IV
675	Hieracium 'indeterminate'	II	II	II
844	Medicago lupulina	II	III	-
968	Pimpinella saxifraga	II	II	III
1349	Trifolium pratense	II	II	II
1360	Tussilago farfara	II	II	III
1429	Viola riviniana	II	I	III
1600	Ctenidium molluscum	II	II	II
1807	Plagiomnium undulatum	II	I	III
2999	Viola seedling/sp	II	II	III
575	Festuca pratensis	II	I	III
655	Avenula pratensis	II	II	I
965	Hieracium pilosella group	II	III	-
1053	Sanguisorba minor	II	I	III
1305	Succisa pratensis	II	II	I
1914	Pseudoscleropodium purum	II	I	IV
256	Bromus erectus	II	I	II
391	Epilobium angustifolium	II	II	-
475	Daucus carota	II	II	I
656	Avenula pubescens	II	II	-
1519	Brachythecium rutabulum	II	I	II
2614	Fraxinus excelsior (s)	II	I	III
788	Listera ovata	II	I	III
995	Polygala vulgaris	II	I	II
1239	Senecio jacobaea	II	II	I
1396	Veronica chamaedrys	II	I	II
1423	Viola hirta	II	-	III
1695	Fissidens taxifolius	II	I	II
466	Dactylorhiza fuchsii	I	II	-
579	Festuca ovina/rubra (vegetativ	I	II	-
1205	Scabiosa columbaria	I	I	I
1401	Veronica officinalis	I	I	II
118	Elymus repens	I	I	II
288	Campanula rotundifolia	I	I	-
403	Leucanthemum vulgare	I	I	I
574	Festuca ovina	I	-	I
680	Holcus lanatus	I	I	I
786	Linum catharticum	I	I	II
1050	Potentilla reptans	I	I	II
1363	Ulex europaeus (s)	I	I	II
2611	Crataegus monogyna (g)	I	I	II
197	Arrhenatherum elatius	I	I	I
706	Hypochoeris radicata	I	I	I
1245	Sesleria albicans	I	-	II
1333	Thymus praecox arcticus	I	I	-
167	Angelica sylvestris	I	I	I
174	Anthyllis vulneraria	I	I	I
230	Bellis perennis	I	I	I
415	Cirsium arvense	I	-	II

455	Cruciata laevipes	I	I	I
633	Geum rivale	I	-	II
702	Hypericum pulchrum	I	-	II
746	Koeleria macrantha	I	I	I
1522	Brachythecium velutinum	I	I	-
1940	Rhytidiadelphus squarrosus	I	I	I
113	Agrimonia eupatoria	I	-	II
234	Stachys officinalis	I	I	I
418	Cirsium palustre	I	-	I
477	Deschampsia cespitosa cespitos	I	-	I
583	Filipendula ulmaria	I	-	I
654	Helianthemum nummularium	I	I	I
981	Poa annua	I	-	I
988	Poa pratensis	I	I	-
1086	Ranunculus bulbosus	I	I	I
1124	Rosa rubiginosa agg.	I	I	-
1339	Tragopogon pratensis	I	I	-
1416	Vicia sepium	I	I	-
1566	Campylium chrysophyllum	I	I	I
1682	Eurhynchium swartzii	I	-	I
3065	Weissia sp	I	-	I
384	Cerastium fontanum triviale	I	-	I
433	Convolvulus arvensis	I	I	I
460	Cynosurus cristatus	I	I	-
528	Epipactis atrorubens	I	-	I
613	Galium verum	I	I	I
649	Gymnadenia conopsea	I	I	-
876	Molinia caerulea	I	I	I
920	Orchis mascula	I	-	I
976	Plantago media	I	I	-
1081	Ranunculus acris	I	-	I
1095	Ranunculus repens	I	I	I
1139	Rumex acetosa	I	I	I
1147	Rumex obtusifolius	I	I	-
1191	Sanicula europaea	I	I	-
1244	Serratula tinctoria	I	-	I
1272	Sonchus asper	I	-	I
1293	Stachys sylvatica	I	I	-
1346	Trifolium medium	I	-	I
1350	Trifolium repens	I	-	I
1356	Trisetum flavescens	I	I	-
1409	Viburnum opulus	I	I	-
1513	Brachythecium glareosum	I	-	I
1514	Brachythecium mildeanum	I	-	I
1562	Homalothecium lutescens	I	-	I
1688	Fissidens cristatus	I	I	-
1795	Plagiomnium rostratum	I	-	I
1801	Rhizomnium punctatum	I	I	-
2003	Thuidium tamariscinum	I	-	I
2232	Jungermannia hyalina	I	-	I
2600	Acer pseudoplatanus (s)	I	-	I
2606	Betula pendula (s)	I	-	I
2625	Quercus petraea (s)	I	-	I
2735	Ranunculus seedling/sp	I	-	I
2746	Rosa seedling/sp	I	I	-
2754	Rosa canina (g)	I	I	-
2760	Rubus fruticosus agg (g)	I	I	I
2822	Cirsium sp	I	-	I
2954	Rosa rubiginosa	I	I	I
2997	Viburnum lantana (s)	I	I	-

a = Dactylis glomerata/Briza media sub-community
b = Brachypodium sylvaticum sub-community

4.1.3.1 *Dactylis glomerata-Briza media* sub community

Constant species: *Plantago lanceolata, Calliergon cuspidatum, Centaurea nigra, Dactylis glomerata, Lotus corniculatus, Briza media, Heracleum sphondylium, Leontodon hispidus, Crataegus monogyna* sapling, *Primula veris, Fragaria vesca.*

Indicator Species: None generated by TWINSPAN

The grasses *Dactylis glomerata* and *Briza media* are constant and of high percentage cover in this sub-community. *Avenula pratensis* and *Festuca ovina* attain a high percentage cover in some of the relevés. The frequency of a few herbaceous species more characteristic of open habitats suggest more open vegetation than the *Brachypodium sylvaticum* sub-community. Of the 20 relevés classified in this sub-community, only 9 were accompanied by a measurement of scrub density. The mean density is less than the neighbouring sub-community, 24.33 shrubs per $10m^2$ as opposed to 56.10. The maximum heights of scrub recorded for these relevés is quite variable, with a minimum of 1.4m and a maximum of 4m (mean maximum height = 3.52m). The maximum density of scrub was recorded for relevé 92, with 31 individuals per $10m^2$, dominated by *Crataegus*. It is interesting to note that all the relevés except 118 (Pittington hillside) were recorded in secondary grasslands. The high constancy of *Briza media* suggests this may be be the next stage in the succession from *Briza media* grassland, a community only developed in abandoned quarrries.

'Match' generates a good correlation of 60.8% with CG3 *Bromus erectus* grassland, but *B. erectus* has a constancy of only I and never occurs at high percentage cover, so there is very little similarity. Neither are there any similarities with the vegetation types described by Shimwell (1968).

4.1.3.2 *Brachypodium sylvaticum* sub-community

Constant species: *Brachypodium sylvaticum, Plantago lanceolata, Carex flacca, Crataegus monogyna* sapling, *Rubus fruticosus* agg., *Calliergon cuspidatum, Festuca rubra, Primula veris, Eurynchium praelongum, Centaurea nigra, Dactylis glomerata, Fragaria vesaca, Heracleum sphondylium, Leontodon hispidus, Lotus corniculatus, Rosa canina agg., Pseudoscleropodium purum.*

Indicator species*:* *Brachypodium sylvaticum, Eurynchium praelongum, Pseudoscleropodium purum, Festuca rubra, Viola hirta.*

This vegetation type differs from the neighbouring *Dactylis glomerata-Briza media* sub-community by the increased frequency of *B. sylvaticum* and *Rubus fruticosus* agg. *Rosa canina* agg, *Eurynchium praelongum, Pseudoscleropodium purum* and *Carex flacca* are also more constant. Most of the relevés in this sub-community are influenced by scrub - 11 of the

13 samples were taken at the middle of a $10m^2$ scrub quadrat. The mean number of scrub individuals counted in these quadrats is 56.1, varying between 26 and 97. The maximum heights of the scrub varies between 0.7 and 3.5m, with a mean of 2.41m. The low scrub of only 0.7m high was dominated by *Ulex*, which had a moderately high density of 50 bushes per $10m^2$, but probably has more of an effect on the flora due to its dense shade and spreading growth form. The 2 relevés without scrub cover were in an area of recent scrub clearance at Thrislington.

Despite the constancy of scrub species and their associated ground flora, low-growing calcicoles such as *Carex flacca* and *Lotus corniculatus* are not excluded. *Epipactis atrorubens* only occurs in relevé 143, a dense area of Crataegus and Fraxinus scrub (97 shrubs /$10m^{2)}$, where it is accompanied by *Brachypodium sylvaticum*, *Heracleum sphondylium* and *Cirsium* spp. *Sesleria* occurs in relevés 123 and 153. The first is an area of low scattered *Rosa canina/Crataegus* scrub and the second is dominated by *Brachypodium sylvaticum* and exhibits evidence of recent scrub removal.

Most of the relevés in this sub-community are from primary grassland, except 65, 66 and 95, which are samples from Raisby and Wingate. The highest correlation coefficient generated by 'Match' is 52.3% with CG3, *Bromus erectus* grassland, but *B. erectus* is not frequent enough here for the two vegetation types to be considered synonymous. Moreover, the whole physiognomy of the two are different, with the sub-community here supporting several woody species as well as shade-tolerant and mesotrophic herbs, lending an extremely rank and scrubby appearance to the vegetation. The southern species of CG3 are also absent. The lack of synonymy of this sub-community with any other is due to the transitional nature of the vegetation, with small calcicoles and vigorous herbs and grasses co-existing under the scrub.

4.1.4 *Holcus lanatus* grassland

Constant species: *Dactylis glomerata, Festuca rubra, Holcus lanatus, Plantago lanceolata, Brachythecium rutabulum, Achillea millefolium, Centaurea nigra, Cerastium fontanum* ssp. *triviale, Heracleum sphondylium, Poa annua, Veronica chamaedrys.*

Indicator species*: Poa annua*

There are only 5 samples in this rank grassland community, characteristic of apparently more mesotrophic areas of Bishop Middleham, Pittington and Wingate quarries. Eutrophication may have been caused by over-grazing or tipping. It is suspected that tipping is the cause of nutrient input at Bishop Middleham and Wingate, whereas overgrazing may be a factor at Pittington.

Three of the relevés are affected by *Crataegus* scrub, but the density of scrub cover is low (14 individuals/ 10m^2) so this is termed a grassland community rather than a scrub community. Because there are so few samples, the mean soil depth and pH are not very meaningful, although it can be seen that the pH remains high. Species common in the *Sesleria albicans* and *Briza media* grasslands such as *Lotus corniculatus, Carex flacca* and *Scabiosa columbaria* are much less frequent here, being replaced by *Achillea millefolium, Cerastium fontanum* ssp. *triviale* and *Heracleum sphondylium*. However, there is a small amount of *Sesleria* in relevé 105, situated in Pittington quarry.

This community shows good agreement with NVC sub-community MG1e (mesotrophic) *Arrenatherum elatius* grassland, *Centaurea nigra* subcommunity (correlation coefficient = 62.7%). *Arrenatherum* is less constant in the data here than in MG1e where it achieves a constancy of V. There are other differences, but these are to be expected in such a small sample size. The community described here also has affinities with Shimwell's association *Centaureo-Arrenatheretum* (Alliance *Arrenathertum elatioris*, Class *Molinio-Arrenatheretea*), sharing most of the constant species.

4.1.5 *Rubus fruticosus* agg. scrub

Constant species (V only): *Centaurea nigra, Festuca rubra, Fragaria vesca, Galium verum, Heracleum sphondylium, Pimpinella saxifraga, Plantago lanceolata, Sanguisorba minor, Rubus fruticosus* agg.

Indicator species: *Rubus fruticosus* agg.

This community has been named a scrub community due to the constancy of *Rubus fruticosus* agg, but only one of the 3 relevés has an associated 10m^2 quadrat. This sample was taken uder a dense cover of *Prunus spinosa* and *C. monogyna* scrub, whereas the other samples were affected by a cover of brambles. When sampling, it was not deemed worthwhile to measure density of *Rubus* scrub due to the difficulties in counting individuals. Because there are only 3 relevés in this community it is difficult to make statements about community composition, but it can be seen that *Festuca rubra* is dominant, accompanied by the herbs *Plantago lanceolata*, *Heracleum sphondylium, Centaurea nigra* and *Galium verum.*

All 3 relevés were situated on Pittington Hill. This highlights again the inter-site differences that exist. In contrast to the other sites, which seem to suffer most from *Crataegus* invasion, the primary grassland at Pittington is encroached by *Rubus fruticosus* agg. to a large extent, along with some *Ulex europaeus*. This 'community' bears no resemblance to any NVC communities or Shimwell's associations. It should be regarded as an area of *Sesleria* grassland that has been over-run by brambles.

4.1.6 *Festuca rubra* grassland

Constant species (V only): *Achillea millefolium, Dactylis glomerata, Festuca rubra, Plantago lanceolata, Poa annua, Scabiosa columbaria, Trifolium pratense.*

Indicator species: *Trifolium pratense.*

The final community cannot really be considered a community in that there are only 3 relevés that have been classified together due to their dissimilarity from all the other communities. These relevés are all situated at the northern end of Pittington quarry (see appendix 1) and are possibly associated with eutrophication and/or over-grazing. Many of the calcicolous herbaceous spceies are present, but they are accompanied by *Bellis perennis, Senecio jacobea* and *Ranunculus acris. Medicago lupulina* is dominant in 2 of the relevés.

Again, due to the paucity of samples, it is not advisable to discuss community composition or to compare it to other communities. However, the suggestion that this area at Pittington has been subject to some degree of eutrophication is supported by the correlation (55.9%) of these relevés with the NVC *Galium verum* sub-community of MG5, *Cynosurus cristatus - Centaurea nigra* meadow and pasture, a community considered typical of mesotrophic calcareous soils (Rodwell, 1992).

4.2 Ordination

Table 4.4 displays the values of the eigenvalues of the four principal axes of variation extracted by DECORANA. It can be seen that the first 2 axes contribute to most of the variation (62%), whereas axes 3 and 4 only contribute a further 34% between them. Therefore only the first two axes will be considered below.

Table 4.4 Eigenvalues of the first four principal axes of variation in the floristic data

Axis	Eigenvalue
1	0.36433
2	0.25880
3	0.19274
4	0.14224

Fig. 4.1 shows a DECORANA ordination of all species along the 1st and 2nd principal axes of variation. Species codes are given in appendix 3. Species at the extremes of the axes are not important in the analysis because they were recorded very rarely in the whole survey, and so contribute little to the overall trends. Species that are towards the end of the axes but not at

the extremes are the most useful indicators of ecological gradients. Such species at the positive end of the first principal axis include *Trisetum flavescens* (1356), *Cerastium fontanum* ssp. *triviale* (384), *Tragopogon pratensis* (1339), *Cirsium arvense* (415), and saplings of *Crataegus monogyna* (445), *Rosa canina* agg. (1122) and *Fraxinus excelsior* (2614).

These species occur in both primary and secondary grasslands and are species of rough grassland and scrub / woodland. They occur most frequently in the scrub and mesotrophic grassland communities, demonstrated in Fig. 4.2 by the corresponding positions of communities HL (*Holcus lanatus* grassland), DG (*Dactylis glomerata-Briza media* sub-community of *Crategus monogyna* scrub), BS (*Brachypodium sylvaticum* sub-community of *Crataegus monogyna* scrub) and RF (*Rubus fruticosus* agg. scrub).

If the negative end of the first principal axis (P.A.) is examined, it can be seen that there are species characteristic of open dry grassland, such as *Epipactis atrorubens* (528), *Danthonia decumbens* (1249), *Antennaria dioica* (168), and *Anthyllis vulneraria* (174) as well as opportunist shrub seedlings which have colonised open vegetation, including *Salix caprea* (2631), *Viburnum lantana* (2997), *Betula pendula* (2607) and *B. pubescens* (2605). It is notable that these scrub species are restricted to the quarry floors of Bishop Middleham and Raisby which tend to have very shallow soils and areas of bare ground. These species occur most frequently in the *Sesleria albicans* grassland community (HP, AP and BE on Fig. 4.2). The *Hieracium pilosella* sub-community samples remain close to the origin in the ordination, because most of these samples are unaffected by scrub encroachment, and are very open grasslands, often sparsely colonised. The only relevé to be influenced by scrub is relevé 36, but the ground flora of this relevé appears to be very little different from the typical limestone grassland vegetation (see section 4.1.3). The *Avenula pratensis* (AP) and *Bromus erectus* (BE) sub-communities extend further along the axis, because they are taller grassland communities, and some shade-tolerant species are present. The only relevé to be under scrub cover in these two sub-communities is relevé 68, situated in scrub dominated by *Ulex* and *Crataegus* on the primary grassland at Raisby. The position of this relevé in the samples ordination (fig 4.3) is in the middle of the first principal axis, and occupies the most extreme position along this axis of relevés of this sub-community. Appendix 4 gives a brief description and situation of all the relevés.

The ecological tolerances of species along the second principal axis are less clear cut. Species at the positive end of the axis include *Pinguicula vulgaris* (970), *Bryum* sp. (2703), *Ononis repens* (914), *Erigeron acer* (543), *Hieracium pilosella* (965), *Leucanthemum vulgare* (403) *and Hypericum montanum* (700). *P. vulgaris* is a wetland species, and was recorded near the pond at Wingate Quarry, in an area dominated by *Briza media* and *Lotus* *corniculatus*. The other species are more characteristic of open dry grasslands. Species at the other end of the axis also have varied habitat preferences. *Linum perennne anglicum* (784) is a species of open grassland, whereas *Epilobium montanum* (522) tends to colonise shady and disturbed places (Grime *et al.*, 1989). *Pteridium aquilinum* (1066) is ubiquitous on moors, heaths and woodlands and *Potentilla erecta* is usually regarded as a calcifuge characteristic of moorlands. *Rosa pimpinellifolia* is a low shrub, which was only found at Thrislington. Thus this axis does not seem to be related to any physical or chemical factors. If, however, the distribution of these species within the sites is examined it can be seen that most of the species at the positive end of the second axis are confined to secondary grasslands (except *Bryum* sp.), and species restricted to primary grassland tend to lie at the opposite end of the axis. (appendix 5). This is confirmed by the ordination of samples (fig 4.2). There is a clear separation in samples classified in *Briza media* grassland (BM) and those in the *Avenula pratensis* (AP) and *Bromus erectus* (BE) sub-communities of *Sesleria albicans* grassland. There is some overlap with the *B. media* relevés and the *Hieracium pilosella* (HP) relevés, because both these vegetation types are confined to secondary grasslands. Hence the second principal axis is probably a result of whether the grassland is primary or secondary. It may also be a factor of site, because the species at the negative end of the axis only occur at Thrislington and Raisby, and are not found in the other primary grasslands at Pittington and Cassop Vale (appendix 6). The species at the positive end of the axis however, occur at most of the disused quarries, although *P. vulgaris* is confined to Wingate, *Ononis repens* to Bishop Middleham and *Erigeron acer* to Trimdon.

Fig. 4.4 shows the positions of selected species which are either indicators or constants of the communities detailed in section 4.1, or are rare or interesting species such as *Antennaria dioica, Ophrys apifera* and *Pinguicula vulgaris.* Here it can be seen that species characteristic of open grasslands occur towards the centre of the ordination, since they were most frequently recorded. These species may either be positioned at their optima in the ordination or they may be unrelated to the axes (Ter Braak, 1986). Even so, it is clear that species preferring more fertile or shady habitats are positioned along the positive extreme of the first principal axis, with the scrub species *Crataegus, Rubus* and *Ulex.* The position of *Rosa canina* agg. sapling is not displayed here because it coincides almost precisely with *Ulex.*

Species at the positive end of the second axis are not only more common in secondary grasslands, they are also characteristic of open dry grassland, such as *Centaurium erythrea* and *Thymus praecox arcticus* (Grime *et al.*, 1989). *Salix caprea* is also positioned along this second axis, occurring only at Bishop Middleham and associated with open grassland species rather than the shade tolerant/mesotrophic species that tend to occur with *Crataegus, Ulex* and *Rubus* scrub.

Fig. 4.1 Species ordination
Axis 1 v Axis 2

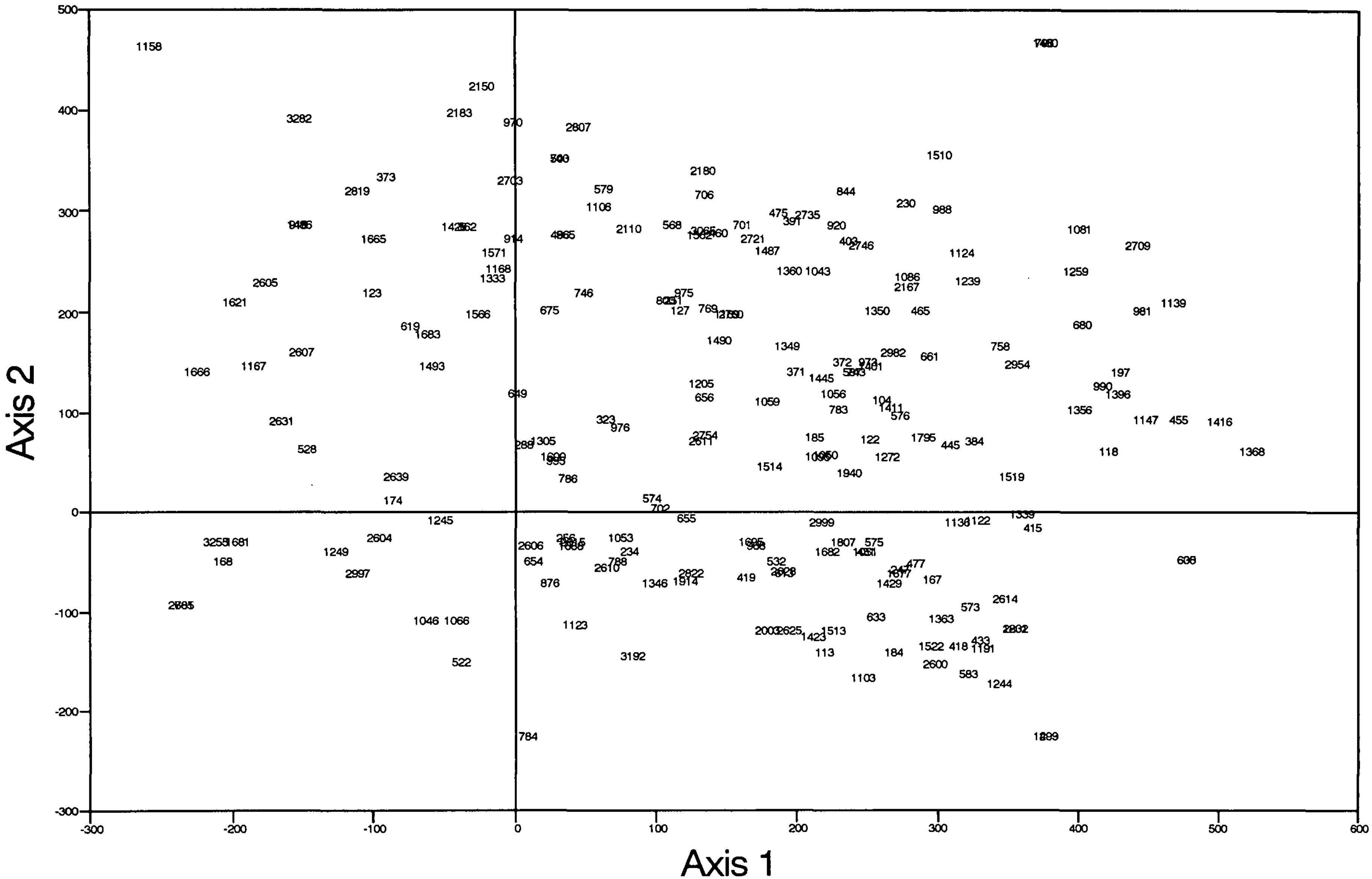


Fig 4.2 Samples ordination (codes)
Axis 1 v Axis 2

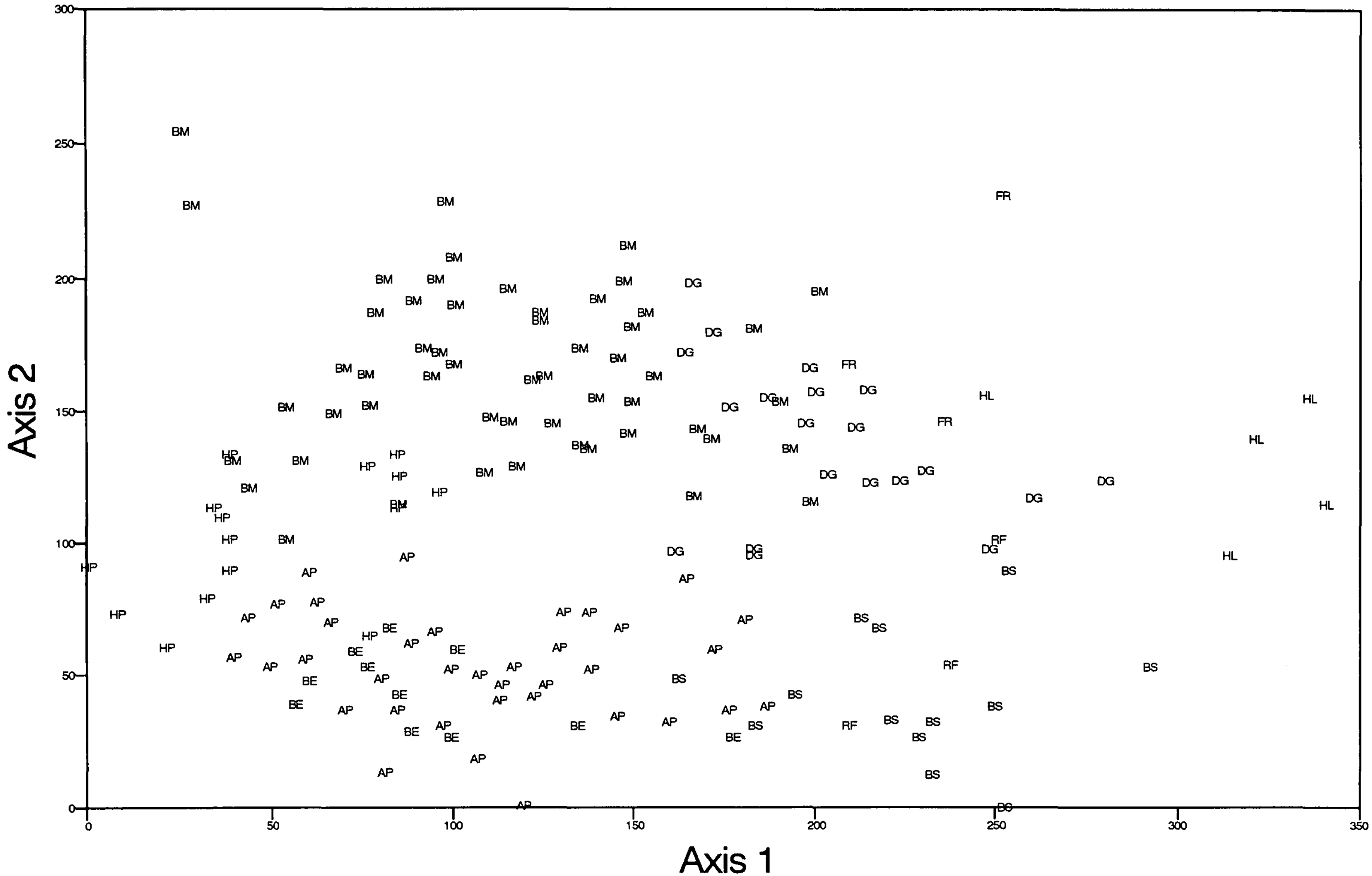
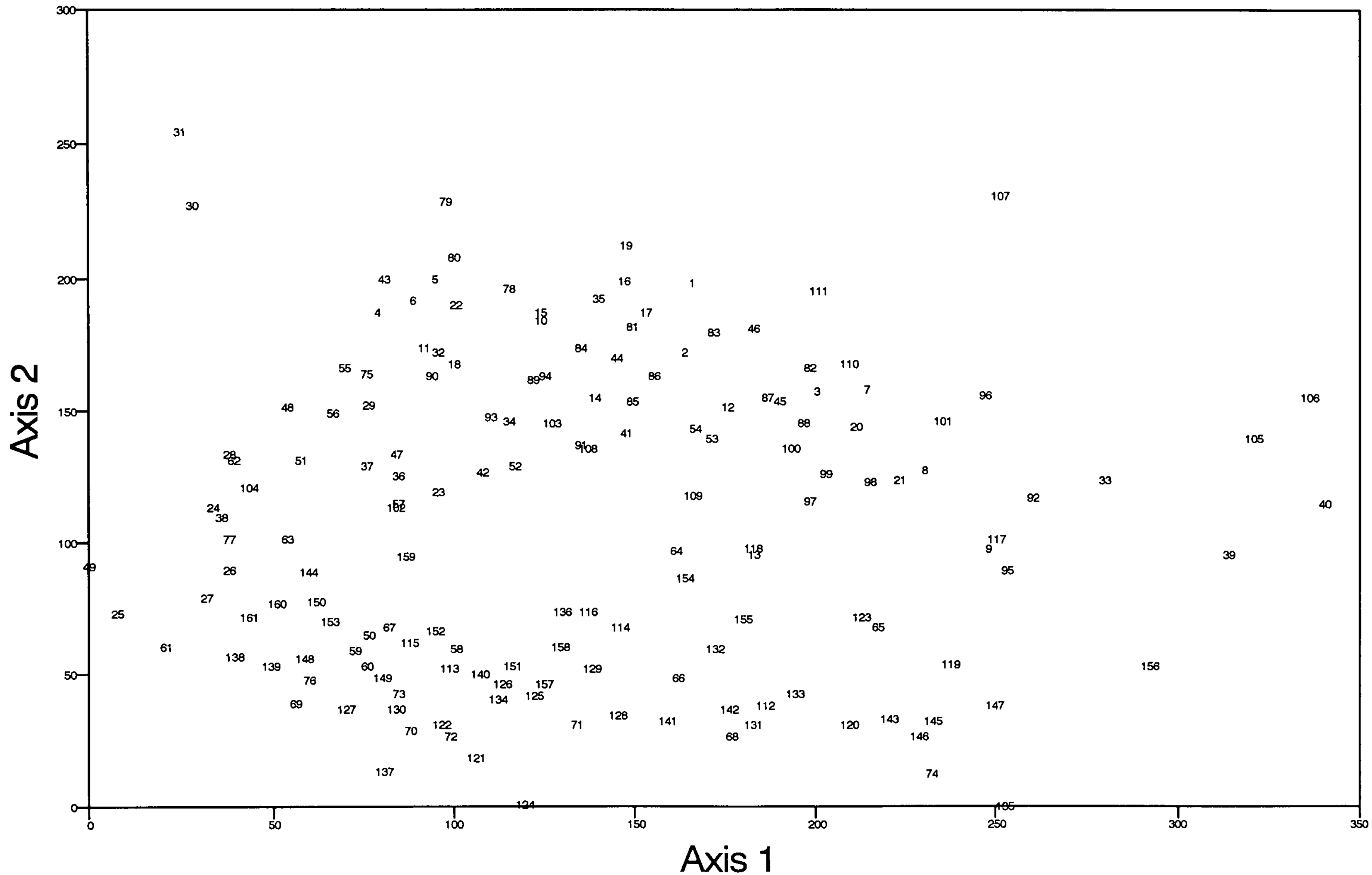


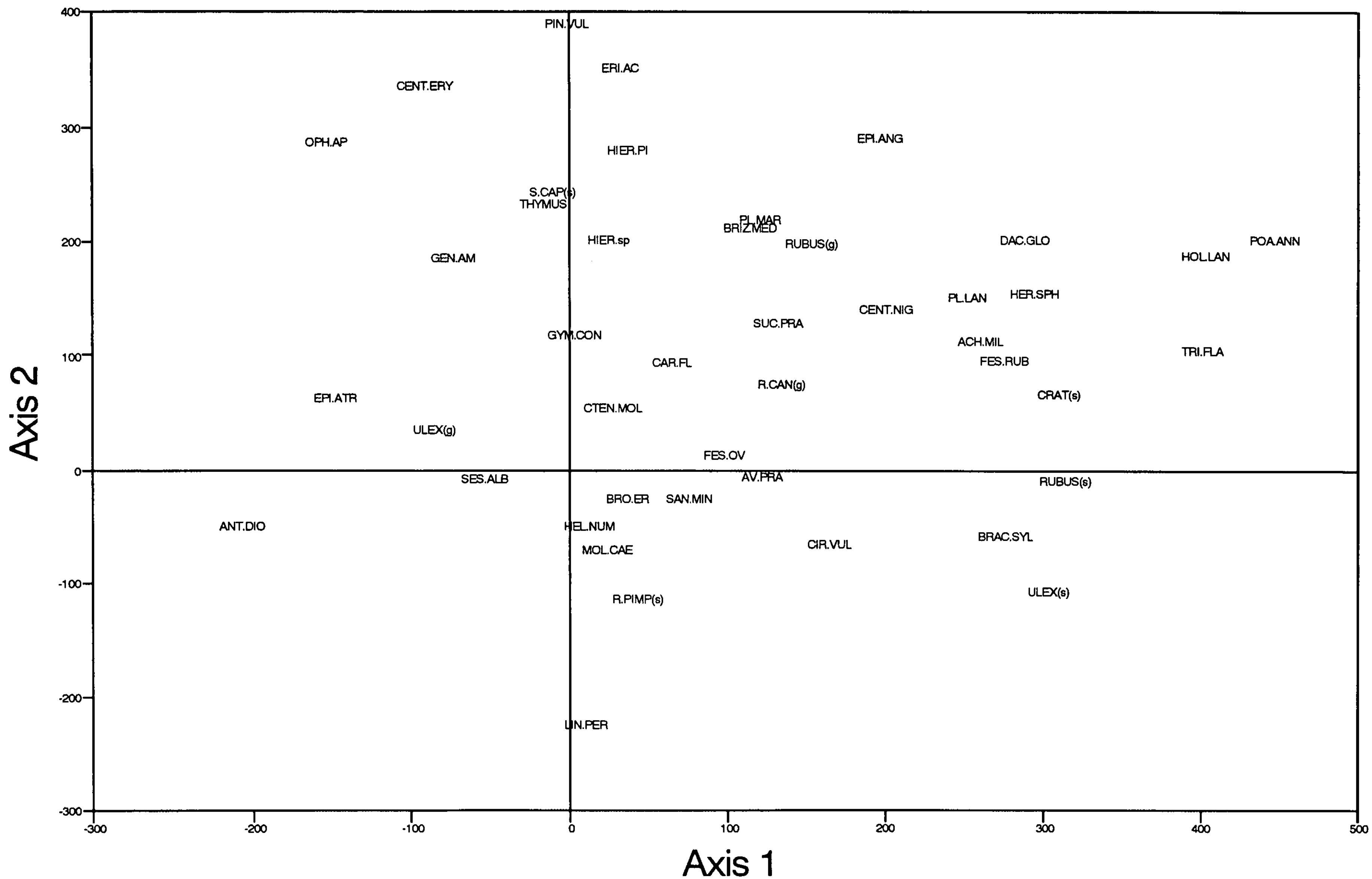
Fig 4.3 Samples ordination
Axis 1 v Axis 2



Species code key for fig. 4.4.

Code	Species	Code	Species
PIN.VUL	*Pinguicula vulgaris*	CENT.NIG	*Centaurea nigra*
ERI.AC	*Erigeron acer*	DAC.GLO	*Dactylis glomerata*
CENT.ERY	*Centaurium erythrea*	HER.SPH	*Heracleum sphondylium*
OPH.API	*Ophrys apifera*	PL.LAN	*Plantago lanceolata*
S.CAP(s)	*Salix caprea sapling*	ACH.MIL	*Achillea millefolium*
THYMUS	*Thymus praecox arcticus*	FES.RUB	*Festuca rubra*
HIER.PI	*Hieracium pilosella*	CRAT(s)	*Crataegus monogyna* sapling
HIER.sp	*Hieracium* sp.	RUBUS(s)	*Rubus fruticosus* agg. shrub
GYM.CON	*Gymnadenia conopsea*	BRAC.SYL	*Brachypodium sylvaticum*
ULEX(g)	*Ulex europaeus* (seedling)	ULEX(s)	*Ulex europaeus* shrub
EPI.ATR	*Epipactis atrorubens*	TRI.FLA	*Trisetum flavescens*
ANT.DIO	*Antennaria dioica*	HOL.LAN	*Holcus lanatus*
SES.ALB	*Sesleria albicans*	POA.ANN	*Poa annua*
HEL.NUM	*Helianthemum nummularium*		
MOL.CAE	*Molinia caerulea*		
R.PIMP(s)	*Rosa pimpinellifolia* shrub		
LIN.PER	*Linum perenne anglicum*		
BRO.ER	*Bromus erectus*		
SAN.MIN	*Sanguisorba minor*		
FES.OV	*Festuca ovina*		
CTEN.MOL	*Ctenidium molluscum*		
CAR.FL	*Carex flacca*		
R.CAN(g)	*Rosa canina* agg. seedling		
AV.PRA	*Avenula pratensis*		
CIR.VUL	*Cirsium vulgare*		
SUC.PRA	*Succisa pratensis*		
RUBUS(g)	*Rubus fruticosus* agg. seedling		
PL.MAR	*Plantago maritima*		
BRIZ.MED	*Briza media*		
EPI.ANG	*Epilobium angustifolium*		

Fig. 4.4 Selected species ordination
Axis 1 v Axis 2



Therefore it seems that the 1st axis of variation is controlled by factors of scrub density, and possibly the identity and age of the scrub species. Other factors such as soil depth, pH, percentage bare ground and nutrient status may also contribute to the variation, but may be dependent on scrub attributes or *vice versa*. The second principal axis appears to be related to whether the grassland is primary or secondary and the identity of the site may also be a contributary factor. Factors related to the successional stage and hence the age of the grassland such as bare ground and soil depth may also contribute to this axis.

4.3 Canonical Correspondence Analyis (CCA)

One CCA and 3 partial CCAs, with the effects of covariables partialled out, were performed:

CCA No variables omitted

PCCA 1 No variables omitted, sites and date as covariables

PCCA 2 All scrub variables except total scrub density omitted, sites and date as covariables

PCCA 3 Total scrub density omitted, only common scrub species variables included, sites and date as covariables

Explanations for the use of covariables and the ommission of certain variables are given below. Table 4.5 shows the eigenvalues of the 4 principal axes generated by the 4 analyses, and compares them with the eigenvalues calculated by the DCA described in section 4.2.

Table 4. 5 Eigenvalues of DCA,CCA and 3 partial CCAs

Analysis	**Axis**				**% variance accounted for by the 4 axes**
	1	2	3	4	
DCA	0.364	0.259	0.193	0.142	95.8
CCA 1	0.294	0.232	0.201	0.145	86.8
Partial CCA 1	0.271	0.165	0.132	0.115	68.3
Partial CCA 2	0.209	0.105	0.091	0.079	48.4
Partial CCA 3	0.265	0.152	0.113	0.108	63.8

4.3.1 CCA

This preliminary analysis employed all the environmental variables measured (see chapter 3), as well as the date the sample was surveyed, the total scrub density and the nominal variables of site identity and whether the site was primary or secondary. In addition, the number of individuals in $10m^2$ and the mean and maximum heights of each scrub species found in the survey were included in the analysis. The scrub species found in the survey are:

Crataegus monogyna, Rosa canina agg., *R. rubiginosa* agg., *Ulex europaeus, Fraxinus excelsior, Salix caprea, Betula pendula, Salix cinerea, Acer pseudoplatanus, Ulmus glabra, Viburnum lantana, Rubus fruticosus, Rosa pimpinellifolia, Sorbus aria and Prunus spinosa.*

The eigenvalues account for a large proportion of the total variation in the data set, and agree fairly well with the DCA, except that the eigenvalue for the first canonical axis of the CCA is somewhat smaller than that of the 1st P.A. of the DCA. This implies that there is another factor contributing to the first axis which was not measured. This variable is probably some factor of soil fertility (section 4.2). However, a Monte-Carlo Permutation Test with 99 permutations performed on the 1st canonical axis calculated a value of $p = 0.01$, showing that the species are significantly related to the measured environmental variables.

The environmental biplot of this ordination is not displayed, because examination of the solution revealed that a large number of the scrub variables had very large inflation factors. These inflation factors are caused by the correlation of the variable in question with other variables, and if they are completely multi-collinear are omitted automatically by CANOCO. However, some variables with inflation factors greater than 20 were not omitted by the program. This problem of multi-collinearity means that the variable has no specific contribution to the regression equation and renders the regression (canonical) coefficients and t-values unstable so that they cannot be usefully interpreted (Ter Braak, 1986). Hence the canconical coefficients are not discussed here. However, the significance of environmental variables can be inferred from the intra-set correlations (correlation coefficients between environmental variables and the species axes). Both the mean and maximum height of *Crataegus monogyna* shrubs are significant on the 1st species axis with correlation coefficients of 0.71 and 0.70 respectively, followed by maximum height of *Rosa canina* agg. (0.65) and mean height of *R. canina* agg. (0.64). The most significant contributors to the 2nd canonical axis are 'primary' (0.80), soil depth (0.54) and date of sampling (0.53).

4.3.2 Partial CCA 1

Due to the significant contribution of date of sampling to the overall variation in the floristic data, it was decided to remove the date from the analysis as a covariable. Date of sampling has a known effect on the species which is not of interest in the interpretation. There are a number of reasons why date has an effect on the species data:

i) Sampling began in early May when some vascular plants were too small to be identified or were not evident at all, e.g. *Gentianella amarella.*

ii) The percentage cover of some species would increase more than others throughout the season.

iii) Most of the abandoned quarries were sampled before the primary grasslands, so differences between the two types of grassland may be part of the effect of date of sampling.
iv) The experience of the sampler increased as the season progressed!

Although the contribution of different sites to floristic variation is both expected and interesting in itself, it may be correlated to whether the site is primary or secondary in origin. Furthermore, some sites (Pittington and Raisby) have areas of both primary and secondary grasslands, so this complicates the interpretation of the ordination. Although each site has its own peculiarities, which are of interest, it was decided to remove the sites as covariables in order to display the variation attributable to environmental factors.

Examination of the solution of this analysis again reveals the presence of large inflation factors for many of the scrub variables. It is to be expected that such variables will be inter-correlated, because the density of all the scrub species depends on all the individual species' densities and the mean and maximum heights of the species will be related to one another. Hence the partial canonical coefficients are not worthy of interpretation and the environmental biplot of this analysis has not been reproduced here. Nevertheless, the partial correlation coefficients between the environmental variables and the species axes indicate that significant contributions to the 1st species axis were made by maximum height of *Crataegus monogyna* (partial correlation coefficient = 0.77), mean height of *C. mongyna* (0.76), maximum height of *Rosa canina* agg. (0.69), mean height of *R. canina* (0.66) and number of *C. monogyna* in 10m^2 (0.62). The number of *Ulex europaeus* bushes in 10m^2 is significant on the 2nd species axis. Furthermore, the Monte-Carlo Permutation Test with 99 permutations performed on the 1st canonical axis calculated a value of $p = 0.01$, showing that the species are significantly related to the measured environmental variables.

4.3.3. Partial CCA 2

This analysis omits all the scrub species variables, and only considers overall density of scrub, with the intention of deducing if a cover of scrub has an effect on the floristic variation. This removes the problem of multi-collinearity and there are no inflation factors larger than 20. The eigenvalues are lower than in the previous analyses and do not correspond well with the DCA (table 4.5). This is to be expected, however, because so many variables have been omitted and so the remaining variables are not sufficient to explain the major variation in the floristic data. However, a Monte-Carlo Permutation Test with 99 permutations performed on the 1st canonical axis calculated a value of $p = 0.01$, demonstrating a significant relationship between species scores and the chosen environmental variables.

Table 4.6 shows the partial correlation coefficients as well as the canonical coefficients and t-values, which can be interpreted in confidence now that the inflation factors have been reduced.

Table 4.6 Partial Correlation coefficients (P.C.C.), canonical coefficients (P.Ca.C.) and t-values of environmental variables

Environmental variable	Species axis 1			Species axis 2		
	P.C.C.	P.Ca.C.	t	P.C.C.	P.Ca.C.	t
Soil pH	-0.24	-0.14	-0.39	0.50	0.06	3.10
Soil depth	0.51	0.35	7.50	-0.37	-0.05	-2.00
Soil horizon depth	0.25	-0.14	-0.33	-0.15	0.02	0.70
Slope	0.01	-0.03	-0.09	-0.29	-0.06	-3.00
% bare ground	-0.19	-0.03	-0.09	0.38	0.09	5.10
'Primary'	-0.05	-0.28	-0.44	-0.64	-0.30	-8.30
Overall scrub density	0.68	0.39	12.60	0.14	0.08	4.90

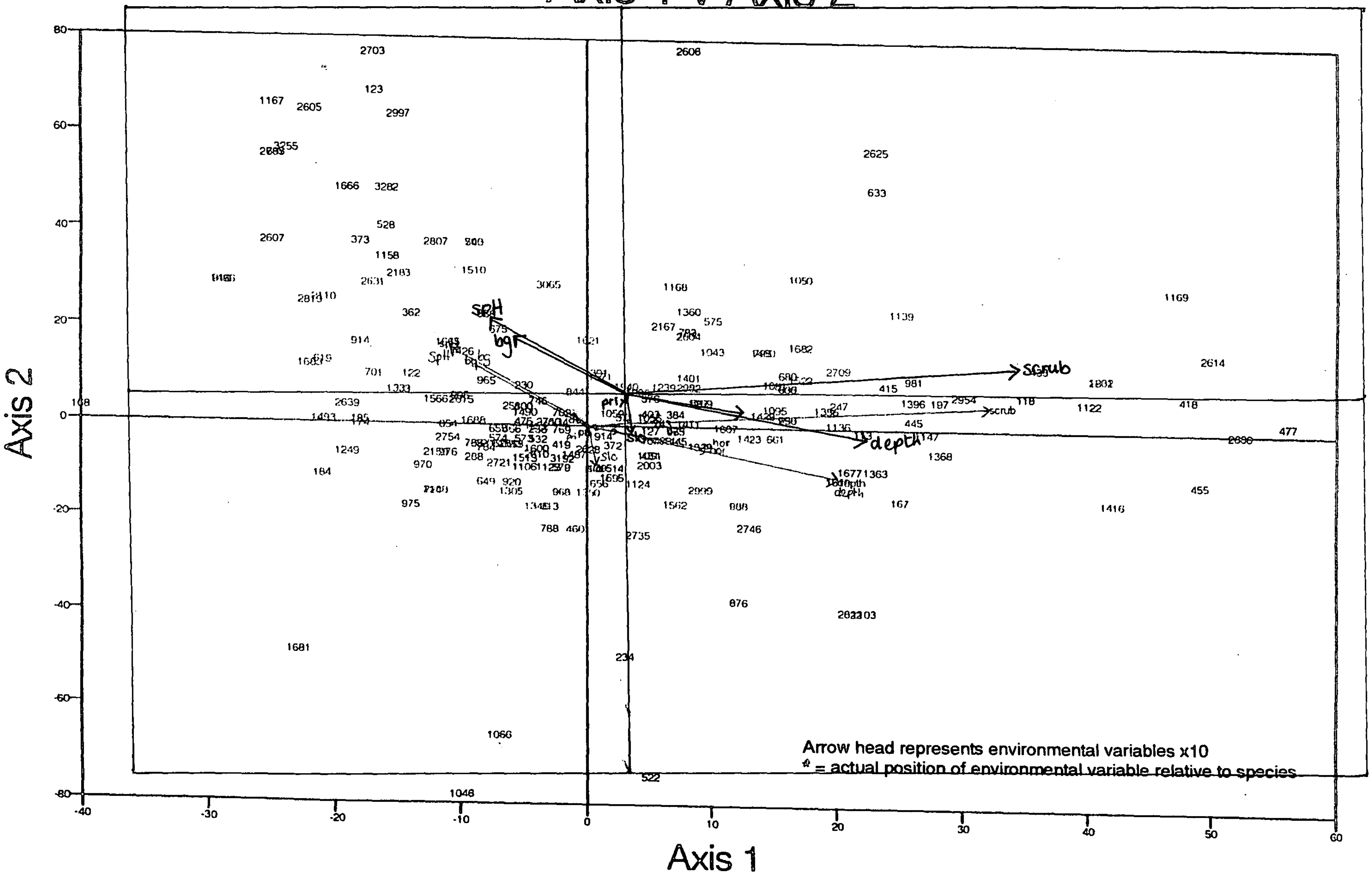
It is clear that overall scrub density and 'primary' contribute most to the 1st and 2nd axes respectively but the significance of the other variables is less obvious. Scrub density contributes most to the 1st principal axis, because it has the most significant partial correlation coefficient, partial canonical coefficient and t-value. Soil depth is the next most important variable, but may be related to scrub density. 'Primary' is the most significant in a negative direction on the 2nd canonical axis; although it's partial canonical coefficient is quite small, it is the largest of any of the variables and the t-value is high. Soil pH is the second most important contributary variable, acting in the positive direction on the 2nd axis but percentage bare ground has a larger partial canonical coefficient and t-value. The environmental biplot (fig. 4.5) suggests that the two variables have a similar magnitude and direction of effect. Both these variables have significant t-values, but the partial canonical coefficients are small.

Fig. 4.5 illustrates the ordination of the species with relation to environmental variables. For clarity the arrows of the environmental variables have been increased by a factor of 10 and some of the outlying species have been omitted from the biplot. The omitted species are *Serratula tinctoria* (1244), *Filipendula ulmaria* (583), *Sanicula europaea* (1191), *Viburnum opulus* (1409) *and Stachys sylvatica* (1293). These species were all recorded once only in the whole survey, and were associated with scrub either at Thrislington or Raisby. This biplot demonstrates the contribution of the overall scrub density (scrub) and soil depth (depth) to the 1st axis. The two factors are probably inter-related, i.e scrub is more likely to develop on a deeper soil and soil development accelerates under scrub cover due to the increased nutrient

Environmental variable key for figs. 4.5-4.8

spH	soil pH
depth	soil depth
hor	soil horizon
slo	slope
bg	percentage bare ground
scrub	scrub density (all species)

Fig.4.5 PCCA 2: Species Axis 1 v Axis 2



and litter input. The depth of the A horizon also contributes to the 1st canonical axis, although its effect is not significant. This is to be expected, since deeper soils have deeper horizons. Species associated with this axis of variation include *Deschampsia cespitosa* (477), *Cirsium palustre* (418), and saplings of *Fraxinus excelsior* (2614), *Acer pseudoplatanus* (2600) and *Rosa canina* agg. (1122).

Some indicator, constant and rare species are displayed in Fig. 4.6. The shrubs *Rubus fruticosus* agg., *Crataegus monogyna* and *Ulex europaeus* are positioned towards the positive end of the 1st axis, along with the grasses *Holcus lanatus, Brachypodium sylvaticum* and *Trisetum flavescens. H. lanatus* and *T. flavescens* occur frequently in the mesotrophic *Holcus lanatus* and *Festuca rubra* grassland communities when there is no scrub cover, so there may be an aspect of soil nutrient status also contributing to this axis. *B. sylvaticum* is also frequent when there is no scrub cover, but tends to occur in areas which have been cleared of scrub, a factor which complicates the interpretation somewhat. It is interesting to note that the seedlings of these scrub species appear to be positioned towards the other end of the axis (*C. monogyna* seedling coincides with *Rubus* seedling, so has been omitted). This suggests that scrub regeneration is ubiquitous in open grasslands. Furthermore, the species score of *Salix caprea* sapling is closer to the 2nd principal axis than it is to the 1st, reinforcing the suggestion that Salix scrub has little influence on the ground vegetation.

Fig. 4.7 is a biplot of the samples, represented by their community codes. As expected, the communities on the positive side of the 1st canonical axis are often associated with a scrub cover - *Holcus lanatus grassland* (HL), *Rubus fruticosus* agg. scrub (RF) and *Dactylis glomerata - Briza media* (DG) and *Brachypodium sylvaticum* sub-communities of *Crataegus monogyna* scrub. The relevé numbers are displayed in fig. 4.8. Relevés at the extreme of the scrub density axis are those whose ground flora is most affected by a cover of scrub. However, they are not neccesarily the relevés with the densest cover of scrub. Relevé 33, situated at Bishop Middleham, is influenced by a scrub cover of only 11 shrubs/10m^2, dominated by *C. monogyna* and *Rosa canina* agg., whereas relevé 135 is at Thrislington and is under a dense cover of 84 shrubs/10m^2 dominated by *Fraxinus excelsior.* If the axis is extended back from the origin it can be seen that communities negatively correlated with scrub density are *Briza media* grassland and the *Avenula pratensis* (AP) and *Hieracium pilosella* (HP) sub-communities of *Sesleria albicans* grassland.

Species code key for fig. 4.6.

PIN.VUL	*Pinguicula vulgaris*
ERI.AC	*Erigeron acer*
CENT.ERY	*Centaurium erythrea*
OPH.API	*Ophrys apifera*
S.CAP(s)	*Salix caprea sapling*
THYMUS	*Thymus praecox arcticus*
HIER.PI	*Hieracium pilosella*
HIER.sp	*Hieracium* sp.
ULEX(g)	*Ulex europaeus* (seedling)
EPI.ATR	*Epipactis atrorubens*
ANT.DIO	*Antennaria dioica*
SES.ALB	*Sesleria albicans*
HEL.NUM	*Helianthemum nummularium*
MOL.CAE	*Molinia caerulea*
BRO.ER	*Bromus erectus*
FES.OV	*Festuca ovina*
CTEN.MOL	*Ctenidium molluscum*
CAR.FL	*Carex flacca*
R.CAN(g)	*Rosa canina* agg. seedling
AV.PRA	*Avenula pratensis*
RUBUS(g)	*Rubus fruticosus* agg. seedling
PL.MAR	*Plantago maritima*
EPI.ANG	*Epilobium angustifolium*
CENT.NIG	*Centaurea nigra*
DAC.GLO	*Dactylis glomerata*
HER.SPH	*Heracleum sphondylium*
ACH.MIL	*Achillea millefolium*
FES.RUB	*Festuca rubra*
CRAT(s)	*Crataegus monogyna* sapling
RUBUS(s)	*Rubus fruticosus* agg. shrub
BRAC.SYL	*Brachypodium sylvaticum*
ULEX(s)	*Ulex europaeus* shrub
TRI.FLA	*Trisetum flavescens*
HOL.LAN	*Holcus lanatus*
R.CAN(s)	*Rosa canina* sapling
PS. PUR	*Pseudoscleropodium purum*

Fig. 4.6 PCCA 2: Selected species
Axis 1 v Axis 2

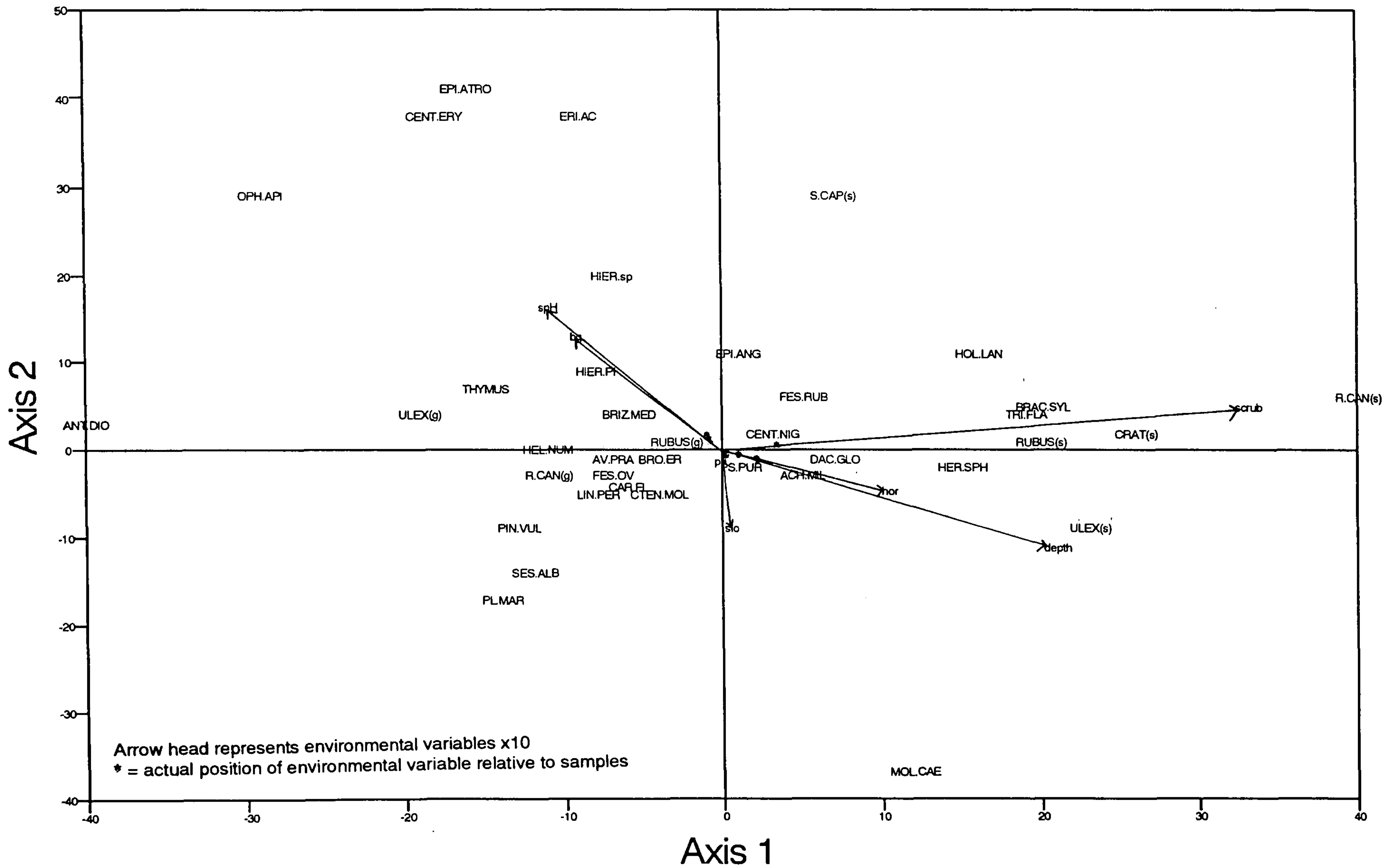


Fig. 4.7 PCCA 2: Samples (codes) Axis 1 v Axis 2

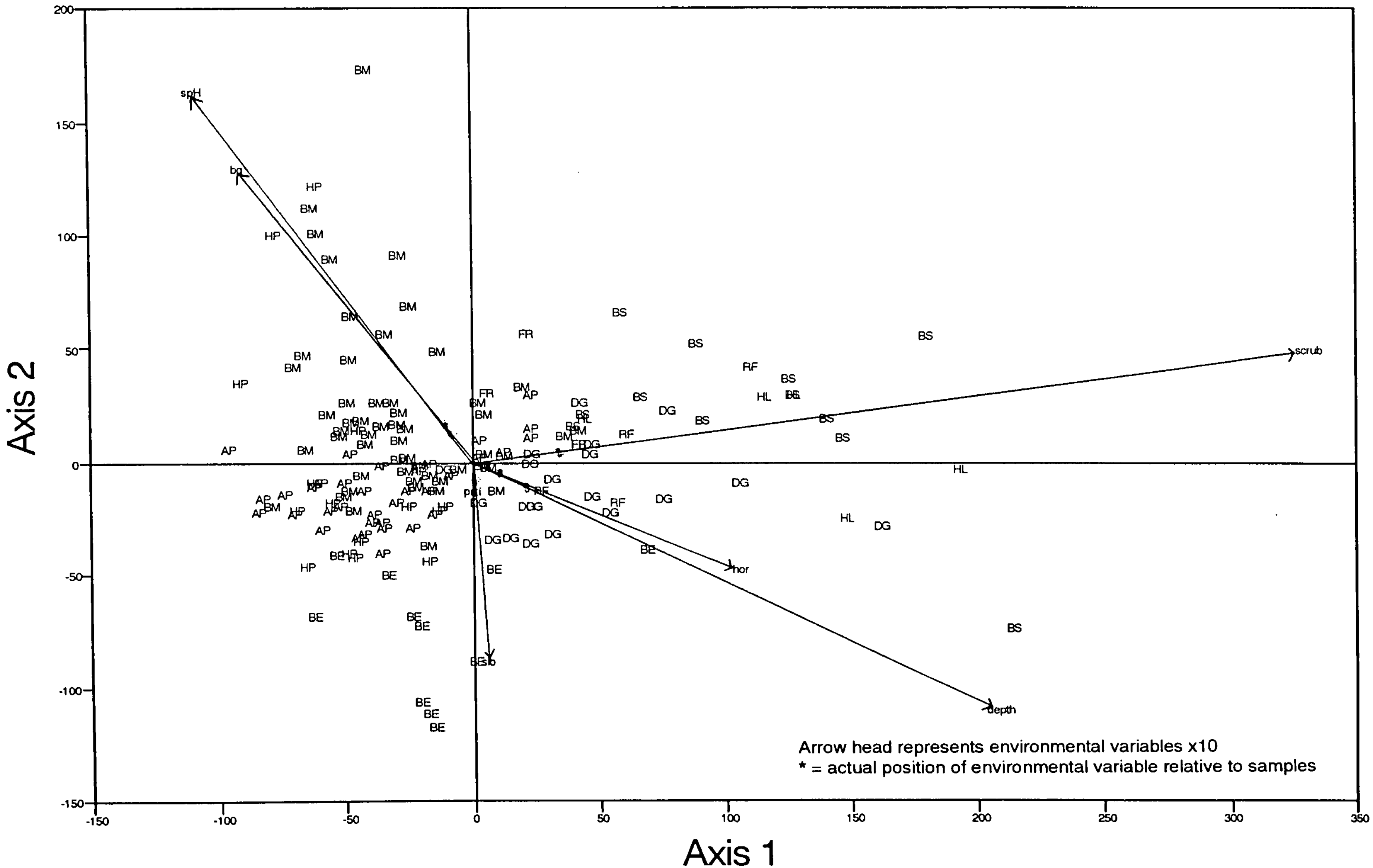
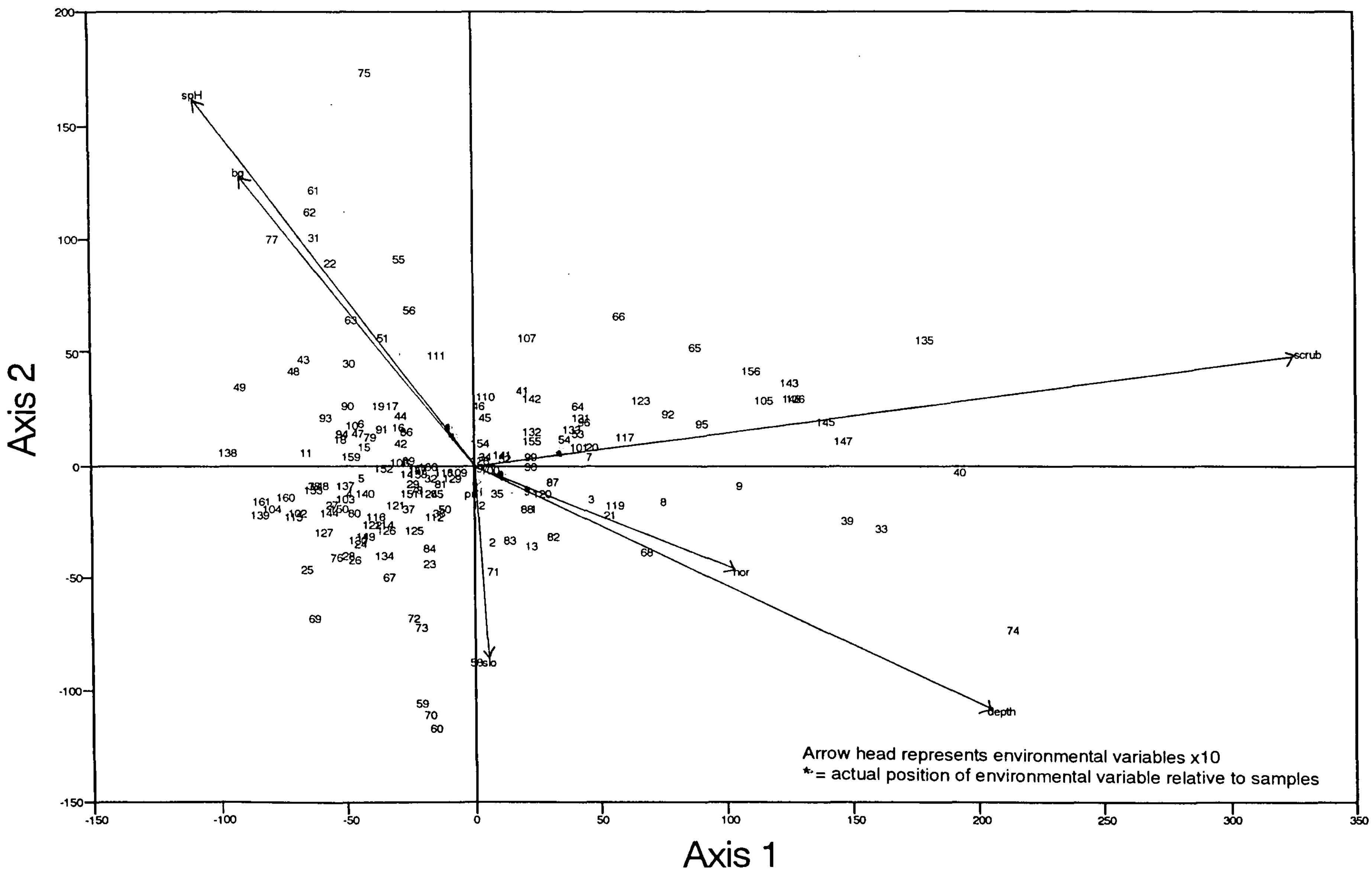


Fig. 4.8 PCCA 2: Samples
Axis 1 v Axis 2



Although the position of the nominal variable 'primary' is quite close to the centre of the ordination, it is closely correlated with the 2nd species axis. Soil pH and % bare ground are closely correlated with one another in the opposite direction. Most of the species furthest along the axis representing 'primary' are species found only at Raisby Hill grassland and occur in the *Bromus erectus* sub-community of *Sesleria albicans* grassland (BE in fig 4.7), including *Pteridium aquinilinum* (1066), *Epilobium montanum* (522) and *Potentilla erecta* (1046). Species closer to the centre of the ordination include *Pimpinella saxifraga* (968), *Avenula pubescens* (656), *Succisa pratensis* (1305) and *Trifolium repens* (1350).

Species associated with the axes of soil pH and percentage bare ground include *Hieracium pilosella* (965), *Carlina vulgaris* (362), *Euphrasia officinalis* agg (568) and *Hieracium* sp. (675). It can be seen from fig. 4.6 that the orchids *Epipactis atrorubens* and *Ophrys apifera* prefer very open vegetation and a high base status, being situated at the ends of the axes for soil pH and bare ground. The species at the positive end of the 2nd canonical axis and hence negatively associated with the nominal variable 'primary' include *Epilobium angustifolium* and *Salix caprea* sapling. These species are restricted to secondary grasslands (Appendix 5), so this relation is to be expected. *Erigeron acer* and *Hieracium* sp. are also positioned at the positive end of the axis, but may be more influenced by the pH and bare ground factors.

Fig. 4.7 shows that samples in the *Briza media* grassland community are allied with the soil pH and bare ground axes, whereas the *Bromus erectus* sub-community of *Sesleria albicans* grassland shows an association with the 'primary' grassland axis. It is of note that the *Avenula pratensis* sub-community would be expected to show a similar pattern, since all the samples in this vegetation type are of a primary origin. It seems that they are influenced to some extent by this axis but show a stronger negative correlation with scrub density. Furthermore, other communities confined to primary grasslands such as *Brachypodium sylvaticum* sub-community of *Crataegus monogyna* scrub are more strongly affiliated with the scrub axis than with the 'primary' axis. This implies that the ordination of species and samples is more heavily dependent on the influence of scrub density rather than if the site is primary or secondary. This is refelected in the markedly different eigenvalues for these two axes (table 4.5).

4.3.4 Partial CCA 3

Now that it has been confirmed that scrub density has an influence on community composition, this analysis aims to determine which scrub species has most effect and whether the changes in the ground flora are more dependent on density of the species or on age (as measured by maximum height). Only some of the scrub species could be included in this analysis due to the production of large inflation factors if all the variables are included. The overall scrub density variable is correlated with all the scrub species variables, so it was omitted, along with the less common species. Variables for number in 10m^2 and maximum height of the following species were analysed: *Crataegus monogyna, Rosa canina, Ulex europaeus, Fraxinus excelsior, Salix caprea* and *Rubus fruticosus* agg. Only the maximum height of *Acer pseudoplatanus* was included, because the number in 10m^2 variable for this species had a large inflation factor.

The eigenvalues calculated for this analysis are larger than the previous partial CCA, but they still do not agree well with those of the DCA. This is to be expected when variables are omitted, however. A significant relationship between the species and the measured environmental variables is demonstrated by a Monte-Carlo Permutation Test with 99 permutations performed on the 1st canonical axis resulting in a p-value of 0.01.

Table 4.7 displays the partial correlation coefficients with the partial canonical coefficients and t- values.

Table 4.7 Partial Correlation coefficients (P.C.C.), canonical coefficients (P.Ca.C.) and t-values of environmental variables

Environmental	**variable**	**Axis 1**			**Axis 2**		
		P.C.C.	**P.Ca.C**	**t**	**P.C.C.**	**P.Ca.C**	**t**
Soil pH		-0.26	-0.13	-3.85	0.14	0.03	1.45
Soil depth		0.48	0.19	3.87	0.14	0.07	2.10
Soil horizon depth		0.25	-0.10	-2.66	-0.02	-0.08	-2.85
Slope		-0.01	-0.005	-0.17	0.12	0.04	1.80
% bare ground		-0.19	-0.03	-1.16	0.11	0.04	1.90
'Primary'		-0.09	-0.22	-3.94	0.26	0.17	4.33
C. monogyna	number	0.62	-0.17	-2.68	0.29	0.22	4.96
	max. height	0.77	0.72	7.79	-0.13	-0.35	-5.44
Rosa canina agg.	number	0.46	0.10	2.19	0.32	0.02	0.49
	max. height	0.69	-0.18	-1.84	-0.07	0.05	0.77
Ulex europaeus	number	0.37	-0.02	-0.21	0.69	0.43	6.58
	max. height	0.41	0.12	1.45	0.26	-0.09	-1.75
Fraxinus excelsior	number	0.33	0.20	4.59	0.32	0.14	4.78
	max. height	0.42	-0.02	-0.51	0.37	-0.10	-2.99
Salix caprea	number	-0.04	-0.03	-0.44	0.02	0.05	1.00
	max. height	-0.05	0.02	0.31	0.03	-0.03	-0.67
Acer pseudoplatanus	max. height	0.26	-0.22	-4.74	0.14	0.12	3.81
Rubus fruticosus agg	number	0.43	0.33	2.74	0.43	-0.12	-1.48
	max. height	0.48	-0.21	-2.2	0.21	0.01	0.18

Table 4.7 shows that the maximum heights of *R. canina* agg. and *C. monogyna* and the number of *Crataegus monogyna* in $10m^2$ are most closely correlated with the 1st axis of species variation. Only the maximum height of *Crataegus monogyna* has a significant partial canonical coefficient and t-value, however. The maximum height of *Acer pseudoplatanus* and the number of individuals of *Fraxinus excelsior* in $10m^2$ also contribute to the variation on this axis, indicated by the significant t-values. The density of *Rubus fruticosus* agg. has a fairly high partial correlation coefficient and t-value, suggesting brambles are more likely to be found under hawthorn scrub as the density of the hawthorn increases, and that the brambles themselves may be having a significant effect on the flora.

The number of *U. europaeus* shrubs in $10m^2$ has the highest partial correlation coefficient on the 2nd principal axis, which is in agreement with the partial canonical coefficient and t-value. The maximum height of *Crataegus* shrubs has a significant negative t-value, implying that *Ulex* tends to occur with low growing hawthorn bushes.

Due to the large number of species and environmental variables, it is difficult to distinguish trends in species scores with the arrow directions in fig. 4.9. Some of the species at the extreme of the first axis have been omitted so that trends can be seen a little more clearly. These species are *Urtica dioica* (1368), *Vicia sepium* (1416), *Cruciata laevipes* (455), *Rumex obtusifolius* (1147), *Rumex acetosa* (1139), *Trifolium* seedling/sp. (2709), *Viburnum opulus* (1409), *Stachys sylvatica* (1293) and *Serratula tinctoria* (1244). It can be seen that the largest contributions to the 1st axis are being made by the maximum heights of *Crataegus monogyna* and *Rosa canina*. It is interesting that the arrows representing the density of these species are situated on the positive side of this axis, although the actual distance separating them is quite small. Since the correlation of these maximum height variables with the 1st species axis is larger than that of the number of shrubs in $10m^2$, it is suggested that height and therefore age of the stand of scrub has more of an influence on the floristic composition than the density of these two species, although it is doubtful if this is significant.

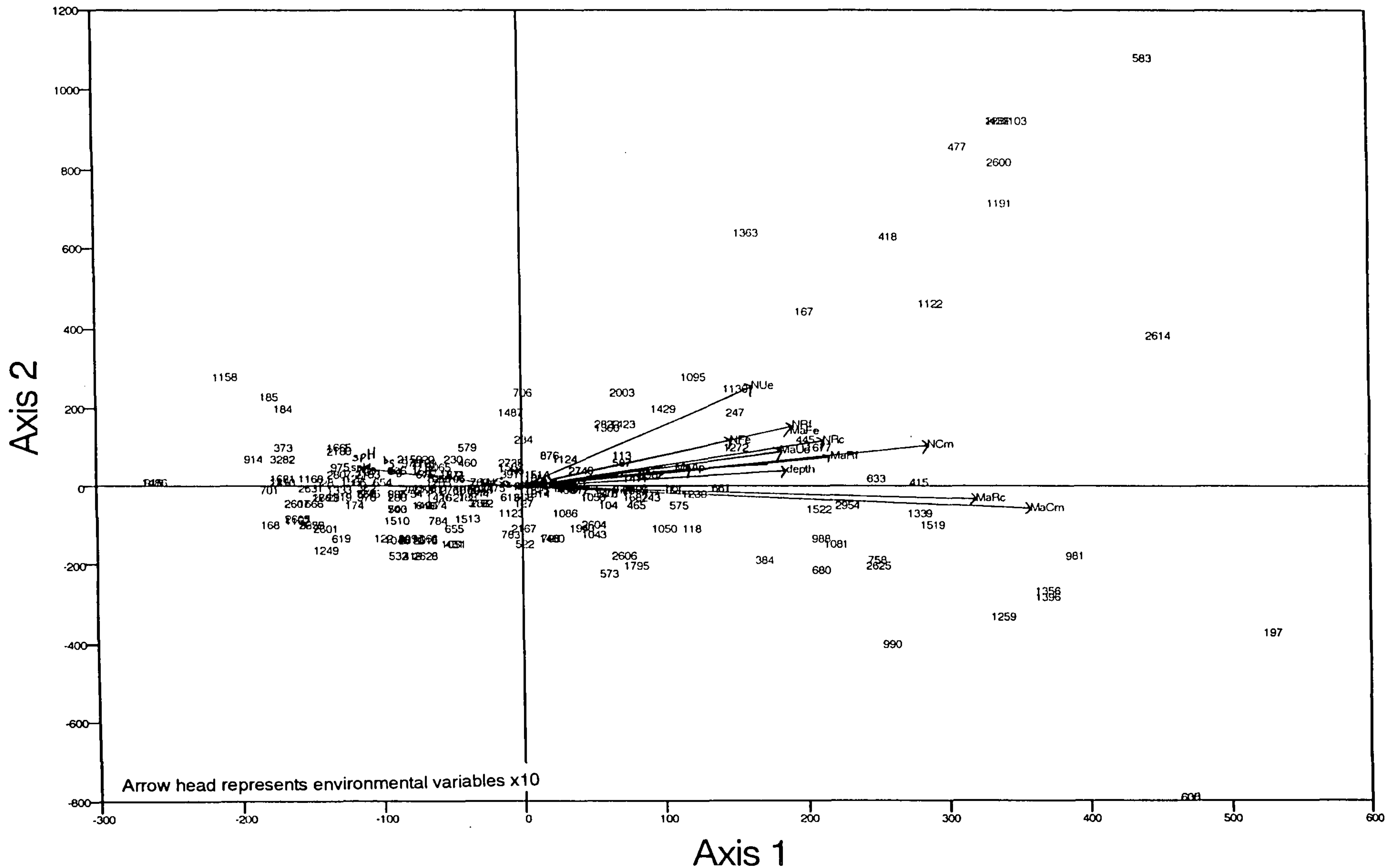
Species associated with the axes for maximum heights of *R.canina* agg.and *C. monogyna* are *Tragopogon pratensis* (1339), *Brachythecium rutabulum* (1519), *B. velutinum* (1522), *Rosa rubiginosa* (2954), *Cirsium arvense* (415) and *Geum rivale* (633). All these species except *B. rutabulum* and *B. velutinum* are confined to communities supporting areas of scrub dominated by *C. monogyna. R. canina* agg. is frequently co-dominant with *Crataegus*, explaining why they are so closely correlated in their influence on species.

Fig. 4.10. displays some scrub species and constants of scrub communities. It is immediately obvious that the typical calcareous grassland species are at the negative end of the 1st axis. It

Environmental variable key for figs.4.9 - 4.11

spH	soil pH
bg	bare ground
depth	soil depth
hor	depth of soil horizon
slo	slope
scrub	scrub density (all species)
pri	'primary'
NCm	Number of *Crataegus monogyna* shrubs
MaCm	Maximum height of *C. monogyna*
NRc	Number of *Rosa canina* agg.shrubs
MaRc	Maximum height of *R. canina* agg.
NUe	Number of *Ulex europaeus* shrubs
MaUe	Maximum height of *U. europaeus*
NFe	Number of *Fraxinus excelsior* shrubs
MaFe	Maximum height of *F. excelsior*
MaAps	Maximum height of *Acer pseudoplatanus*
NRf	Number of *Rubus fruticosus* agg.shrubs
MaRf	Maximum height of *R. fruticosus* agg.
NScp	Number of *Salix caprea* shrubs
MaScp	Maximum height of *Salix caprea*

Fig. 4.9 PCCA 3: Species
Axis 1 v Axis 2



<u>Species code key for fig. 4.10</u>

S.CAP(s)	*Salix caprea* sapling
SES.ALB	*Sesleria albicans*
ULEX(g)	*Ulex europaeus* seedling
BRI.MED	*Briza media*
CAR.FL	*Carex flacca*
AV.PRA	*Avenula pratensis*
CRAT(g)	*Crataegus monogyna* seedling
GAL.VER	*Galium verum*
PS.PUR	*Pseudoscleropodium purum*
FES.RUB	*Festiuca rubra*
ACH.MIL	*Achillea millefolium*
PL.LAN	*Plantago lanceolata*
HER.SPH	*Heracleum sphondylium*
GEU.RIV	*Geum rivale*
CIR.ARV	*Cirsium arvense*
ELY.REP	*Elymus repens*
POA.ANN	*Poa annua*
TRI.FLA	*Trisetum flavescens*
VER.CHA	*Veronica chamedrys*
HOL.LAN	*Holcus lanatus*
FRAX(s)	*Fraxinus excelsior* sapling
R.CAN(s)	*Rosa canina* agg. sapling
ULEX(s)	*Ulex europaeus* shrub
RUBUS	*Rubus fruticosus* agg. shrub
BRAC.SYL	*Brachypodium sylvaticum*
CRAT(s)	*Crataegus monogyna* sapling
CALL.CUS	*Calliergon cuspidatum*
CAR.FL	*Carex flacca*

Fig. 4.10 PCCA 3: Selected Species
Axis 1 v Axis 2

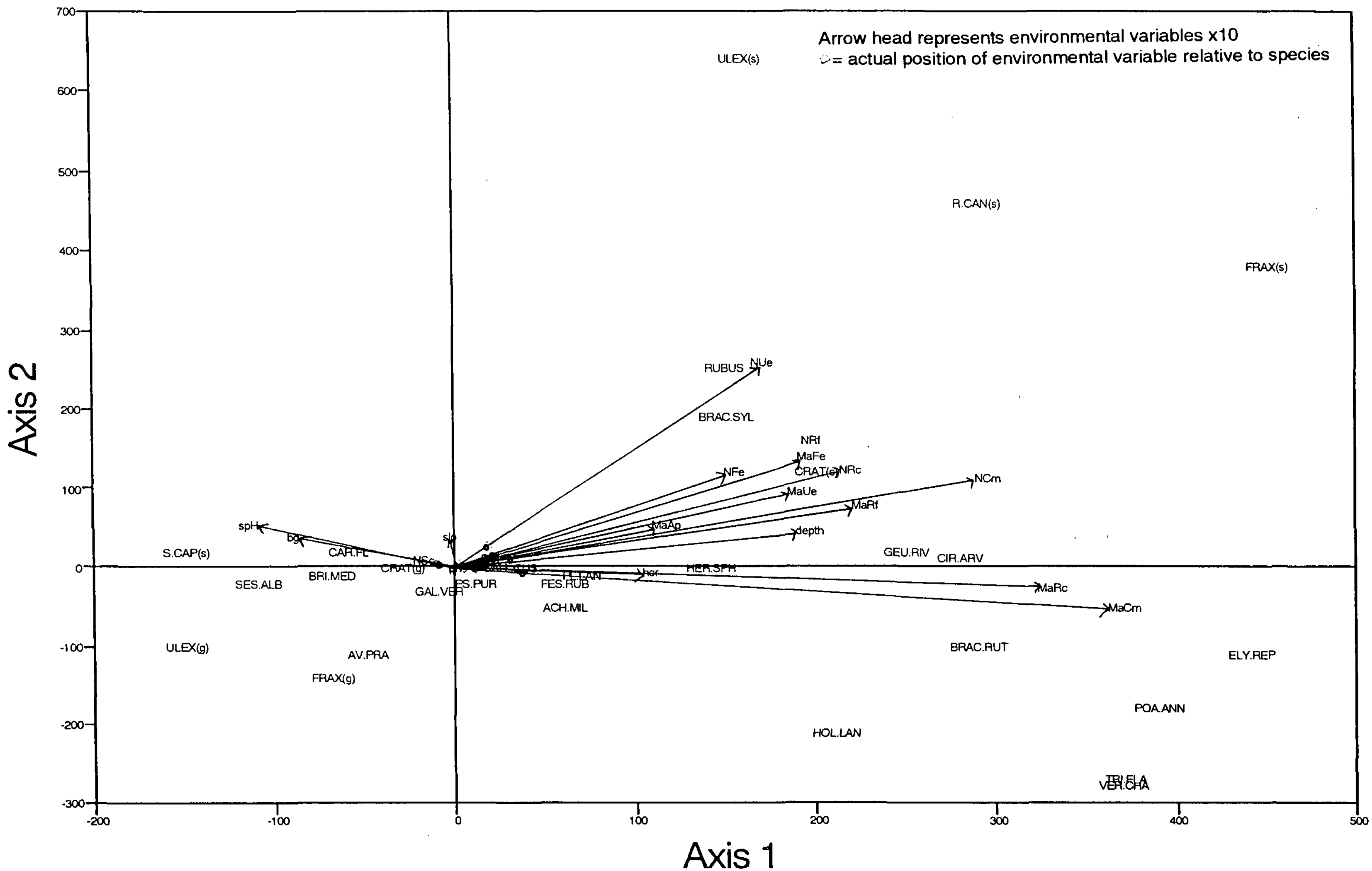
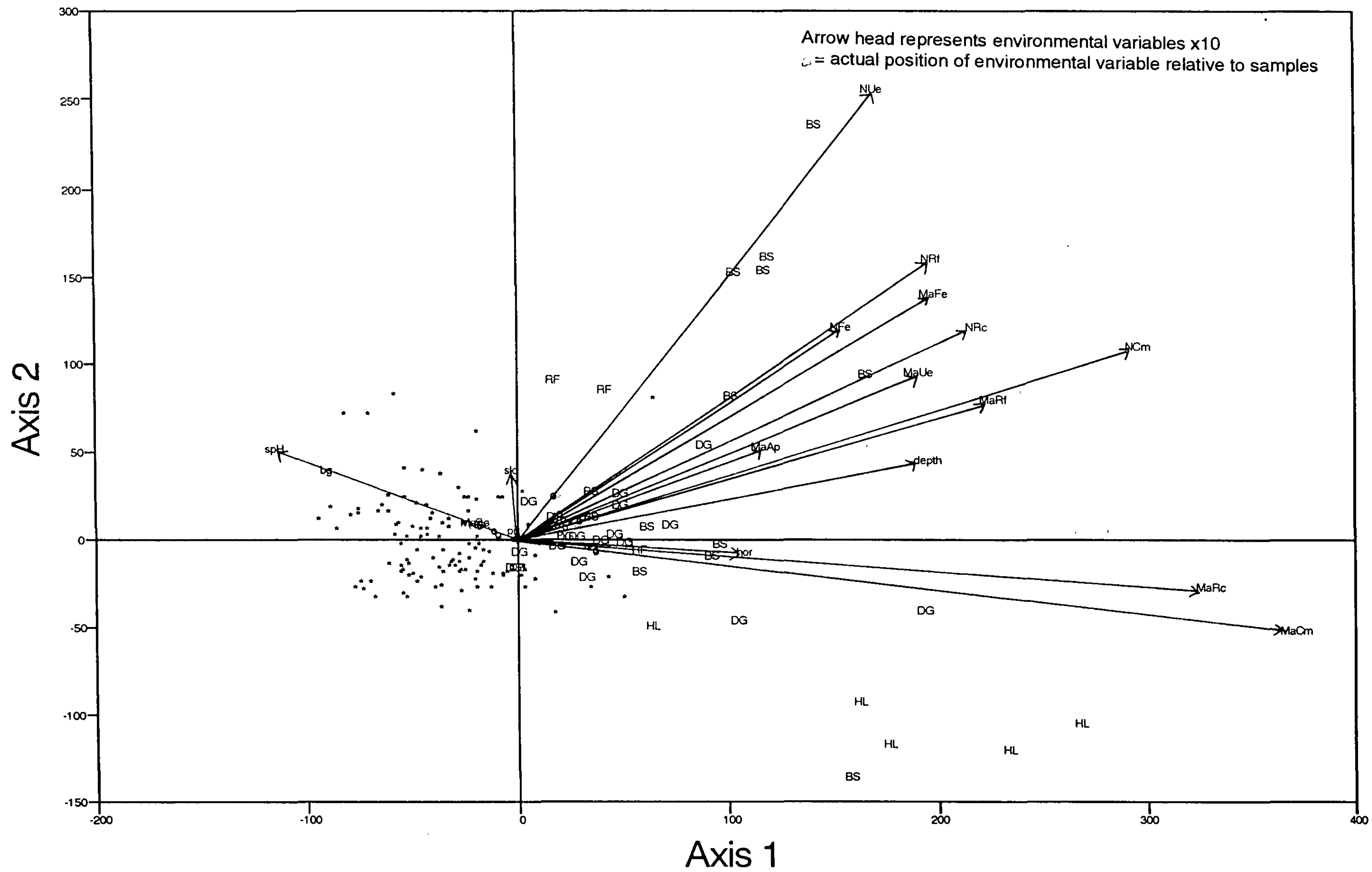


Fig.4.11 PCCA 3: Samples (codes)
Axis 1 v Axis 2



is interesting that *Salix caprea* sapling and seedlings of *C. monogyna*, *Fraxinus excelsior* and *Ulex europaeus* are also at this end of the axis, indicating that open grasslands are undergoing widespread invasion by woody species, and that these woody species require open vegetation for germination and seedling establishment. Although grasses such as *Holcus lanatus*, *Poa annua*, *Trisetum flavescens* and *Elymus repens* are separated from other species by the *C. monogyna/R.canina* axes, they are not closely associated with the axes. This is because these species occur frequently in rank grassland, as well as under a cover of scrub, and may be responding more to soil nutrient status than to the shading effect of a scrub canopy. This is reflected in fig. 4.11 in the positions of the *Holcus lanatus* grassland relevés (HL), which are only affected by a low density of *Crataegus* scrub, if at all.

The main contributor to the 2nd species axis is the number of *Ulex europaeus* in $10m^2$. Fig. 4.9 shows that *Rubus fruticosus* agg. (1136), *Angelica sylvestris* (167), *Rumex acetosa* (1138), *Brachypodium sylvaticum* (247), *Ranunculus repens* (1095) and *Viola riviniana* (1429) are associated with this axis. Both grassland and shade-tolerant species are represented here. Fig. 4.10 shows that the species scores of *U. europaeus* and *R. canina* agg. are more associated with this axis than with any of the others. It is no surprise that the species score for *Ulex* lies here, but the position of *R. canina* agg. is rather aberrant. Figure 4.11 indicates that relevés from the *Brachypodium sylvaticum* sub-community of *C. monogyna* scrub and *Rubus fruticosus* agg. scrub are allied with this axis, although they are not confined to this axis. It certainly appears that they are preferential for *Ulex* however, and that the *Dactylis glomerata-Briza media* sub-community of *C. monogyna* scrub tends to be associated with other species of scrub. There is a large amount of overlap in these trends, however, because there are very few 'monocultures' of scrub, and species interact with one another to produce an integrated impact on community composition. There is also some overlap of samples not classified in "scrub communities" onto the positive side of the 1st axis, but some of these are influenced by scrub or may have been in the past. The most extreme of these relevés is sample 68, which is a scrub-invaded area of primary grassland on Raisby Hill Grassland.

4.4 Specific effects of scrub invasion on soil pH and calcicolous species

A t-test on the pH of soil samples of relevés in *Sesleria albicans* grassland and *Crataegus monogyna* scrub communities revealed there is no significant difference between the two ($t = -1.739$, 66 d.f. $p > 0.05$). There is no significant effect of scrub density on soil pH ($r = -0.014$, 25 d.f. $p > 0.05$) amongst those releves influenced by a cover of scrub. The approximate age of the scrub cover also has no significant impact on the soil pH ($r = 0.021$, 25 d.f., $p > 0.05$). It seems that the changes in ground flora are therefore due to the shading effect rather than soil pH changes, although it cannot be ruled out that as the scrub ages further or becomes more dense changes in pH may occur, or that changes in the ground flora are mediated by increased nutrient inputs to the soil.

Table 4. 8 The occurrence of seven calcicoles under scrub

Releve	Density of scrub /10m^2	Maximum height /m	Dominant species	L.c.	P.v.	C.f.	S.p.	C.m.	L.ca	D.f.
33	11	2.3	C.m./ R.c.	√	√	√	-	-	-	-
39	14	4.0	C.m.	-	-	-	-	-	-	-
40	14	4.0	C.m	-	√	-	-	-	-	-
105	14	3.3	C.m	-	√	√	-	-	-	-
119	22	1.4	R.c./ C.m	√	-	-	-	-	√	-
118	22	2.3	C.m	√	-	-	-	-	√	-
1	26	2.8	C.m	√	-	√	√	√	-	√
156	26	3.5	C.m	-	-	-	-	-	-	-
64	29	3.5	A.p./ C.m.	√	√	√	-	-	-	-
65	29	3.5	C.m	√	√	-	-	-	-	-
66	29	3.5	C.m	√	√	√	-	-	-	-
92	31	2.9	C.m	√	√	-	-	-	-	-
36	34	2.3	S.c.	√	-	√	√	√	-	√
95	35	3.5	C.m	√	√	√	-	-	-	-
68	50	3.5	U.e./ C.m.	-	-	√	√	√	-	-
145	50	0.7	C.m. /U.e.	√	√	√	√	-	√	-
146	50	0.7	C.m. /U.e.	-	-	√	-	-	√	-
147	50	0.7	C.m. /U.e.	-	-	√	-	-	√	-
41	61	2.1	S.c.	√	√	√	-	-	-	-
117	62	2.5	P.s.	√	√	-	-	-	-	-
123	65	3.5	R.c. /C.m.	√	√	√	-	-	-	-
74	81	2.3	C.m./U.e.	-	-	-	-	-	-	-
135	84	1.8	F.e.	-	√	√	-	-	-	-
143	97	3.5	C.m./ F.e.	√	√	√	-	√	-	-

C.m. = *Crataegus monogyna*, R.c. = *Rosa canina* agg., A.p. = *Acer pseudoplatanus*, S.c. = *Salix caprea*, U.e. = *Ulex europaeus*, P.s. = *Prunus spinosa*, L.c. = *Lotus corniculatus*, P.v. = *Primula veris*, S.p. = *Succisa pratensis*, C.m. = *Ctenidium molluscum*, L.ca = *Linum catharticum*, D.f. = *Dactylorhiza fuchsii.*

An attempt was made to evaluate at what density of scrub certain calcicolous species disappear from the ground flora. Species were chosen on the merits of occurring at all the study sites and being common and widespread in open swards of Magnesian Limestone grassland. Species fulfilling these criteria are *Dactylorhiza fuchsii, Linum catharticum, Lotus corniculatus, Primula veris, Succisa pratensis, Ctenidium molluscum* and *Carex flacca.* Table 4.8 denotes presence/absence of these species at different scrub densities and maximum heights.

There is no discernible trend in the disappearance of the 7 species as scrub density increases, although *Succisa pratensis*, *Ctenidium molluscum*, *Linum catharticum* and *Dactylorhiza fuchsii* are more prone to be absent from scrubby areas than *Lotus corniculatus* and *Carex flacca.* However, *Ctenidium molluscum* and *Linum catharticum* are present in quite dense scrub in relevés 145, 146 and 147 at Cassop Vale, although absent from some of the sparse scrub areas. It is notable that most of the species are present in relevé 36, in *Salix caprea* scrub at Bishop Middleham and in relevé 145, in which *C. monogyna* and *U. europaeus* are co-dominant at Cassop Vale, whereas none are present in less dense *C. monogyna* scrub at Cassop Vale (releve 156) or in relevé 74, which is dense scrub on Raisby Hill Grassland.

CHAPTER FIVE
DISCUSSION

5.1 Succession

5.1.1 A suggested successional sequence

A precise time scale cannot be placed on the pattern of succession described below because different parts of some quarries were worked until more recently than others and a variety of substrates were left after abandonment which are colonised at different rates. Richardson (1956) found that hard rocky quarry floors are slower to be colonised than the soft marl of gently sloping spoil heaps. However, steep spoil heaps are subject to erosion as a result of surface compaction, low permeability and water run-off (Booy, 1975). From personal observations made during this investigation, the spoil heaps at Wingate and Raisby are well-vegetated, whereas the large steep spoil heaps at Bishop Middleham are quite sparsely covered. All the quarries in this study have no substantial areas of bare ground except on spoil heaps and quarry walls where the soil is unstable and often rocky. In general, the quarry floors have now weathered to such an extent that there is a shallow layer of friable soil which can support vegetation.

A successional sequence can be postulated by examining the communites described in section 4.1. Most of the relevés in the *Briza media* grassland community are in the early stages of colonisation and occur in all the abandoned quarries (appendix 4), except on the quarry floor at Bishop Middleham, where the colonisation of *Sesleria albicans* from the remnant of primary grassland at the rim has given this vegetation the appearance of the open *Hieracium pilosella* sub-community of *S. albicans* grassland. Richardson (1956) found that the grass was an early coloniser of Highland House Quarry, near Bishop Middleham, because it could take advantage of the lack of competition and it grew so vigorously that it excluded many other species. At Bishop Middleham, it is notable that *Sesleria* has not colonised the sparsely vegetated large spoil heaps or the area of grassland to the east of these spoil heaps (appendix 1). These areas are classified as *B. media* grassland, except in the area of scrub, which is thought to have been affected by tipping.

The *B. media* grassland community may have replaced something akin to the *Encalypta-Plantago maritima* association described by Shimwell (1968) and implies that *B. media* is quite an early coloniser of bare ground. However, Grime *et al.* (1988) found that *B. media* prefers undisturbed habitats such as old pastures, although it is soon out-competed by more vigorous species. When there is a local source of *Sesleria, Briza media* grassland may develop into the *Hieracium pilosella* sub-community of *Sesleria albicans* grassland, although colonisation of *Sesleria* may be hampered by a tall sward of *B. media.* If there is no *Sesleria* seed available and no grazing, scrub species will invade and a *Dactylis glomerata-Briza media* sub-community of *Crataegus monogyna* scrub will develop. Alternatively, *Holcus lanatus* grassland with some *Crataegus* scrub invasion may be dominant on more mesotrophic soils.

It is not clear how the *Hieracium pilosella* sub-community of *S. albicans* grassland might develop - it may be invaded directly by scrub or become either *Avenula pratensis* or *Bromus erectus* sub-communities, depending on the local seed source and the grazing regime. Rodwell (1992) suggests that *Bromus erectus* may increase in response to a lack of grazing, and the grass can be easily controlled by the introduction of herbivores.

The primary grasslands in this survey are mostly of the *Avenula pratensis* or *Bromus erectus* sub-community of *Seleria albicans* grassland. The *Avenula pratensis* sub-community is synonymous with Shimwell's (1968) sub-association Typicum of *Seslerio- Helictotrichetum*. He suggests that this sub-association has been subject to minimal anthropogenic influence in the past and may even be the climax vegetation on very shallow soils. The *Bromus erectus*-dominated sward is peculiar to Raisby Hill grassland, where it is co-dominant with Sesleria. *B. erectus* is abundant in some areas at Thrislington, but efforts are being made to control it by grazing sheep.

In the absence of grazing a succession to hawthorn scrub and then to ash woodland is the inevitable result in both primary and secondary grasslands. It seems that scrub can grow on even skeletal soils, so the suggestion that *Sesleria albicans* grassland is the climax vegetation, at least in some areas of the Magnesian Limestone, is not supported. However, the lack of extensive woodland development except on deeper drift material implies that shallow soils may limit the establishment of trees. Furthermore, the apparently immature scrub vegetation predominant on many of the sites implies a comparatively recent invasion, perhaps stimulated by increased atmospheric nitrogen inputs in the last few decades.

The *Brachypodium sylvaticum* sub-community of *Crataegus* scrub is confined to primary grasslands and *B. sylvaticum* persists when scrub has been removed, lending a yellow-green patchy appearance to the vegetation. There is no apparent reason why this sub-community should be restricted to primary grasslands, except that the antiquity of the primary grasslands may mean that the scrub is older than that developed in the old quarries, and so has exerted its influence for a longer period of time. This sub-community is found under generally higher densities of scrub than the *Dactylis glomerata- Briza media* sub-community, so this implies that denser scrub is present in primary grassland than in secondary, again probably due to the longer time that scrub vegetation has had to develop.

The effect of overgrazing and eutrophication on primary grasslands is also detrimental, possibly encouraging the growth of species such as *Holcus lanatus* and *Rubus fruticosus* agg.. The invasion of brambles on Pittington Hill merited the designation of this area as a community of *Rubus fruticosus* agg. scrub. The specific effects of scrub on the grassland flora is discussed in section 5.2.

5.1.2 Colonisation

It is difficult to describe the early vegetation in abandoned quarries as communities; because the precise species which colonise seem to involove a substantial element of chance, with some species arriving due to successful dispersal rather than being suited to the seral conditions. Furthermore, some species may germinate but seedling establishment may be hampered by drought or nutrient deficiency. However, Richardson (1956) noted that only acrocarpous mosses could gain a hold on the bare rock of quarry floors, whereas the softer spoil heaps were colonised by herbaceous species and grasses such as *Epilobium angustifoilium, Festuca rubra, Hieracium boreale, Ononis repens, Prunella vulgaris* and *Sagina procumbens.* Shimwell (1968) suggests that the *Encalypta-Plantago maritima* association of abandoned quarries replaces a weed flora dominated by *Epilobium angustifoilium, Hypericum* spp. and *Erigeron acer.* This survey found that *E. angustifolium* and *E. acer* are confined to abandoned quarries (appendix 5), but *Hypericum perforatum* and *H. pulchrum* occur in both primary and secondary grasslands. There is no evidence of an *Encalypta-P.maritima* community, because neither species are common and *P. maritima* occurs only at Cassop Vale (primary) and Pittington quarry (secondary). Species of *Encalypta* however, are confined to areas of bare soil in old quarries.

It has been stressed throughout the community descriptions (section 4.1) that each site has its own peculiarities and the species that colonise an abandoned quarry depend to a large extent on the surrounding vegetation. The isolation of the quarry and its proximity to a seed source determines to some extent which species colonise. The success of *Sesleria* at Bishop Middleham has already been mentioned, and the grass was found on the quarry floor at Raisby, although not widespread, where it has presumably dispersed from the nearby population on the hillside. *Sesleria albicans* is completely absent from Trimdon and from Wingate quarries due to the absence of a nearby seed source. The invasion of ruderal species such as *E. angustifolium* at Trimdon seems to be more of a problem than at other sites, and this may be a factor of the site being surrounded by agricultural land and perhaps because Trimdon was abandoned during the War which was a period of huge agricultural expansion and hence depletion of a seed source of the natural vegetation. Spencer (1976) suggests that the expansion of agriculture has encouraged the spread of weeds such as *Senecio jacobea, Urtica dioica* and *Epilobium angustifolium* into the remaining natural vegetation and abandoned quarries. These tall ruderals may either shade out existing species in natural vegetation or may prevent the colonisation of disused quarries by limestone grassland species.

The identity of species colonising quarry floors is not just a factor of the proximity of a seed source. Richardson (1956) noted the presence of some species which must have undergone long distance dispersal to arrive in abandoned quarries. For example,. the first inland record for *Anacamptis pyramidalis* was at Garmondsway Quarry in 1950 (Richardson and Evans, 1987). This orchid was observed at Bishop Middleham this summer, although not recorded in any of the relevés (photograph 19).

Photograph 19: Pyramidal orchid (*Anacamptis pyramidalis*) in willow scrub at Bishop Middleham

Richardson and Evans (1987) detail the successional sequence over 40 years at Bishop Middleham. Early colonisers noted at Bishop Middleham were *Agrostis tenuis, Epilobium angustifoilium, Fragaria vesca, Hieracium pilosella, Hypochoeris radicata, Linum catharticum, Lotus corniculatus* and *Tussilago farfara.* All these species except *A. tenius* were found at Bishop Middleham in this survey. The common spotted orchid *Dactylorhiza fuchsii* (photograph 20) is an early coloniser dependent on disturbed ground and the fragrant orchid *Gymnadenia conopsea* (photograph 21) appears just before the community closes (Richardson 1956; Richardson *et al.*, 1980).

Photograph 20: Common spotted orchid (*Dactylorhiza fuchsii*)

Photograph 21: Fragrant orchid (*Gymnadenia conopsea*)

Studies on the colonisation of bare chalk in southern England (Tansley, 1922; Hope-Simpson, 1940; Locket, 1946; Lloyd and Pigott, 1967) have all found that woody species can colonise bare chalk and do not require a well-developed soil to establish. Lloyd and Pigott (1967) suggest this is because the large seed reserves of shrubs and treees mean they are not dependent on soil nutrients for germination and stand a better chance of survival in the absence of competition from vigorous herbs. Other early colonisers are small dicotyledonous herbs and legumes which also have low nutrient requrements. Annual grasses with small seed reserves cannot tolerate the low fertility and the chalk's susceptibility to drought. However, *Arrenatherum elatius* is an early and ubiquitous component of the sward (Locket, 1946; Ward and Jennings, 1990). A study on Aston Rowant National Nature Reserve in Hampshire by Ward and Jennings (1990) revealed that *A. elatius* became dominant very quickly, tending to oppress smaller species such as *Linum catharticum* and *Leontodon hispidus.* Other coarse grasses such as *Brachypodium sylvaticum* and *Bromus erectus* also increased in frequency as time progressed.

The results of this study also suggest that woody species are early colonisers of bare ground. There are some well-developed stands of scrub in all the abandoned quarries, but on shallower soils, perhaps where a hard rocky substrate was left, the vegetation is still quite open. However, as can be clearly seen on the quarry floors of Bishop Middleham, Trimdon and Raisby, scrub encroachment of even the shallowest soils is ubiquitous. The willow scrub at Bishop Middleham has been present for approximately 30 years (Richardson & Evans, 1987), and as yet has had little impact on the ground flora (photograph 22). However, the quarry floor at Bishop Middleham was not colonised by woody species until 23 years after abandonment, the first species being *Ulex europaeus. Fraxinus excelsior* and *Salix* spp. did not appear until 30 years after abandonment, when the herbaceous cover of the ground was at least 50%.

It seems that woody species can colonise even the most skeletal soils but may not be able to take hold. Hambler and Dixon (1986) noted that early colonisers of a Limestone Quarry floor in Yorkshire included many small herbaceous species as well as the grasses *Avenula pratensis*, *Agrostis stolenifera* and seedlings of *Acer pseudoplatanus* and *Fraxinus excelsior.* They noted that most of these seedlings were depauperate and short-lived, tending to establish against small stones, which trap the propagules and may provide a favourable microclimate. This may be a factor in the diversity of woody species that have colonised the quarry floor at Raisby. There are small individuals of *Viburnum lantana, Betula pubescens,*and *B. pendula* growing amongst the boulders strewn on the quarry floor.

Photograph 22: Orchids in willow scrub ar Bishop Middleham

5.1.3 Development

The course of succession after colonisation is determined by other factors such as grazing, the proximity of a seed source for further colonisation, invasion by scrub and management regime. Grazing is essential for maintaining the plagioclimax vegetation, but overgrazing can also upset local stability of the limestone grassland community by opening gaps for colonisation by other species, especially ruderals. For example, the *Sesleria* at Pittington has been eaten back so far that other species have colonised and the grass is no longer dominant (Richardson, 1956). Community composition may also change under a heavy grazing pressure because of eutrophication by grazing animals (Spencer, 1976). For example tall grasses such as *Dactylis glomerata* and *Bromus erectus* are encouraged, which might shade out small herbaceous species. If there is no grazing, however, scrub invades, and if allowed to take hold may completely change the ground flora by shading and by irreversibly changing the soil chemistry (section 5.2). If this occurs, a similar limestone grassland community may never return after scrub clearance. For example, Richardson (1956) sugests that *D. glomerata*, *Senecio jacobea* and *Heracleum sphondylium* may increase after scrub clearance in response to disturbance and the enhanced nutrient status of the soil.

5.2 The impact of scrub on limestone grassland vegetation

The association of mesotrophic and shade-tolerant species along the first axis in the DCA ordination and the second partial CCA (sections 4.2 and 4.3.3) suggest that scrub cover and /or fertility are the main factors affecting floristic composition. These two components are probably inter-related. Studies on *Crataegus monogyna*, the most common woody species on the Magnesian Limestone, suggest that the shrub causes irreversible changes to the soil via nutrient input and acidification, as well as altering the soil moisture content and adding a thick layer of organic matter which may prevent the establishment of smaller species (McCulloch, 1974; Hodgkin, 1984).

5.2.1 Nutrient input

The small prostrate and rosette herbaceous species typical of calcareous grasslands thrive in the nutrient deficient but base-rich soils of the Magnesian Limestone because they can cope with the lack of nutrients and are free of competition from taller species. Analyses of soils at Thrislington (Booy, 1975) produced the following results:

Table 5.1 Analysis of soils from Thrislington (from Booy (1975))

Calcium carbonate ($CaCO_3$)	59%
Magnesium carbonate ($MgCO_3$)	40%
Alumina (Al_2O_3)	0.15%
Ferric oxide (Fe_2O_3)	0.60%
Silica (SiO_2)	0.25%

Soil nutrient analyses by Richardson and Evans (1986) demonstrated the deficiency of nitrogen, phosphorus and potassium. with concentrations of 2.9 ppm nitrogen in the form of nitrate, 0.6 ppm phosphorus and 4.4 ppm potassium. Furthermore, experiments with *Dactylis glomerata* revealed growth enhancement in a NPK treatment.

McCulloch (1974) noted higher nutrient levels in hawthorn scrub than in adjacent limestone grassland. An investigation on sand dunes in Anglesey recorded enrichment of the topsoil under hawthorn bushes (Hodgkin, 1984). Nutrients are added to the soil by the high input of organic material by shrubs. Woody species may be able to obtain nutrients from the soil that are out of reach of small species by virtue of their deeper roots. Moreover, they may possess mycorrhizae that are able to release previously tightly bound nutrients. Atmospheric deposition is also more likely to be intercepted by the larger surface area presented by leaves as opposed to small herbs and grasses. The surface area presented to the Scrub encroachment may also induce an indirect method of nutrient addition by encouraging roosting birds.

The addition of nutrients to the soil by hawthorn bushes encourages the growth of fast-growing grasses such as *Holcus lanatus* and *Dactylis glomerata* as well as tall herbs such as *Heracleum sphondylium* which shade out the chamaephytes and therophytes. Davy and Bishop (1984) found that the occurrence of *Hieracium pilosella* on calcareous soils in Breckland decreased in response to fertlilty due to competition from *Festuca ovina* and *Koeleria macrantha,* whose growth was promoted. Hodgkin (1984) noted that weedy nutrient-demanding species were encouraged by a cover of scrub and if allowed to become dominant may remain even after scrub has been cleared. Here lies the major problem in management of the Magnesian Limestone grasslands - will the typical low-growing species return once scrub is cleared? This problem will be considered in section 5.5.

It is interesting to note that there has been apparently no impact on the vegetation under the willow scrub at Bishop Middleham, suggesting that *Salix* spp. do not enhance fertility to the same extent as *Crataegus*. However, this may be partly due to the age of the willow scrub and its less intense shading effect. Without nutrient data for the soils it is impossible to attribute vegetation change to any one factor.

5.2.2 Acidification

McCulloch (1974) found that both *Ulex europaeus* and *Crataegus monogyna* have an acidifying effect on soil and suggests a mechanism whereby this occurs. Limestone soils have very high levels of free carbonate, which is considered the most important factor governing the regeneration of calcareous vegetation (De Silva, 1934; Rorison 1960). McCulloch found that the percentage of free carbonate in the soil is correlated with pH and is negatively correlated with the age of hawthorn bushes, indicating the progressive removal of free carbonate from the soil as the shrub grows. The rate of acidiification was also postulated to depend on the density of the hawthorn scrub as well as it's age. Furthermore, there is a knock-on effect in that once the free carbonate has been removed from the soil, the buffering capacity is reduced and the rate of acidification increases still further.

This proposed acidifying effect may may explain why pH has a negative correlation with axis 1 in both the third and fourth partial CCAs, although it is not significantly correlated with scrub density. However, pH is correlated with percentage bare ground, as shown by the super-position of these two axes in the environmental biplots and the generally high pH of *Briza media* grassland relevés. It appears that a decline in pH is associated with soil development, possibly due to leaching as the profile deepens. There is no evidence in this investigation that the pH of samples taken under a cover of scrub is any different to that of *Avenula pratensis* or *Bromus erectus* sub-communities of *Sesleria albicans* grassland. It appears, therefore that the scrub studied in this investigation is not old enough to have caused changes in soil pH and that calcicoles will return after scrub clearance provided tall competitive species are also removed.

5.2.3 Shading

As well as the soil chemistry changes caused by scrub encroachment, there is also the more immediate physical effect of shading the ground flora. The small prostrate and rosette herbaceous species typical of calcareous grasslands thrive when the vegetation is open and become etoilated or disappear altogether in rank grassland or scrub. For example, *Leontodon hispidus* cannot germinate in the shade of rank grassland (Silvertown, 1980) and *Thymus praecox arcticus* only persists as small etoilated individuals under tall *Arrenatherum elatius* grassland (Ward & Jennings, 1990). These two species were not used as 'typical' calcicoles in the analysis in section 4.4, because they do not occur in all the sites. However, Ward & Jennings (1990) found that *Linum catharticum* decreases in abundance as scrub density increases, suggesting this is because this therophytic plant requires bare ground for germination. In this investigation, *L. catharticum* was one of the four species that seemed to be most prone to be excluded from scrubby areas, although it was not completely absent even from dense scrub. Indeed, there were no clear trends in the disappearance of calcicoles from scrub at all. This may be a factor of inter-site differences and a study of scrub densities within each site may reveal a pattern. Furthermore, the amount of shade cast by a cover of scrub depends not only on the density but also on the height and width of the bushes. Hence it may be more useful to have a measure of overhead cover of the canopy or some 'index of scrubbiness'. It must also be considered that other factors affect species that survive under scrub, such as the community composition before scrub invasion and past management.

5.3 Effects of different scrub species

The age of the major scrub species *Crataegus monogyna* and *Rosa canina* appears to be more important than density. This is demonstrated by their significant contribution to the first canonical axis in the third partial CCA (section 4.3.4). However, the number of *C. monogyna* shrubs in $10m^2$ also contributes to this axis. This may be expected, since *C. monogyna* occurred in all the scrub samples that were taken, apart from the *Salix caprea*-dominated areas at Bishop Middleham. *Acer pseudoplatanus* and *Fraxinus excelsior* also contribute to this axis, possibly because they occur most frequently with *Crataegus* and rarely on their own. The density of *Ulex europaeus* is the most significant variable on the 2nd axis of this analysis, suggesting that this species has a somewhat different effect on the ground flora than scrub dominated by hawthorn. However, this may also be a factor of inter-site differences, because *Ulex* is only dominant at Cassop Vale.

It is difficult to elucidate individual effects of different species and their age/density due to past scrub clearance and other management affecting the composition of the flora, as well as the peculiarities of different sites. For example, an individual of *Epipactis atrorubens* occurs at Thrislington under the densest area of scrub recorded in the whole investigation. Other species co-dominant or accompanying the major scrub species may also have a significant impact, especially *Rubus fruticosus* agg. which probably has a large impact, but because it is low growing and individuals are difficult to count, it does not contribute significantly to the species variation. Despite these difficulties, it is clear that the *Salix caprea* scrub at Bishop Middleham has had little effect on the ground flora. Again, this may due to the individuality of the site itself or a factor of soil depth or pH. In reality, the impact of a scrub cover on ground vegetation is likely to be a combination of factors which may themselves be inter-related.

5.4 Differences between primary and secondary grasslands

There are distinct differences in the grassland communities of primary and secondary grasslands, attributable mainly to the rarity or absence of *Sesleria albicans* in most of the abandoned quarries. These differences have been discussed in section 5.1 in relation to the successional status of the sites. The second principal axis of the ordination (section 4.1) appears to be related to the origin of the grasslands, and this is supported by the significant contribution of the nominal variable 'primary' to the 2nd canonical axis in the second and third partial CCAs (sections 4.3.3 and 4.3.4). However, inter-site differences may again be playing a role, and it is not clear if the axis is related to successional stage of the grassland rather than the fact that it is primary or secondary. The position of the *Hieracium pilosella* sub-community in the middle of the samples ordination (fig. 4.2) suggests not only that Bishop Middleham (the source of most of these relevés) is beginning to imitate primary grasslands, but that the 2nd axis may be related to bare ground or to 'openess' of the sward. Support for the importance of the successional stage is given by the contribution of soil pH and percentage bare ground to the 2nd principal axis. It has already been mentioned that soil naturally acidifys as it develops (section 5.2.2). Obviously these factors are inter-linked and it cannot be precluded that the abandoned quarries will one day emulate the primary grasslands in floristic composition. It is clear, however, that sites near to a seed source of *Sesleria* and other 'primary' species (Bishop Middleham, Raisby and Pittington quarries) are more likely to achieve this than the more isolated sites of Trimdon and Wingate.

Secondary grasslands do not appear to be any more prone to scrub invasion than primary grasslands. Although the open vegetation provides opportunities for colonisation of woody seedlings other workers have suggested that they may be only short-lived (Hambler & Dixon, 1986). In addition, there is no support for Dalby's (1991) hypothesis that abandoned quarries support more species of a southern distribution than primary grasslands. Appendix 5 reveals no pattern in the distribution of species confined to primary or secondary grasslands.

5.5 Suggestions for management

It is not clear how far soil change has advanced in the stands of scrub sudied here and scrub control by cutting and then herbicide treatment of some of the stumps may be successful if the scrub is not too dense. However, in areas where the canopy has closed and the limestone grassland flora has been completely shaded out, it is unlikely that calcicoles will be able to re-colonise once the scrub is cleared. This seems to be more of a problem with hawthorn scrub rather than with gorse. A calcicolous grassland community can be re-created after removal of a cover of gorse, but is irreversibly changed by hawthorn (T. Barrett, pers. comm.). Hence areas which are already covered by an inpenetrable cover of hawthorn scrub should be left alone and efforts concentrated on preventing invasion of expanses of grassland.

Since many of the species of interest in abandoned quarries are favoured by disturbance and open ground, it may be feasible to literally destroy areas of grassland, say every 30 years, to return the succession to the beginning. As long as the seed bank is preserved and any invading ruderals are removed, this radical solution may particularly favour orchids such as *Dactylorhiza fuchsii* and *Gymnadenia conopsea*. To preserve the aesthetic appeal of sites this should only be carried out on small areas at a time.

These suggestions are merely remedies for scrub invasion however. It is an inescapable fact that prevention is better than a cure and the only way to prevent scrub regeneration once scrub has been cleared is to introduce a light grazing pressure to the grassland. This is already practised at Thrislington and Cassop Vale but other sites present difficulties due to their popularity with dog-walkers or their precipitous cliffs.

In conclusion, there is a requirement for continuous scrub control at all the SSSIs. It seems that calcicoles still persist under scrub, at least at the densities examined here, but the competition from both the woody species and nutrient-demanding herbs and grasses may eventually cause displacement of the light-demanding calcicoles. Scrub should be removed before this occurs, since soil changes and dominance of tall grasses and herbaceous species may prevent the calcicoles re-colonising.

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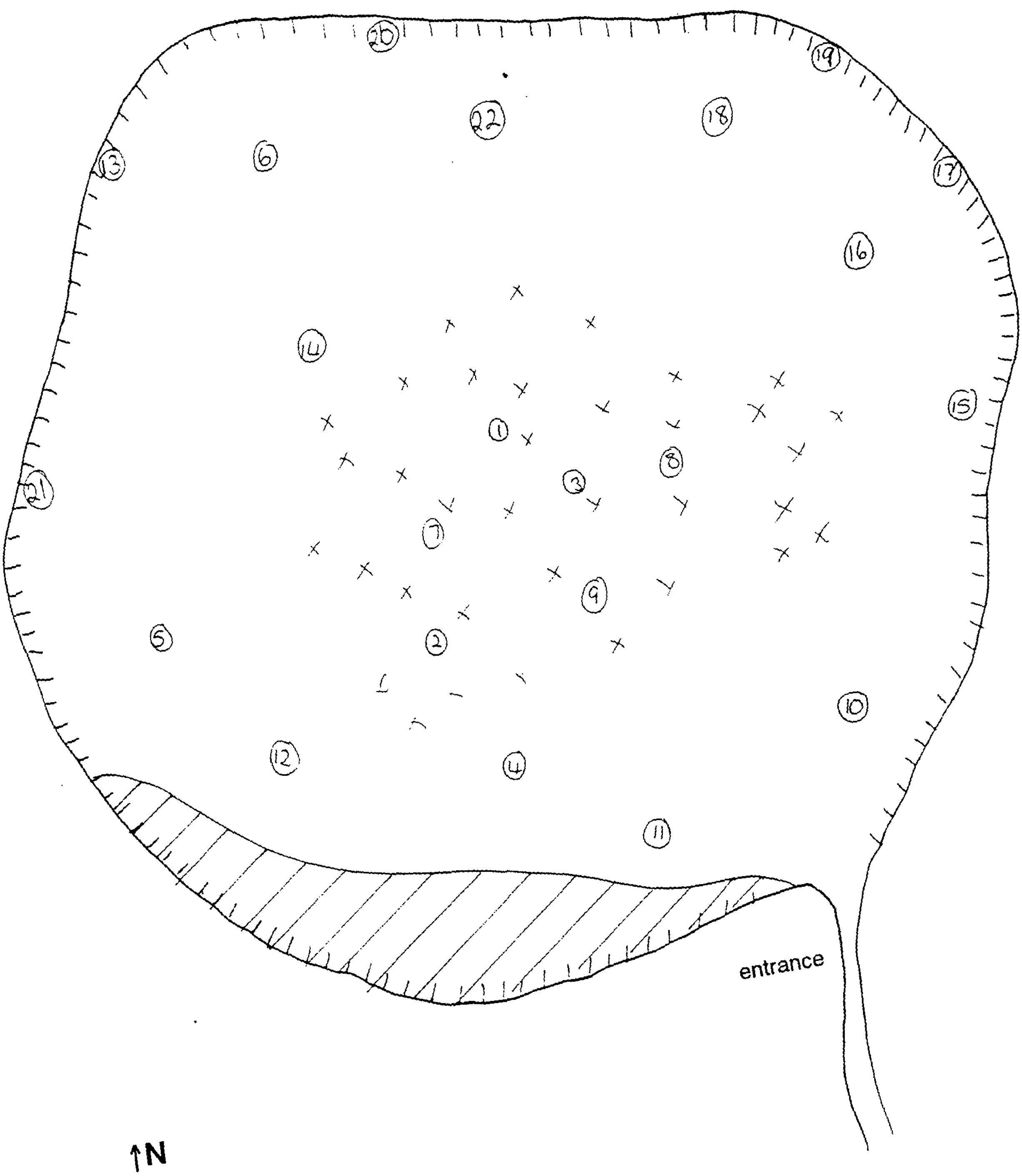
Appendix 1 Site Maps to show positions of quadrats

KEY

- Calcicolous grassland
- Scattered scrub
- Dense scrub
- Acid grassland
- Semi-improved neutral grassland
- Unimproved neutral grassland
- Woodland
- Quarry
- Spoil heap
- Releve number

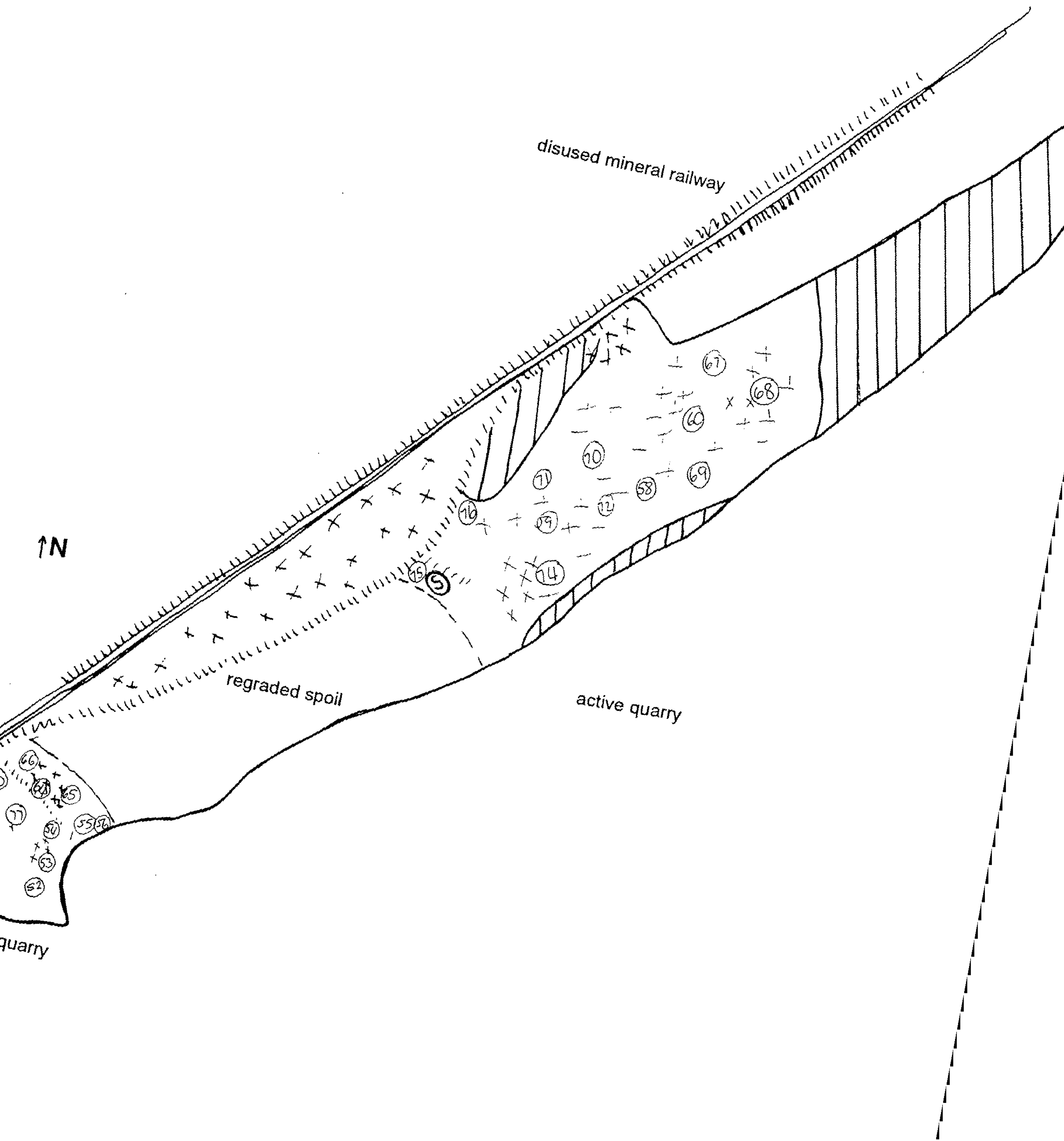
Map 1 Trimdon



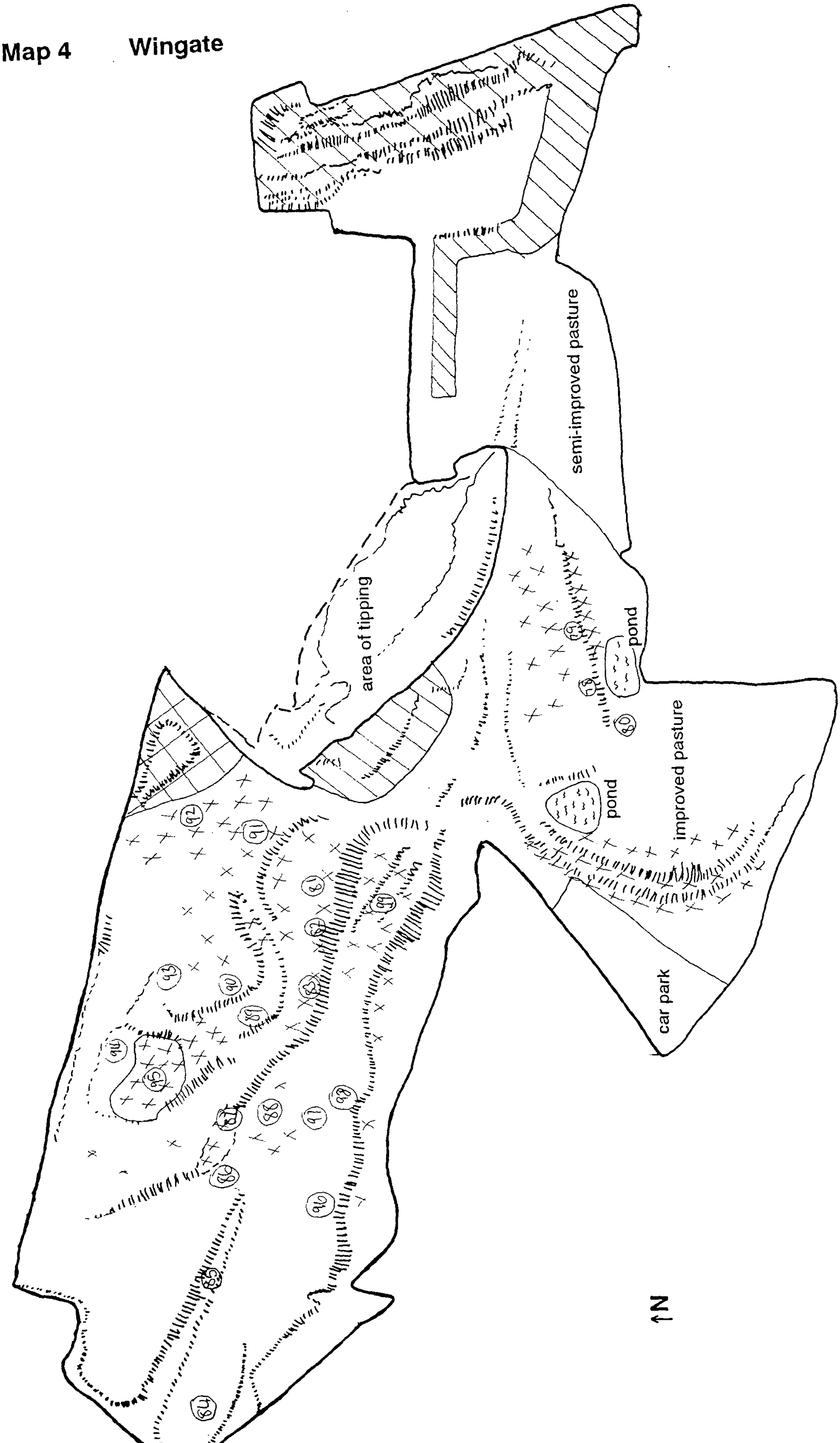
Map 2 Bishop Middleham

↑N

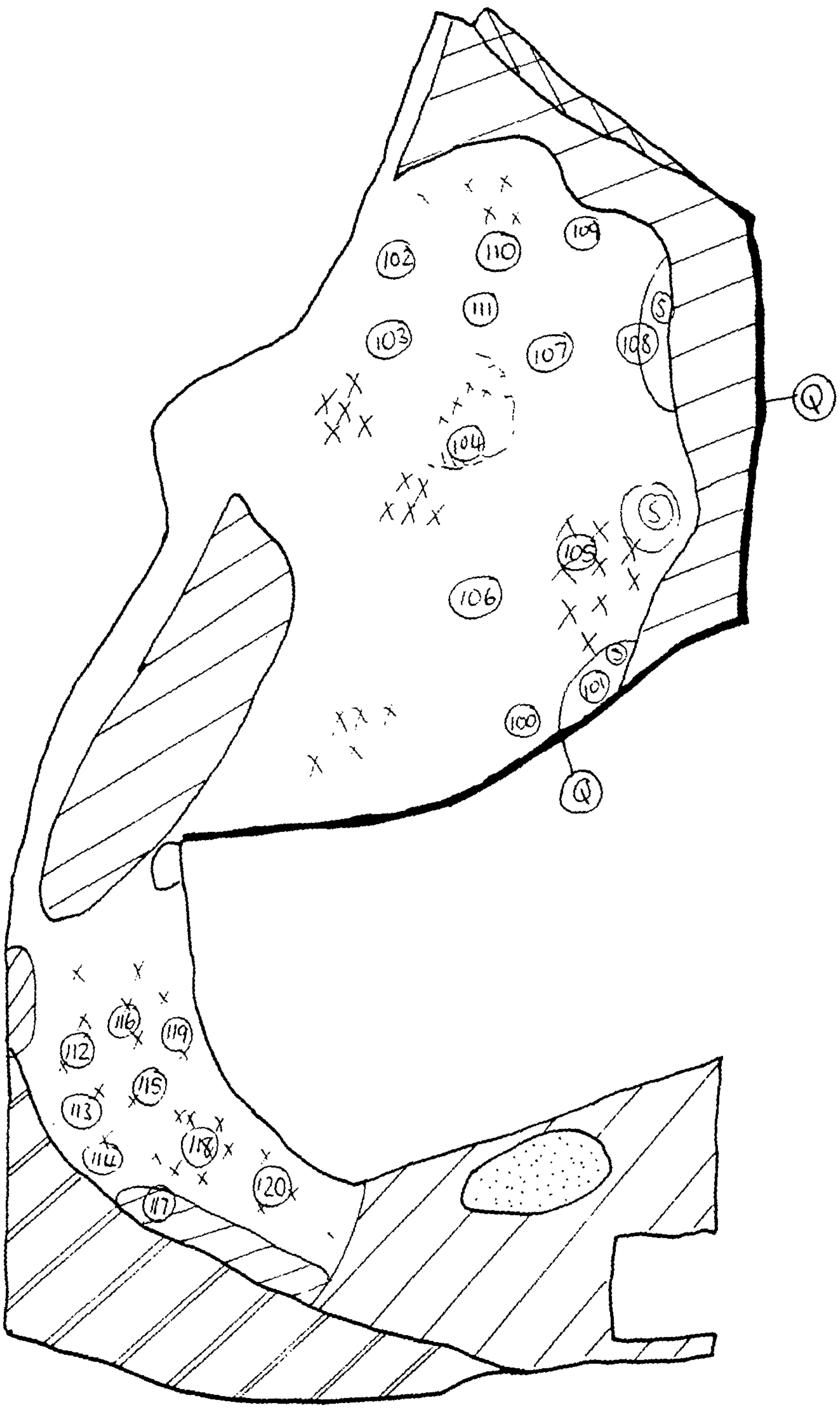
Map 3 Raisby


disused mineral railway
↑N
regraded spoil
active quarry
quarry

Map 4 Wingate

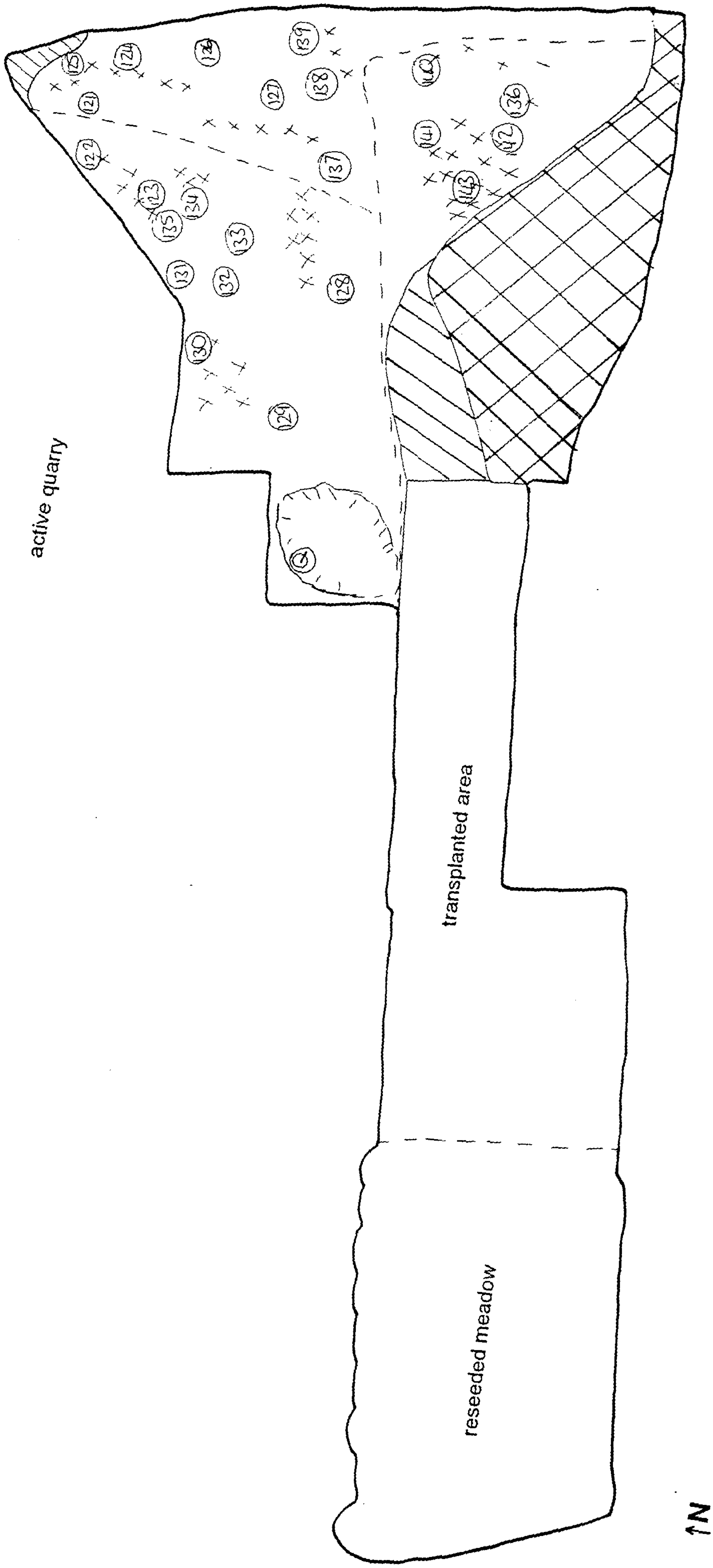


Map 5 **Pittington**

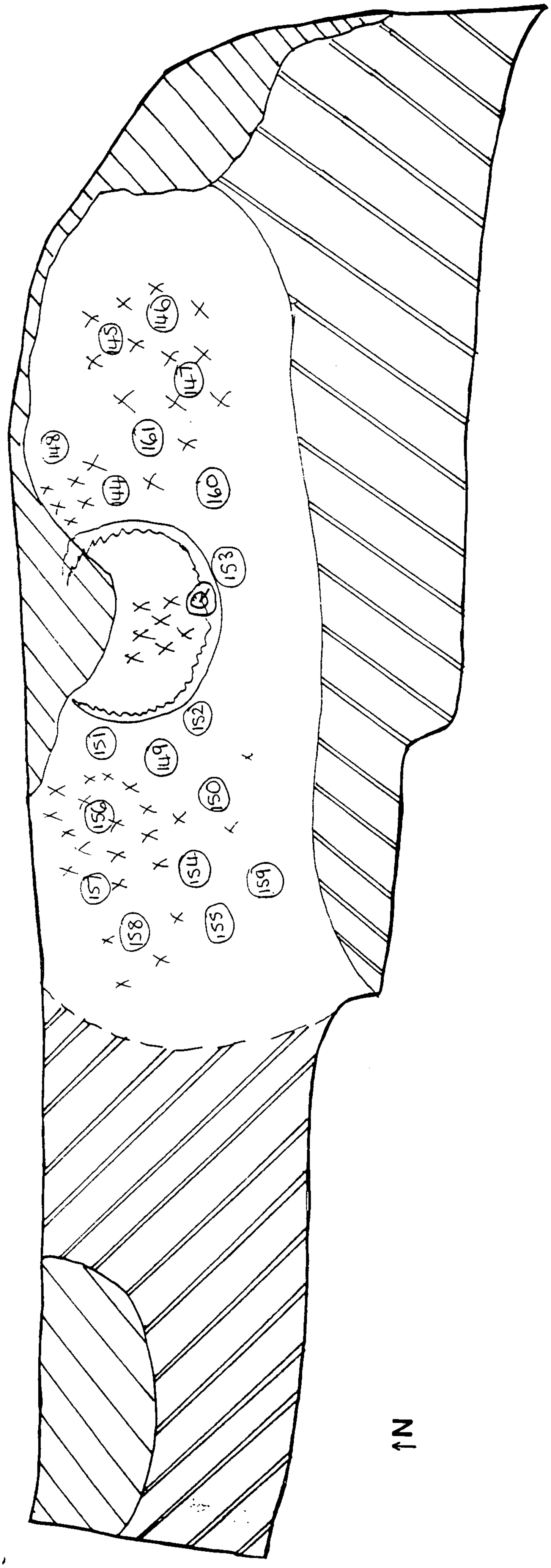


↑N

Map 6 **Thrislington**



Map 7 **Cassop Vale**



Appendix 2 - Phytosociological tables

Table 1 *Sesleria albicans* grassland - *Avenula pratensis* sub-community (in pocket)

Table 2 *Sesleria albicans* grassland - *Bromus erectus* sub-community

Table 3 *Sesleria albicans* grassland - *Hieracium pilosella* sub-community

Table 4 *Briza media* grassland (in pocket)

Table 5 *Crataegus monogyna* scrub - *Dactylis glomerata* - *Briza media* sub-community

Table 6 *Crataegus monogyna* scrub - *Brachypodium sylvaticum* sub-community

Table 7 *Holcus lanatus* grassland

Table 8 *Rubus fruticosus* agg. scrub

Table 9 *Festuca rubra* grassland

Table 2 *Sesleria albicans* grassland - *Bromus erectus* sub-community

	Relevé number	58	59	60	67	68	69	70	71	72	73	76	
	Soil pH	7.6	7.7	7.8	7.7	7.9	7.7	7.4	7.7	7.6	7.7	7.7	
	Soil depth (centimetres)	15	15	22	13	13	13	15	14	16	14	20	
	Scrub density (all species/10m^2)	0	0	0	0	50	0	0	0	0	0	0	
1245	*Sesleria albicans*	7	8	7	6	2	5	4	5	6	5	8	V
1600	*Ctenidium molluscum*	7	3	4	3	3	3	3	3	3	3	3	V
288	*Campanula rotundifolia*	3	3	3	2		2	1	3	2	1	1	V
323	*Carex flacca*	8	6	8	5	5	6	3	3		3	4	V
574	*Festuca ovina*	4			1	1	3	2	2	2	2	3	V
786	*Linum catharticum*	2	2		1		2	2	2	2	2	2	V
788	*Listera ovata*	2	3	3	1		1		1	1	1	1	V
800	*Lotus corniculatus*	3	5		3		2	2	3	2	2	2	V
2999	*Viola* seedling/sp	1		2	2	3		2	3	2	1	1	V
251	*Briza media*	1			2		2	1	1	2	3	2	IV
256	*Bromus erectus*				8	6	7	6	3	5	7	2	IV
371	*Centaurea nigra*	2			2	2	2		2	2	3	2	IV
1305	*Succisa pratensis*	3			1	1	3	3	2		2	4	IV
2611	*Crataegus monogyna* (g)		2	2	1	1	1	1	1	1			IV
234	*Stachys officinalis*	3	3	3	2	1	1	1					IV
661	*Heracleum sphondylium*	1	1	1	1	1		1			1		IV
769	*Leontodon hispidus*	1	2	1	1			1		2	2		IV
968	*Pimpinella saxifraga*	3	1				2	2	3	2		1	IV
1445	*Calliergon cuspidatum*	3	1		1	2		2	2		2		IV
1914	*Pseudoscleropodium purum*	3		2	1	2	2	1		2			IV
247	*Brachypodium sylvaticum*	1	1			4			1	1	2		III
649	*Gymnadenia conopsea*	1			1		1			1	1	1	III
656	*Avenula pubescens*	9	7	8	2	2		1					III
973	*Plantago lanceolata*	1		2	1	1		1		2			III
1046	*Potentilla erecta*		1	1			1	1		2	1		III
1677	*Eurhynchium praelongum*	1	1			2			1	2		2	III
1695	*Fissidens taxifolius*	1	1					1	2	2	2		III
675	*Hieracium* 'indeterminate'				1			1	1		1	2	III
1519	*Brachythecium rutabulum*	1			1	2			2		1		III
655	*Avenula pratensis*						1	2	6			4	II
995	*Polygala vulgaris*		1				1			2	1		II
1053	*Sanguisorba minor*		2				1			2		3	II
1059	*Prunella vulgaris*					1			1	1		1	II
1566	*Campylium chrysophyllum*		2						1		2	2	II
587	*Fragaria vesca*		1		2	3							II
702	*Hypericum pulchrum*							1	2	2			II
876	*Molinia caerulea*							7			3	2	II
1346	*Trifolium medium*							2		2	2		II
1423	*Viola hirta*								2		2	2	II
2639	*Ulex europaeus* (g)		1					1				1	II
167	*Angelica sylvestris*		1							1			I
613	*Galium verum*							4	3				I
1056	*Primula veris*								1	1			I
1136	*Rubus fruticosus* agg.					4					1		I
1249	Danthonia decumbens							1				1	I
1349	*Trifolium pratense*							1				1	I
1363	*Ulex europaeus* (s)					1			3				I
1795	*Plagiomnium rostratum*	1							2				I
1807	*Plagiomnium undulatum*					1				2			I
2615	*Fraxinus excelsior* (g)			1								1	I
2754	*Rosa canina* (g)				1				1				I
2822	*Cirsium sp*				1			1					I
197	*Arrhenatherum elatius*							1					I
372	*Centaurea scabiosa*	1											I
418	*Cirsium palustre*								1				I
445	*Crataegus monogyna* (s)	1											I
465	*Dactylis glomerata*					1							I
477	*Deschampsia cespitosa cespitos*								1				I
522	*Epilobium montanum*							1					I
576	*Festuca rubra*		2										I
583	*Filipendula ulmaria*								1				I
701	*Hypericum perforatum*								1				I
746	*Koeleria macrantha*											3	I
1066	*Pteridium aquilinum*										1		I
1103	*Reseda lutea*					1							I
1122	*Rosa canina agg.*					1							I
1350	*Trifolium repens*							1					I
1360	*Tussilago farfara*							1					I
1487	*Barbula fallax*					2							I
1490	*Barbula hornschuchiana*								2				I
1681	*Eurhynchium striatum*		2										I
1688	*Fissidens cristatus*											2	I
2003	*Thuidium tamariscinum*					2							I
2600	*Acer pseudoplatanus* (s)					1							I
2614	*Fraxinus excelsior* (s)					1							I
2760	*Rubus fruticosus* agg (g)							1					I
3065	*Weissia* sp			1									I
3282	*Seligeria* sp.				1								I
	Number of species per sample	28	26	16	28	30	21	37	36	29	29	29	

Table 3 *Sesleria albicans* grassland - *Hieracium pilosella* sub-community

	Relevé number	23	24	25	26	27	28	36	37	38	47	49	50	61	77	102	
	Soil pH	7.4	7.6	8.0	7.7	8.2	8.0	7.8	7.8	8.1	8.1	8.0	7.5	8.2	8.1	8.1	
	Soil depth (centimetres)	5	15	4	14	28	4	5	9	5	5	5	10	2	10	15	
	Scrub density (all species/$10m^2$)	0	0	0	0	0	0	35	0	0	0	0	0	0	0	0	
	Bare ground (%)	0	0	15	0	0	0	0	0	15	0	40	0	0	30	0	
965	*Hieracium pilosella* group	3	2	2	3	3	3	2	3	1	2	1	1	3	3	2	V
323	*Carex flacca*	5	4	3	3		3	3	3	6	4	3	2	5	2	8	V
800	*Lotus corniculatus*		3	2	1	3	5	3	3	2	5	3	1	2	3	3	V
1245	*Sesleria albicans*	6	9	9	10	6	8	4	4	8	7	5	3	6		7	V
654	*Helianthemum nummularium*	2	2	3	3	8	3	1	3	1		4	3	2	7		V
1600	*Ctenidium molluscum*		4	4	3		2	2	1	2		3	4	3	3	3	IV
675	*Hieracium* 'indeterminate'	1	2	1	3	1	1	2			2	2		1	3		IV
251	*Briza media*	1					2	3	2	2	4		3	4	2	2	IV
466	*Dactylorhiza fuchsii*	3	2		2		2	3	1	1	2	1	1				IV
1053	*Sanguisorba minor*	3			3	2	4			1	1	2	3	1		1	IV
1566	*Campylium chrysophyllum*	2		2	2		4	2		2	4	3		2	3		IV
288	*Campanula rotundifolia*	2	1	3	1			1		2	1				2	2	III
649	*Gymnadenia conopsea*	1	1	1			3	1	1	1	1		1				III
371	*Centaurea nigra*	1						3	3		2		3	1	1	2	III
574	*Festuca ovina*							2	2	1	3	2			3	3	III
769	*Leontodon hispidus*	2		1		2	1	3			2					3	III
1333	*Thymus praecox arcticus*	4	2			3			2	2	4	2					III
1914	*Pseudoscleropodium purum*	1	2	2	2						2		4	3			III
1205	*Scabiosa columbaria*	2	2		1					2	1					3	II
1305	*Succisa pratensis*	2	2		3	1		3	3								II
256	*Bromus erectus*	1				5							4	6	4		II
995	*Polygala vulgaris*			2	1					1				1		2	II
1056	*Primula veris*	2		1	1								1	1			II
1349	*Trifolium pratense*	1					1		1		2					2	II
2611	*Crataegus monogyna* (g)	1			1								1		2	1	II
528	*Epipactis atrorubens*									2	2	2			2		II
579	*Festuca ovina/rubra (vegetativ*	3	3		2		4										II
786	*Linum catharticum*			1							1	1		1			II
973	*Plantago lanceolata*	1						1	2		1						II
1059	*Prunella vulgaris*	2	2		1						1						II
1445	*Calliergon cuspidatum*							2	1		2			2			II
391	*Epilobium angustifolium*									1				1	1		I
568	*Euphrasia officinalis* agg										1				2	1	I
587	*Fragaria vesca*				1						1		1				I
844	*Medicago lupulina*	1				1	1										I
968	*Pimpinella saxifraga*	3			1			3									I
976	*Plantago media*	2						1								3	I
1665	*Encalypta streptocarpa*			2		1				1							I
2631	*Salix caprea* (g)								1	1				2			I
104	*Achillea millefolium*								2		1						I
174	*Anthyllis vulneraria*	1		3													I
362	*Carlina vulgaris*														2	1	I
373	*Centaurium erythraea*		2		1												I
576	*Festuca rubra*										3					3	I
656	*Avenula pubescens*				1								6				I
788	*Listera ovata*							1								1	I
1168	*Salix caprea* (s)							1			1						I
1363	*Ulex europaeus* (s)	1	1														I
1411	*Vicia cracca*					1		1									I
1493	*Barbula recurvirostra*	2			1												I
1519	*Brachythecium rutabulum*	2												1			I
1666	*Encalypta vulgaris*											2		1			I
1695	*Fissidens taxifolius*	1												1			I
2605	*Betula pubescens* (g)													1	1		I
2607	*Betula pendula* (g)													2		1	I
2615	*Fraxinus excelsior* (g)													2	1		I
2997	*Viburnum lantana* (s)													4	1		I
2999	*Viola* seedling/sp												1	2			I
123	*Agrostis capillaris*												1				I
230	*Bellis perennis*															1	I
247	*Brachypodium sylvaticum*														1		I
372	*Centaurea scabiosa*	3															I
384	*Cerastium fontanum triviale*															1	I
403	*Leucanthemum vulgare*										1						I
415	*Cirsium arvense*									1							I
445	*Crataegus monogyna* (s)													2			I
465	*Dactylis glomerata*	4															I
475	*Daucus carota*							1									I
575	*Festuca pratensis*													1			I
613	*Galium verum*				1												I
655	*Avenula pratensis*										2						I
661	*Heracleum sphondylium*								1								I
706	*Hypochoeris radicata*															1	I
743	*Knautia arvensis*	2															I
746	*Koeleria macrantha*								3								I
758	*Lathyrus pratensis*									1							I
914	*Ononis repens*			2													I
975	*Plantago maritima*															1	I
1050	*Potentilla reptans*							2									I
1167	*Salix aurita*													2			I
1487	*Barbula fallax*									2							I
1571	*Campylium stellatum*								1								I
1681	*Eurhynchium striatum*			2													I
1807	*Plagiomnium undulatum*			2													I
2601	*Acer pseudoplatanus* (g)													2			I
2604	*Betula pubescens* (s)												1				I
2606	*Betula pendula* (s)														1		I
2754	*Rosa canina* (g)								1								I
2785	*Alchemilla vulgaris* agg													1			I
2982	*Taraxacum* seedling/sp										2						I
3255	*Ulmus minor* (s)													2			I
	Number of species per sample	35	18	20	25	13	16	25	22	23	31	15	20	33	22	25	0

Table 5 Crataegus monogyna scrub - Dactylis glomerata-Briza media sub-community *continued*

1401	*Veronica officinalis*			1		2														1		I
1429	*Viola riviniana*			3				1	3													I
1695	*Fissidens taxifolius*			1								2									2	I
1807	*Plagiomnium undulatum*											1		1				2				I
2614	*Fraxinus excelsior* (s)											1	1			1						I
118	*Elymus repens*											5							3			I
174	*Anthyllis vulneraria*				1	1																I
575	*Festuca pratensis*								2				1									I
706	*Hypochoeris radicata*														2						1	I
746	*Koeleria macrantha*				1		1															I
786	*Linum catharticum*																			1	2	I
788	*Listera ovata*													2		2						I
988	*Poa pratensis*					1						2										I
1053	*Sanguisorba minor*								4												4	I
1124	*Rosa rubiginosa* agg.				1						4											I
1339	*Tragopogon pratensis*																			1	2	I
1416	*Vicia sepium*								1			2										I
1677	*Eurhynchium praelongum*		2									2										I
2611	*Crataegus monogyna (g)*													1	2							I
167	*Angelica sylvestris*						1															I
230	*Bellis perennis*									3												I
234	*Stachys officinalis*								3													I
455	*Cruciata laevipes*											4										I
460	*Cynosurus cristatus*															1						I
649	*Gymnadenia conopsea*														1							I
654	*Helianthemum nummularium*																				2	I
920	*Orchis mascula*																2					I
1050	*Potentilla reptans*												2									I
1086	*Ranunculus bulbosus*											1										I
1139	*Rumex acetosa*																	1				I
1147	*Rumex obtusifolius*																			1		I
1272	*Sonchus asper*																				1	I
1350	*Trifolium repens*		4																			I
1356	*Trisetum flavescens*																				5	I
1363	*Ulex europaeus* (s)								1													I
1522	*Brachythecium velutinum*																				1	I
1562	*Homalothecium lutescens*																1					I
1566	*Campylium chrysophyllum*								2													I
1795	*Plagiomnium rostratum*			1																		I
1914	*Pseudoscleropodium purum*																	2				I
1940	*Rhytidiadelphus squarrosus*																	4				I
2735	*Ranunculus* seedling/sp													1								I
2746	*Rosa* seedling/sp															1						I
2954	*Rosa rubiginosa* (g)						1															I
	Number of species per sample	23	23	29	26	28	24	24	25	21	21	29	24	22	21	23	25	28	21	31	31	

Table 6 *Crataegus monogyna scrub - Brachypodium sylvaticum* sub-community

	Relevé number	65	66	74	95	123	131	133	135	143	145	146	147	156	
	Soil pH	8.0	8.0	8.0	8.0	7.7	7.7	7.8	7.7	7.5	7.9	7.8	7.8	7.6	
	Soil depth (centimetres)	4	9	33	15	20	22	20	24	17	22	17	18	14	
	Scrub density (all species/10m^2)	29	29	81	35	65	0	0	84	97	50	50	50	26	
247	*Brachypodium sylvaticum*	4	2	4	5	7	8	8	4	5	5	7	7	1	V
973	*Plantago lanceolata*	3	3	3	2	3	1	2	2		2	3	3	2	V
445	*Crataegus monogyna (s)*	1	1	4	1	2	1	1	2	2			2	2	V
1136	*Rubus fruticosus agg.*	1		4		1	2	1	2	3	5	3	3	1	V
323	*Carex flacca*		1		4	2	2	5	5	5	4	5	2		IV
576	*Festuca rubra*	8	7		5	6	5	5			6	4	5	2	IV
1445	*Calliergon cuspidatum*	3	3	2	4	3		3	1	3	2		2		IV
465	*Dactylis glomerata*	2			3	2	1	1	1	1	1			1	IV
661	*Heracleum sphondylium*	4		4	5	2	1		1	1		3		2	IV
1056	*Primula veris*	2	2		2	2	1	1	1	1	2				IV
1677	*Eurhynchium praelongum*			2	3	3	2	2	4	3		2	1		IV
371	*Centaurea nigra*	2	2	2		2			5	4	1		2		IV
587	*Fragaria vesca*		2	1	2		3	1		3		1	2		IV
769	*Leontodon hispidus*	3	3	1	2	2	1					2	2		IV
800	*Lotus corniculatus*	4	2		2	3	1	1		3	2				IV
1059	*Prunella vulgaris*		1		1	3		1			1	3	1	1	IV
1122	*Rosa canina agg.*	1		2	1	1			1	1		3	4		IV
1807	*Plagiomnium undulatum*			2	3	3	2	2		2	2			3	IV
1914	*Pseudoscleropodium purum*	8	5				2	2		1	2	2	2		IV
575	*Festuca pratensis*	4	3		6	1	1	2	3						III
1053	*Sanguisorba minor*		3			3	2	2		2	1		1		III
1411	*Vicia cracca*	1			2	1	1			1		2	2		III
1423	*Viola hirta*	1		2		4		1	3	3		4			III
1429	*Viola riviniana*	1					2		3	2	3	3	3		III
2982	*Taraxacum* seedling/sp				1	1				1	2	1	1		III
2999	*Viola* seedling/sp		2	2	3	1		3						3	III
251	*Briza media*			1		3	2	1		1					II
788	*Listera ovata*		2			1	1		1	1					II
968	*Pimpinella saxifraga*	3				2	1	1	2						II
1050	*Potentilla reptans*	2	3			2			1					3	II
1360	*Tussilago farfara*	2	2	2					1			1			II
1519	*Brachythecium rutabulum*			3		2			1	2				3	II
2614	*Fraxinus excelsior* (s)		1		1				6	2	4				II
256	*Bromus erectus*	2	8				5	2							II
372	*Centaurea scabiosa*				1	1	1		2						II
415	*Cirsium arvense*					1						1	1	2	II
675	*Hieracium 'indeterminate'*		2					1		1		1			II
743	*Knautia arvensis*	2	2			2							1		II
1245	*Sesleria albicans*					1		1			1		1		II
1349	*Trifolium pratense*					2		2	2				2		II
1363	*Ulex europaeus* (s)			4							6	7	8		II
1396	*Veronica chamaedrys*				2	1							1	3	II
1695	*Fissidens taxifolius*			2		3		1	2						II
2611	*Crataegus monogyna* (g)				1						2	2		2	II
104	*Achillea millefolium*					3	1	2							II
118	*Elymus repens*									5	1	1			II
633	*Geum rivale*	1	3									1			II
655	*Avenula pratensis*		2				1							2	II
680	*Holcus lanatus*				2								2	6	II
702	*Hypericum pulchrum*						2			1	2				II
758	*Lathyrus pratensis*				2								1	3	II
786	*Linum catharticum*										3	2	1		II
995	*Polygala vulgaris*					1				1			2		II
1401	*Veronica officinalis*	1			1							1			II
1522	*Brachythecium velutinum*							1	4					3	II
1600	*Ctenidium molluscum*		6	3						2					II
113	*Agrimonia eupatoria*						1			1					I
167	*Angelica sylvestris*										1		3		I
230	*Bellis perennis*										1		1		I
288	*Campanula rotundifolia*			1		1									I
384	*Cerastium fontanum triviale*					1								2	I
418	*Cirsium palustre*									2	2				I
455	*Cruciata laevipes*				2				1						I
475	*Daucus carota*						1	1							I
477	*Deschampsia cespitosa cespitos*			4									2		I
574	*Festuca ovina*			2										7	I
583	*Filipendula ulmaria*			4							1				I
706	*Hypochoeris radicata*			1						1					I
981	*Poa annua*					1					4				I
1086	*Ranunculus bulbosus*										1			1	I
1205	*Scabiosa columbaria*							2				1			I
1239	*Senecio jacobaea*										1		1		I
1682	*Eurhynchium swartzii*		1							1					I
1940	*Rhytidiadelphus squarrosus*										1	1			I
3065	*Weissia sp*					2						1			I
122	*Agrostis stolonifera*													1	I
174	*Anthyllis vulneraria*										1				I

Table 6 *Crataegus monogyna scrub - Brachypodium sylvaticum* sub-community *continued*

197	*Arrhenatherum elatius*	2													I
234	*Stachys officinalis*			3											I
403	*Leucanthemum vulgare*				2										I
433	*Convolvulus arvensis*											1			I
528	*Epipactis atrorubens*									1					I
573	*Festuca gigantea*													3	I
605	*Galium aparine*													2	I
613	*Galium verum*									2					I
630	*Geranium robertianum*													2	I
654	*Helianthemum nummularium*						4								I
746	*Koeleria macrantha*										1				I
876	*Molinia caerulea*			2											I
976	*Plantago media*						2								I
990	*Poa trivialis*													2	I
1081	*Ranunculus acris*												1		I
1095	*Ranunculus repens*											1			I
1191	*Sanicula europaea*									1					I
1244	*Serratula tinctoria*			2											I
1293	*Stachys sylvatica*								3						I
1305	*Succisa pratensis*										2				I
1346	*Trifolium medium*												2		I
1356	*Trisetum flavescens*													2	I
1409	*Viburnum opulus*								1						I
1513	*Brachythecium glareosum*							2							I
1514	*Brachythecium mildeanum*						2								I
1566	*Campylium chrysophyllum*					2									I
1688	*Fissidens cristatus*											1			I
1801	*Rhizomnium punctatum*										1				I
2003	*Thuidium tamariscinum*										2				I
2232	*Jungermannia hyalina*										1				I
2600	*Acer pseudoplatanus* (s)									1					I
2606	*Betula pendula* (s)		1												I
2625	*Quercus petraea* (s)		1												I
2754	*Rosa canina* (g)							4							I
2760	*Rubus fruticosus agg* (g)				2										I
2822	*Cirsium sp*			1											I
2997	*Viburnum lantana* (s)	1													I
	Number of species per sample	27	29	29	30	42	32	32	28	37	37	31	34	28	

Table 7 *Holcus lanatus* grassland

	Relevé number	39	40	96	105	106	
	Soil pH	7.7	7.6	8.0	7.7	7.8	
	Soil depth (centimetres)	20	25	12	7	9	
465	*Dactylis glomerata*	3	3	5	4	4	V
576	*Festuca rubra*	7	7	3	7	7	V
680	*Holcus lanatus*	3	3	4	6	8	V
973	*Plantago lanceolata*	3	4	3	5	5	V
1519	*Brachythecium rutabulum*	7	7	2	3	2	V
104	*Achillea millefolium*	2	4	3		1	IV
371	*Centaurea nigra*	4	5	2	1		IV
384	*Cerastium fontanum triviale*	2	2		1	1	IV
661	*Heracleum sphondylium*	3	3	3		1	IV
981	*Poa annua*	2	6		6	5	IV
1396	*Veronica chamaedrys*	2	2		3	5	IV
118	*Elymus repens*		7		3	2	III
197	*Arrhenatherum elatius*	8	4	2			III
758	*Lathyrus pratensis*		3		3	2	III
1081	*Ranunculus acris*		1		3	2	III
1356	*Trisetum flavescens*	2	3		4		III
2982	*Taraxacum* seedling/sp	1	2	1			III
372	*Centaurea scabiosa*	2	3				II
655	*Avenula pratensis*			3	3		II
1056	*Primula veris*		1		2		II
1239	*Senecio jacobaea*				2	1	II
1339	*Tragopogon pratensis*	1	1				II
1349	*Trifolium pratense*				1	2	II
1411	*Vicia cracca*		2	3			II
1416	*Vicia sepium*	3	4				II
1677	*Eurhynchium praelongum*	3	2				II
2611	*Crataegus monogyna (g)*	1	1				II
251	*Briza media*			2			I
323	*Carex flacca*				1		I
391	*Epilobium angustifolium*			2			I
415	*Cirsium arvense*	1					I
445	*Crataegus monogyna* (s)				1		I
455	*Cruciata laevipes*		4				I
466	*Dactylorhiza fuchsii*			2			I
613	*Galium verum*	3					I
649	*Gymnadenia conopsea*	2					I
743	*Knautia arvensis*		2				I
800	*Lotus corniculatus*			3			I
968	*Pimpinella saxifraga*	3					I
1059	*Prunella vulgaris*				1		I
1136	*Rubus fruticosus* agg.				1		I
1139	*Rumex acetosa*				1		I
1147	*Rumex obtusifolius*	2					I
1205	*Scabiosa columbaria*				2		I
1245	*Sesleria albicans*				1		I
1259	*Silene vulgaris*	1					I
1350	*Trifolium repens*					2	I
1360	*Tussilago farfara*			1			I
1368	*Urtica dioica*	1					I
1445	*Calliergon cuspidatum*					2	I
1795	*Plagiomnium rostratum*				3		I
2614	*Fraxinus excelsior* (s)		1				I
2615	*Fraxinus excelsior* (g)	1					I
2709	*Trifolium* seedling/sp				3		I
	Number of species per sample	27	27	17	26	17	0

Table 8: *Rubus fruticosus* agg. scrub

	Relevé number	117	119	120	
	Soil pH	8.0	7.8	7.7	
	Soil depth (centimetres)	10	7	8	
	Scrub density (all species/$10m^2$)	62	0	0	
	Percentage bare ground	0	0	5	
371	*Centaurea nigra*	3	2	2	V
576	*Festuca rubra*	6	7	7	V
587	*Fragaria vesca*	2	1	1	V
613	*Galium verum*	1	2	2	V
661	*Heracleum sphondylium*	2	3	1	V
968	*Pimpinella saxifraga*	2	2	2	V
973	*Plantago lanceolata*	3	3	2	V
1053	*Sanguisorba minor*	2	3	4	V
1136	*Rubus fruticosus* agg.	4	6	4	V
104	*Achillea millefolium*	2	2		IV
415	*Cirsium arvense*	1	1		IV
465	*Dactylis glomerata*	3	3		IV
654	*Helianthemum nummularium*		2	3	IV
656	*Avenula pubescens*	3	1		IV
1056	*Primula veris*	1		2	IV
1205	*Scabiosa columbaria*	2		2	IV
1245	*Sesleria albicans*		1	1	IV
1356	*Trisetum flavescens*	3		1	IV
1363	*Ulex europaeus* (s)		4	3	IV
1396	*Veronica chamaedrys*	2	1		IV
1423	*Viola hirta*	1		2	IV
2611	*Crataegus monogyna* (g)		1	1	IV
2982	*Taraxacum* seedling/sp	1	1		IV
122	*Agrostis stolonifera*		1		II
185	*Arabis hirsuta*			2	II
247	*Brachypodium sylvaticum*	2			II
384	*Cerastium fontanum triviale*			1	II
445	*Crataegus monogyna* (s)	1			II
655	*Avenula pratensis*			1	II
675	*Hieracium* 'indeterminate'			1	II
680	*Holcus lanatus*	6			II
800	*Lotus corniculatus*	2			II
844	*Medicago lupulina*	1			II
976	*Plantago media*	2			II
1059	*Prunella vulgaris*	2			II
1086	*Ranunculus bulbosus*	1			II
1122	*Rosa canina* agg.			1	II
1339	*Tragopogon pratensis*			1	II
1349	*Trifolium pratense*	2			II
1429	*Viola riviniana*			1	II
1682	*Eurhynchium swartzii*	2			II
1695	*Fissidens taxifolius*	1			II
2999	*Viola* seedling/sp	1			II
3065	*Weissia* sp	1			II
	Number of species per sample	32	20	24	0

Table 9 *Festuca rubra* grassland

	Relevé number	101	107	110	
	Soil pH	7.8	7.8	8.0	
	Soil depth (centimetres)	14	12	10	
104	*Achillea millefolium*	1	1	1	V
465	*Dactylis glomerata*	1	2	2	V
576	*Festuca rubra*	8	7	6	V
973	*Plantago lanceolata*	3	3	2	V
981	*Poa annua*	2	2	2	V
1205	*Scabiosa columbaria*	1	2	3	V
1349	*Trifolium pratense*	3	3	3	V
230	*Bellis perennis*		4	3	IV
251	*Briza media*	2		2	IV
371	*Centaurea nigra*	8		2	IV
568	*Euphrasia officinalis agg*		2	2	IV
786	*Linum catharticum*	1		1	IV
800	*Lotus corniculatus*	6		6	IV
844	*Medicago lupulina*		9	7	IV
976	*Plantago media*	1	1		IV
1056	*Primula veris*	4		2	IV
1081	*Ranunculus acris*	1	3		IV
1239	*Senecio jacobaea*	1	1		IV
1356	*Trisetum flavescens*	2		1	IV
1445	*Calliergon cuspidatum*		1	2	IV
1519	*Brachythecium rutabulum*	3	1		IV
1795	*Plagiomnium rostratum*	3		2	IV
2807	*Bryum sp*		2	1	IV
118	*Elymus repens*			1	II
288	*Campanula rotundifolia*	1			II
323	*Carex flacca*	2			II
384	*Cerastium fontanum triviale*			1	II
403	*Leucanthemum vulgare*	2			II
445	*Crataegus monogyna (s)*	1			II
574	*Festuca ovina*			2	II
613	*Galium verum*			1	II
661	*Heracleum sphondylium*	3			II
680	*Holcus lanatus*	3			II
746	*Koeleria macrantha*			2	II
769	*Leontodon hispidus*	3			II
796	*Lolium perenne*		1		II
965	*Hieracium pilosella group*	1			II
990	*Poa trivialis*	2			II
1059	*Prunella vulgaris*	1			II
1086	*Ranunculus bulbosus*			2	II
1305	*Succisa pratensis*			1	II
1460	*Amblystegium serpens*		1		II
1487	*Barbula fallax*		2		II
1490	*Barbula hornschuchiana*			2	II
1682	*Eurhynchium swartzii*			1	II
1807	*Plagiomnium undulatum*			1	II
1940	*Rhytidiadelphus squarrosus*			2	II
	Number of species per sample	28	19	30	0

Appendix 3 - Complete species list with codes

2600	Acer pseudoplatanus (s)
2601	Acer pseudoplatanus (g)
104	Achillea millefolium
113	Agrimonia eupatoria
122	Agrostis stolonifera
123	Agrostis capillaris
127	Ajuga reptans
2785	Alchemilla vulgaris agg
167	Angelica sylvestris
168	Antennaria dioica
174	Anthyllis vulneraria
184	Arabidopsis thaliana
185	Arabis hirsuta
197	Arrhenatherum elatius
655	Avenula pratensis
656	Avenula pubescens
230	Bellis perennis
2606	Betula pendula (s)
2607	Betula pendula (g)
2604	Betula pubescens (s)
2605	Betula pubescens (g)
247	Brachypodium sylvaticum
251	Briza media
256	Bromus erectus
288	Campanula rotundifolia
323	Carex flacca
362	Carlina vulgaris
371	Centaurea nigra
372	Centaurea scabiosa
373	Centaurium erythraea
384	Cerastium fontanum triviale
2822	Cirsium sp
415	Cirsium arvense
418	Cirsium palustre
419	Cirsium vulgare
431	Conopodium majus
433	Convolvulus arvensis
2610	Corylus avellana (g)
2611	Crataegus monogyna (g)
445	Crataegus monogyna (s)
455	Cruciata laevipes
460	Cynosurus cristatus
465	Dactylis glomerata
3192	Dactylorhiza sp.
466	Dactylorhiza fuchsii
3192	Dactylorhiza sp.
3255	Ulmus minor (s)
1249	Danthonia decumbens
475	Daucus carota
477	Deschampsia cespitosa
118	Elymus repens
391	Epilobium angustifolium
522	Epilobium montanum
528	Epipactis atrorubens
532	Equisetum arvense
543	Erigeron acer
568	Euphrasia officinalis agg
573	Festuca gigantea
574	Festuca ovina
575	Festuca pratensis
576	Festuca rubra
579	Festuca ovina/rubra
583	Filipendula ulmaria
587	Fragaria vesca
2614	Fraxinus excelsior (s)
2615	Fraxinus excelsior (g)
605	Galium aparine
613	Galium verum
619	Gentianella amarella
630	Geranium robertianum
633	Geum rivale
649	Gymnadenia conopsea
654	Helianthemum nummularium
661	Heracleum sphondylium
675	Hieracium sp.
965	Hieracium pilosella group
680	Holcus lanatus
700	Hypericum montanum
701	Hypericum perforatum
702	Hypericum pulchrum
706	Hypochoeris radicata
743	Knautia arvensis
746	Koeleria macrantha
758	Lathyrus pratensis
769	Leontodon hispidus
403	Leucanthemum vulgare
783	Linaria vulgaris
784	Linum perenne anglicum
786	Linum catharticum
788	Listera ovata
796	Lolium perenne
800	Lotus corniculatus
844	Medicago lupulina
876	Molinia caerulea
914	Ononis repens
918	Ophrys apifera
920	Orchis mascula
968	Pimpinella saxifraga
970	Pinguicula vulgaris
973	Plantago lanceolata
975	Plantago maritima
976	Plantago media
2721	Poa sp
981	Poa annua
988	Poa pratensis
990	Poa trivialis
995	Polygala vulgaris
1043	Potentilla anserina
1046	Potentilla erecta
1050	Potentilla reptans
1051	Potentilla sterilis
1056	Primula veris
1059	Prunella vulgaris
1066	Pteridium aquilinum
2625	Quercus petraea (s)
2628	Quercus robur (g)
2735	Ranunculus seedling/sp
1081	Ranunculus acris
1086	Ranunculus bulbosus
1095	Ranunculus repens
1103	Reseda lutea
1106	Rhinanthus minor
2746	Rosa seedling/sp
2754	Rosa canina (g)
1122	Rosa canina agg.
1123	Rosa pimpinellifolia
1124	Rosa rubiginosa agg.
2954	Rosa rubiginosa
2760	Rubus fruticosus agg (g)
1136	Rubus fruticosus agg.
1139	Rumex acetosa
1147	Rumex obtusifolius
1158	Sagina procumbens
167	Salix aurita
2631	Salix caprea (g)
1168	Salix caprea (s)
1169	Salix cinerea (s)
1053	Sanguisorba minor

1191 Sanicula europaea
1205 Scabiosa columbaria
1239 Senecio jacobaea
1244 Serratula tinctoria
1245 Sesleria albicans
1259 Silene vulgaris
1272 Sonchus asper
234 Stachys officinalis
1293 Stachys sylvatica
1305 Succisa pratensis
2982 Taraxacum seedling/sp
1333 Thymus praecox arcticus
1339 Tragopogon pratensis
2709 Trifolium seedling/sp
1346 Trifolium medium
1349 Trifolium pratense
1350 Trifolium repens
1356 Trisetum flavescens
1360 Tussilago farfara
2639 Ulex europaeus (g)
1363 Ulex europaeus (s)
3255 Ulmus minor (s)
1368 Urtica dioica
1396 Veronica chamaedrys
1401 Veronica officinalis
2997 Viburnum lantana (s)
1409 Viburnum opulus
1411 Vicia cracca
1416 Vicia sepium
2999 Viola seedling/sp
1423 Viola hirta
1426 Viola odorata
1429 Viola riviniana
1460 Amblystegium serpens
1486 Barbula cylindrica
1487 Barbula fallax
1490 Barbula hornschuchiana
1493 Barbula recurvirostra

1510 Brachythecium albicans
1513 Brachythecium glareosum
1514 Brachythecium mildeanum
1519 Brachythecium rutabulum
1522 Brachythecium velutinum
2807 Bryum sp
1445 Calliergon cuspidatum
1566 Campylium chrysophyllum
1571 Campylium stellatum
1600 Ctenidium molluscum
1621 Dicranella varia
1665 Encalypta streptocarpa
1666 Encalypta vulgaris
1677 Eurhynchium praelongum
1681 Eurhynchium striatum
1682 Eurhynchium swartzii
1683 Fissidens adianthoides
1688 Fissidens cristatus
1695 Fissidens taxifolius
1562 Homalothecium lutescens
1795 Plagiomnium rostratum

1807 Plagiomnium undulatum
1914 Pseudoscleropodium purum
1801 Rhizomnium punctatum
1940 Rhytidiadelphus squarrosus
3282 Seligeria sp.
2003 Thuidium tamariscinum
3065 Weissia sp

2819 Cephalozia sp
2703 Cephaloziella sp
2110 Conocephalum conicum
2150 Leiocolea badensis
2167 Lophocolea bidentata
2180 Lophozia ventricosa
2232 Jungermannia hyalina
2183 Marchantia polymorpha

Appendix 4: Description of relevés

Trimdon

1	DG	*Crataegus/Rosa canina* scrub
2	DG	quarry floor, near scrub
3	DG	quarry floor, near scrub
4	BM	quarry floor, short grassland
5	BM	quarry floor, short grassland
6	BM	quarry floor, short grassland
7	DG	*Crataegus* scrub
8	DG	*Crataegus* scrub
9	DG	*Crataegus* scrub
10	BM	quarry floor, short grassland
11	BM	quarry floor, short grassland
12	DG	quarry floor, near scrub
13	DG	quarry wall, well-colonised
14	BM	quarry floor, short grassland
15	BM	quarry floor, short grassland
16	BM	quarry floor, short grassland
17	BM	quarry wall, sparsely colonised
18	BM	quarry floor, sparsely colonised
19	BM	quarry floor, sparsely colonised
20	DG	quarry wall, well-colonised
21	DG	quarry wall, well-colonised
22	BM	quarry floor, sparsely colonised

Bishop Middleham

23	HP	quarry rim, well-colonised
24	HP	quarry floor, well-colonised
25	HP	quarry floor, well-colonised
26	HP	quarry floor, well-colonised
27	HP	quarry wall, well-colonised
28	HP	quarry floor, well colonised
29	BM	quarry floor, sparsely colonised
30	BM	top of spoil heap, sparsely colonised
31	BM	top of spoil heap, sparsely colonised
32	BM	top of spoil heap, sparsely colonised
33	DG	*Crataegus/Fraxinus* scrub
34	BM	quarry wall, sparsely colonised
35	BM	east of spoil heap, well-colonised
36	HP	*Salix* scrub on quarry floor
37	HP	quarry floor, well-colonised
38	HP	1st shelf, well-colonised
39	HL	*Crataegus/Rosa* scrub
40	HL	*Crataegus/Rosa* scrub
41	BM	*Salix* scrub on quarry floor
42	BM	quarry floor, open grassland
43	BM	quarry floor, open grassland
44	BM	quarry floor, open grassland
45	BM	quarry floor, open grassland
46	BM	quarry floor, open grassland
47	HP	1st shelf, well-colonised
48	BM	1st shelf, sparsely colonised
49	HP	1st shelf, well-colonised

Wingate

50	HP	quarry floor - well-colonised
51	BM	quarry floor - well-colonised
52	BM	quarry floor - well-colonised
53	BM	quarry floor - well-colonised
54	BM	quarry floor - well-colonised
55	BM	quarry floor - sparsely colonised
56	BM	quarry floor - sparsely colonised
57	BM	quarry floor - well-colonised
58	BE	hillside - grassland
59	BE	hillside - grassland
60	BE	hillside - grassland
61	HP	quarry floor - well-colonised
62	BM	quarry floor - sparsely colonised
63	BM	quarry floor - sparsely colonised
64	DG	spoil heap in quarry - mixed scrub
65	BS	spoil heap in quarry - mixed scrub
66	BS	spoil heap in quarry - mixed scrub
67	BE	hillside - grassland
68	BE	hillside - in mixed scrub
69	BE	hillside - grassland
70	BE	hillside - grassland
71	BE	hillside - grassland
72	BE	hillside - grassland
73	BE	hillside - grassland
74	BS	hillside - in mixed scrub
75	BM	sparsely colonised spoil, on hillside
76	BE	hillside - grassland
77	HP	quarry floor - sparsely colonised

Raisby

78	BM	open grassland
79	BM	open grassland
80	BM	open grassland
81	BM	open grassland
82	DG	tall grassland on spoil heap
83	DG	tall grassland on spoil heap
84	BM	quarry floor - open grassland
85	BM	quarry floor - open grassland
86	BM	quarry floor - open grassland
87	DG	tall grassland on spoil heap
88	DG	quarry floor - tall grassland
89	BM	quarry floor - open grassland
90	BM	quarry floor - open grassland
91	BM	quarry floor - open grassland
92	DG	*Crataegus* scrub
93	BM	quarry floor - open grassland
94	BM	quarry floor - open grassland
95	BS	*Crataegus* scrub
96	HL	tall grassland on spoil heap
97	BM	tall grassland on spoil heap
98	DG	tall grassland on spoil heap
99	DG	*Crataegus/Rosa* scrub

Pittington

100	BM	quarry floor - open grassland
101	FR	slope of spoil heap - tall grassland
102	HP	quarry floor - open grassland
103	BM	quarry floor - open grassland
104	BM	quarry floor - open grassland
105	HL	quarry floor - mixed scrub
106	HL	quarry floor - tall grassland
107	FR	quarry floor - short herbaceous
108	BM	quarry floor - open grassland
109	BM	quarry floor - open grassland
110	FR	quarry floor - short herbaceous
111	BM	quarry floor - open grassland
112	AP	hillside - primary grassland
113	AP	hillside - primary grassland
114	AP	hillside - primary grassland
115	AP	hillside - primary grassland
116	AP	hillside - primary grassland
117	RF	hillside - in *Prunus spinosa* scrub
118	DG	hillside - in *Crataegus* scrub
119	RF	hillside - *Rubus fruticosus* scrub
120	RF	hillside - *Rubus fruticosus* scrub

Thrislington

121	AP	grassland
122	AP	grassland
123	BS	*Crataegus/Rosa* scrub
124	AP	grassland
125	AP	grassland
126	AP	grassland
127	AP	grassland
128	AP	grassland
129	AP	grassland
130	AP	grassland
131	BS	grassland - in area of scrub clearance
132	AP	grassland - in area of scrub clearance
133	BS	grassland - in area of scrub clearance
134	AP	grassland
135	BS	*Fraxinus* scrub
136	AP	grassland
137	AP	grassland
138	AP	grassland
139	AP	grassland
140	AP	grassland
141	AP	grassland
142	AP	grassland
143	BS	*Crataegus* scrub

Cassop Vale

144	AP	grassland
145	BS	*Ulex/Crataegus* scrub
146	BS	*Ulex/Crataegus* scrub
147	BS	*Ulex/Crataegus* scrub
148	AP	grassland
149	AP	grassland
150	AP	grassland
151	AP	grassland
152	AP	grassland
153	AP	grassland
154	AP	grassland
155	AP	grassland
156	BS	*Crataegus* scrub
157	AP	grassland
158	AP	grassland
159	AP	grassland
160	AP	grassland
161	AP	grassland

Appendix 5 Species confined to primary and secondary grasslands and their distributions

Primary only	Distribution	Secondary only	Distribution
Agrimonia eupatoria	W	*Agrostis capillaris*	W
Antennaria dioica	NM	*Ajuga reptans*	W
Arabidopsis thaliana	CS	*Alchemilla vulgaris* agg.	CN
Brachythecium glareosum	W	*Betula pubescens*	W
Cirsium palustre	W	*Epilobium angustifolium*	W
Conopodium majus	W	*Erigeron acer*	C
Convolvulus arvensis	W	*Hypericum montanum*	W
Corylus avellana	W	*Linaria vulgaris*	W
Epilobium montanum	W	*Lolium perenne*	W
Galium aparine	W	*Ononis repens*	W
Geranium robertanium	W	*Ophrys apifera*	CN
Linum perenne anglicum	ENDEMIC	*Orchis mascula*	W
Potentilla erecta	W	*Pinguicula vulgaris*	W
Potentilla sterilis	W	*Poa pratensis*	W
Pteridium aqunilinum	W	*Potentilla anserina*	C
Quercus robur	W	*Quercus patraea*	W
Reseda lutea	SSA (intro.)	*Rosa rubiginosa*	W
Rosa pimpinellifolia	W	*Rumex acetosa*	CN
Sanicula europaea	W	*Rumex obtusifolius*	W
Serratula tinctoria	C	*Sagina procumbens*	W
Sonchus asper	W	*Salix aurita*	W
Stachys sylvatica	W	*Salix caprea*	W
Viburnum opulus	W	*Salix cinerea*	W
		Silene vulgaris	W
Rhizomnium punctatum		*Ulmus minor*	W
Thuidium tamariscinum		*Urtica dioica*	W
Jungermannia hyalina		*Viburnum lantana*	W
		Vicia sepium	W
		Amblystegium serpens	
		Barbula cylindrica	
		Brachythecium albicans	
		Dicranella varia	
		Encalypta streptocarpa	
		Encalypta vulgaris	
		Cephalozia sp.	
		Conocephalum conicum	
		Leiocolea badensis	
		Lophocolea bidentata	
		Lophozia ventricosa	
		Marchantia polymorpha	

W = WIDE ELEMENT - Species which are widespread and have a nearly continuous distribution in Europe; also cosmopolitan worldwide.
NM = NORTHERN MONTANE - Species with distributions centred on northern Europe where they occur in woodland or sub-alpine zones. Restricted to sub-alpine or montane habitats in southern Europe.
CS = CONTINENTAL SOUTHERN - Species of central and southern Europe, extending into the Mediterranean region. They do not extend further north than South Scandinavia.
ENDEMIC = endemic to County Durham.
SSA (intro.) = SOUTHERN SUB-ATLANTIC (Introduced) = Species widespread in the Atlantic province of Europe, reaching parts of central Europe but absent from Fennoscandia (or only in the extreme south)
C = CONTINENTAL - Species with an eastern distribution in Europe, with headquarters in central Europe but may extend into Russia and Asia.
CN = CONTINENTAL NORTHERN - Species of northern or central Europe, extending northwards to the Arctic Circle. (After Graham, 1988).

Appendix 6

Species lists

These species lists are not comprehensive, since only grassland and moderately dense areas of scrub were surveyed. Species occurring in only dense scrub, woodland or other habitats are not included.

Trimdon Species List

Achillea millefolium
Angelica sylvestris
Anthyllis vulneraria
Arrhenatherum elatius
Avenula pratensis
Avenula pubescens
Bellis perennis
Brachypodium sylvaticum
Briza media
Carex flacca
Carlina vulgaris
Centaurea nigra
Centaurea scabiosa
Centaurium erythraea
Crataegus monogyna
Dactylis glomerata
Dactylorhiza fuchsii
Daucus carota
Epilobium angustifolium
Erigeron acer
Euphrasia officinalis agg
Festuca ovina
Festuca pratensis
Festuca rubra
Fragaria vesca
Gentianella amarella
Gymnadenia conopsea
Heracleum sphondylium
Hieracium sp
Hieracium pilosella
Holcus lanatus
Hypericum montanum
Hypericum pulchrum
Knautia arvensis
Koeleria macrantha
Lathyrus pratensis
Leontodon hispidus
Leucanthemum vulgare
Linum catharticum
Lotus corniculatus
Medicago lupulina
Pimpinella saxifraga
Plantago lanceolata
Plantago media
Poa pratensis
Polygala vulgaris
Primula veris
Prunella vulgaris
Ranunculus bulbosus
Rosa canina agg.
Rosa rubiginosa agg.
Rubus fruticosus agg.
Sanguisorba minor
Senecio jacobaea
Stachys officinalis
Succisa pratensis
Taraxacum seedling/sp
Thymus praecox arcticus
Trifolium pratense
Trifolium repens
Tussilago farfara
Ulex europaeus
Veronica chamaedrys
Veronica officinalis
Vicia cracca
Vicia sepium
Viola odorata
Viola riviniana
Viola seedling/sp

Barbula recurvirostra
Brachythecium rutabulum
Bryum sp
Calliergon cuspidatum
Campylium chrysophyllum
Ctenidium molluscum
Encalypta streptocarpa
Eurhynchium praelongum
Fissidens adianthoides
Fissidens taxifolius
Plagiomnium rostratum

Bishop Middleham Species List

Achillea millefolium
Agrostis stolonifera
Anthyllis vulneraria
Arabis hirsuta
Arrhenatherum elatius
Avenula pratensis
Avenula pubescens
Bellis perennis
Betula pubescens
Brachypodium sylvaticum
Briza media
Bromus erectus
Campanula rotundifolia
Carex flacca
Centaurea nigra
Centaurea scabiosa
Centaurium erythraea
Cerastium fontanum triviale
Cirsium arvense
Crataegus monogyna
Cruciata laevipes
Dactylis glomerata
Dactylorhiza fuchsii
Daucus carota
Elymus repens
Epilobium angustifolium
Epipactis atrorubens
Euphrasia officinalis agg
Festuca ovina
Festuca rubra
Fragaria vesca
Fraxinus excelsior
Galium verum
Gymnadenia conopsea
Helianthemum nummularium
Heracleum sphondylium
Hieracium sp.
Hieracium pilosella
Holcus lanatus
Hypericum perforatum
Hypericum pulchrum
Hypochoeris radicata
Knautia arvensis
Koeleria macrantha
Lathyrus pratensis
Leontodon hispidus
Leucanthemum vulgare
Linum catharticum
Listera ovata
Lotus corniculatus
Medicago lupulina
Ononis repens
Ophrys apifera
Orchis mascula
Pimpinella saxifraga
Plantago lanceolata
Plantago media
Poa annua
Poa pratensis
Polygala vulgaris
Potentilla reptans
Primula veris
Prunella vulgaris
Ranunculus acris
Ranunculus bulbosus
Rhinanthus minor
Rosa canina
Rubus fruticosus agg
Rumex obtusifolius
Sagina procumbens
Salix caprea
Salix cinerea
Sanguisorba minor
Scabiosa columbaria
Sesleria albicans
Silene vulgaris
Succisa pratensis
Taraxacum seedling/sp
Thymus praecox arcticus
Tragopogon pratensis
Trifolium pratense
Trisetum flavescens
Tussilago farfara
Ulex europaeus
Urtica dioica
Veronica chamaedrys
Veronica officinalis
Vicia cracca
Vicia sepium
Viola seedling/sp

Barbula cylindrica
Barbula fallax
Barbula hornschuchiana
Barbula recurvirostra
Brachythecium rutabulum
Bryum sp
Calliergon cuspidatum
Campylium chrysophyllum
Campylium stellatum
Ctenidium molluscum
Encalypta streptocarpa
Encalypta vulgaris
Eurhynchium praelongum
Eurhynchium striatum
Fissidens cristatus
Fissidens taxifolius
Plagiomnium undulatum
Pseudoscleropodium purum
Seligeria sp.
Weissia sp
Lophozia ventricosa

Raisby Species List

Acer pseudoplatanus
Agrostis capillaris
Alchemilla vulgaris agg
Angelica sylvestris
Arrhenatherum elatius
Avenula pratensis
Avenula pubescens
Betula pendula
Betula pubescens
Brachypodium sylvaticum
Briza media
Bromus erectus
Campanula rotundifolia
Carex flacca
Carlina vulgaris
Centaurea nigra
Centaurea scabiosa
Centaurium erythraea
Cerastium fontanum
Cirsium palustre
Crataegus monogyna
Dactylis glomerata
Dactylorhiza fuchsii
Danthonia decumbens
Deschampsia cespitosa
Epilobium montanum
Epilobium angustifolium
Epipactis atrorubens
Euphrasia officinalis agg
Festuca ovina
Festuca pratensis
Festuca rubra
Filipendula ulmaria
Fragaria vesca
Fraxinus excelsior
Galium verum
Geum rivale
Gymnadenia conopsea
Helianthemum nummularium
Heracleum sphondylium
Hieracium sp
Hieracium pilosella
Hypericum perforatum
Hypericum pulchrum
Hypochoeris radicata
Knautia arvensis
Koeleria macrantha
Lathyrus pratensis
Leontodon hispidus
Leucanthemum vulgare
Linum catharticum
Listera ovata
Lotus corniculatus
Medicago lupulina
Molinia caerulea
Pimpinella saxifraga
Plantago lanceolata
Polygala vulgaris
Potentilla anserina
Potentilla erecta
Potentilla reptans
Primula veris
Prunella vulgaris
Pteridium aquilinum
Quercus petraea
Reseda lutea
Rhinanthus minor
Rosa canina agg.
Rubus fruticosus agg.
Salix aurita
Salix caprea
Sanguisorba minor
Serratula tinctoria
Sesleria albicans
Stachys officinalis
Succisa pratensis
Taraxacum seedling/sp
Thymus praecox arcticus
Trifolium medium
Trifolium pratense
Trifolium repens
Tussilago farfara
Ulex europaeus
Ulmus minor
Viburnum lantana
Veronica officinalis
Vicia cracca
Viola hirta
Viola odorata
Viola riviniana
Viola seedling/sp

Barbula fallax
Barbula hornschuchiana
Barbula recurvirostra
Brachythecium rutabulum
Brachythecium velutinum
Bryum sp
Calliergon cuspidatum
Campylium chrysophyllum
Campylium stellatum
Ctenidium molluscum
Encalypta vulgaris
Eurhynchium praelongum
Eurhynchium striatum
Eurhynchium swartzii
Fissidens cristatus
Fissidens taxifolius
Plagiomnium rostratum
Plagiomnium undulatum
Pseudoscleropodium purum
Seligeria sp.
Thuidium tamariscinum
Weissia sp
Cephalozia sp
Cephaloziella sp
Marchantia polymorpha

Wingate Species List

Achillea millefolium
Arrhenatherum elatius
Brachypodium sylvaticum
Briza media
Bromus erectus
Campanula rotundifolia
Carex flacca
Carlina vulgaris
Centaurea nigra
Centaurea scabiosa
Crataegus monogyna
Cruciata laevipes
Cynosurus cristatus
Dactylis glomerata
Dactylorhiza fuchsii
Elymus repens
Epilobium angustifolium
Euphrasia officinalis agg
Festuca ovina
Festuca pratensis
Festuca rubra
Fragaria vesca
Fraxinus excelsior
Gymnadenia conopsea
Avenula pratensis
Avenula pubescens
Heracleum sphondylium
Hieracium sp
Hieracium pilosella
Holcus lanatus
Hypochoeris radicata
Knautia arvensis
Lathyrus pratensis
Leontodon hispidus
Leucanthemum vulgare
Linum catharticum
Listera ovata
Lotus corniculatus
Medicago lupulina
Orchis mascula
Pimpinella saxifraga
Pinguicula vulgaris
Plantago lanceolata
Poa sp
Polygala vulgaris
Primula veris
Prunella vulgaris
Ranunculus seedling/sp
Rhinanthus minor
Rosa canina agg.
Rubus fruticosus agg.
Rosa seedling/sp
Rumex acetosa
Rumex obtusifolius
Scabiosa columbaria
Senecio jacobaea
Stachys officinalis
Succisa pratensis
Taraxacum seedling/sp
Tragopogon pratensis
Trifolium medium
Trifolium pratense
Tussilago farfara
Veronica chamaedrys
Veronica officinalis
Vicia cracca
Viola seedling/sp

Barbula fallax
Barbula recurvirostra
Brachythecium mildeanum
Brachythecium rutabulum
Bryum sp
Calliergon cuspidatum
Homalothecium lutescens
Campylium chrysophyllum
Ctenidium molluscum
Encalypta streptocarpa
Eurhynchium praelongum
Fissidens adianthoides
Fissidens cristatus
Fissidens taxifolius
Plagiomnium undulatum
Pseudoscleropodium purum
Rhytidiadelphus squarrosus
Weissia sp
Cephalozia sp
Cephaloziella sp
Conocephalum conicum
Leiocolea badensis
Marchantia polymorpha

Pittington species list

Achillea millefolium
Agrostis stolonifera
Ajuga reptans
Arabidopsis thaliana
Arabis hirsuta
Avenula pratensis
Avenula pubescens
Bellis perennis
Betula pendula
Brachypodium sylvaticum
Briza media
Bromus erectus
Campanula rotundifolia
Carex flacca
Carlina vulgaris
Centaurea nigra
Centaurea scabiosa
Centaurium erythraea
Cerastium fontanum
Crataegus monogyna
Cirsium arvense
Crataegus monogyna
Cynosurus cristatus
Dactylis glomerata
Dactylorhiza fuchsii
Elymus repens
Euphrasia officinalis agg
Festuca gigantea
Festuca ovina
Festuca pratensis
Festuca rubra
Fragaria vesca
Galium verum
Helianthemum nummularium
Heracleum sphondylium
Hieracium sp.
Hieracium pilosella
Holcus lanatus
Hypochoeris radicata
Knautia arvensis
Koeleria macrantha
Lathyrus pratensis
Leontodon hispidus
Leucanthemum vulgare
Linaria vulgaris
Linum catharticum
Listera ovata
Lolium perenne
Lotus corniculatus
Medicago lupulina
Pimpinella saxifraga
Plantago lanceolata
Plantago maritima
Plantago media
Poa annua
Poa trivialis
Polygala vulgaris
Primula veris
Prunella vulgaris
Ranunculus acris
Ranunculus bulbosus
Ranunculus repens
Rosa canina agg.
Rubus fruticosus agg.
Rumex acetosa
Sanguisorba minor
Scabiosa columbaria
Senecio jacobaea
Sesleria albicans
Sonchus asper
Stachys officinalis
Succisa pratensis
Taraxacum seedling/sp
Thymus praecox arcticus
Tragopogon pratensis
Trifolium medium
Trifolium pratense
Trifolium repens
Trisetum flavescens
Ulex europaeus
Veronica chamaedrys
Vicia cracca
Viola hirta
Viola riviniana
Viola seedling/sp

Amblystegium serpens
Barbula fallax
Barbula hornschuchiana
Brachythecium albicans
Brachythecium rutabulum
Brachythecium velutinum
Bryum sp
Calliergon cuspidatum
Campylium chrysophyllum
Ctenidium molluscum
Dicranella varia
Encalypta streptocarpa
Eurhynchium swartzii
Fissidens taxifolius
Plagiomnium rostratum
Plagiomnium undulatum
Rhytidiadelphus squarrosus
Weissia sp
Lophocolea bidentata

Thrislington Species List

Acer pseudoplatanus
Achillea millefolium
Agrimonia eupatoria
Antennaria dioica
Anthyllis vulneraria
Avenula pratensis
Avenula pubescens
Brachypodium sylvaticum
Briza media
Bromus erectus
Campanula rotundifolia
Carex flacca
Centaurea nigra
Centaurea scabiosa
Cerastium fontanum
Cirsium arvense
Cirsium palustre
Crataegus monogyna
Cruciata laevipes
Dactylis glomerata
Dactylorhiza fuchsii
Dactylorhiza sp.
Danthonia decumbens
Daucus carota
Elymus repens
Epipactis atrorubens
Festuca ovina
Festuca pratensis
Festuca rubra
Fragaria vesca
Fraxinus excelsior
Galium verum
Gentianella amarella
Gymnadenia conopsea
Helianthemum nummularium
Heracleum sphondylium
Hieracium sp
Hieracium pilosella group
Hypericum pulchrum
Hypochoeris radicata
Knautia arvensis
Koeleria macrantha
Lathyrus pratensis
Leontodon hispidus
Linum perenne anglicum
Linum catharticum
Listera ovata
Lotus corniculatus
Medicago lupulina
Pimpinella saxifraga
Plantago lanceolata
Plantago media
Poa annua
Polygala vulgaris
Potentilla reptans
Primula veris
Prunella vulgaris
Rhinanthus minor
Rosa canina agg.
Rosa pimpinellifolia
Rubus fruticosus agg.
Sanguisorba minor
Sanicula europaea
Scabiosa columbaria
Sesleria albicans
Stachys officinalis
Stachys sylvatica
Succisa pratensis
Taraxacum seedling/sp
Thymus praecox arcticus
Trifolium medium
Trifolium pratense
Trifolium repens
Tussilago farfara
Ulex europaeus
Veronica chamaedrys
Viburnum opulus
Vicia cracca
Viola hirta
Viola riviniana
Viola seedling/sp

Barbula fallax
Barbula hornschuchiana
Brachythecium glareosum
Brachythecium mildeanum
Brachythecium rutabulum
Brachythecium velutinum
Bryum sp
Calliergon cuspidatum
Campylium chrysophyllum
Ctenidium molluscum
Eurhynchium praelongum
Eurhynchium swartzii
Fissidens adianthoides
Fissidens cristatus
Fissidens taxifolius
Plagiomnium rostratum
Plagiomnium undulatum
Pseudoscleropodium purum
Thuidium tamariscinum
Weissia sp

Cassop Vale Species List

Achillea millefolium
Agrostis stolonifera
Angelica sylvestris
Anthyllis vulneraria
Avenula pratensis
Bellis perennis
Brachypodium sylvaticum
Briza media
Bromus erectus
Campanula rotundifolia
Carex flacca
Carlina vulgaris
Centaurea nigra
Centaurium erythraea
Cerastium fontanum triviale
Cirsium arvense
Cirsium palustre
Cirsium vulgare
Conopodium majus
Convolvulus arvensis
Corylus avellana
Crataegus monogyna
Dactylis glomerata
Dactylorhiza fuchsii
Danthonia decumbens
Deschampsia cespitosa
Elymus repens
Equisetum arvense
Euphrasia officinalis agg
Festuca gigantea
Festuca ovina
Festuca rubra
Filipendula ulmaria
Fragaria vesca
Fraxinus excelsior
Galium aparine
Galium verum
Gentianella amarella
Geranium robertianum
Geum rivale
Gymnadenia conopsea
Helianthemum nummularium
Heracleum sphondylium
Hieracium sp.
Hieracium pilosella
Holcus lanatus
Hypericum pulchrum
Knautia arvensis
Koeleria macrantha
Lathyrus pratensis
Leontodon hispidus
Linum catharticum
Listera ovata
Lotus corniculatus
Pimpinella saxifraga
Plantago lanceolata
Plantago maritima
Plantago media
Poa annua
Poa trivialis
Polygala vulgaris
Potentilla reptans
Potentilla sterilis
Primula veris
Prunella vulgaris
Quercus robur
Ranunculus acris
Ranunculus bulbosus
Ranunculus repens
Rosa canina agg.
Rubus fruticosus agg.
Sanguisorba minor
Scabiosa columbaria
Senecio jacobaea
Sesleria albicans
Stachys officinalis
Succisa pratensis
Taraxacum seedling/sp
Thymus praecox arcticus
Trifolium medium
Trifolium pratense
Trifolium repens
Trisetum flavescens
Tussilago farfara
Ulex europaeus
Veronica chamaedrys
Veronica officinalis
Vicia cracca
Viola hirta
Viola riviniana
Viola seedling/sp

Barbula recurvirostra
Brachythecium rutabulum
Brachythecium velutinum
Calliergon cuspidatum
Campylium chrysophyllum
Ctenidium molluscum
Eurhynchium praelongum
Fissidens adianthoides
Fissidens cristatus
Fissidens taxifolius
Plagiomnium rostratum
Rhizomnium punctatum
Plagiomnium undulatum
Pseudoscleropodium purum
Rhytidiadelphus squarrosus
Thuidium tamariscinum
Weissia sp
Jungermannia hyalina

Table 1 *Sesleria albicans grassland - Avenula pratensis sub-community*

	Relevé number	112	113	114	115	116	121	122	124	125	126	127	128	129	130	132	134	136	137	138	139	140	141	142	144	148	149	150	151	152	153	154	155	157	158	159	160	161	
	Soil pH	7.9	7.8	7.5	7.8	7.5	7.7	7.8	7.8	7.8	7.8	8.0	7.8	7.7	8.4	7.7	7.6	7.8	7.8	7.8	7.7	7.4	7.5	7.7	7.8	7.8	7.5	7.5	7.6	7.7	7.9	7.7	7.6	7.5	7.6	7.6	7.8	7.8	
	Soil depth (centimetres)	6	4	9	8	7	20	9	30	32	15	20	19	32	17	17	20	17	17	7	10	14	23	14	19	17	10	11	14	10	7	11	18	11	15	12	5	9	
	Bare ground (%)	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
323	Carex flacca	1	7	4	3	2	4	3	1	3	1	3	2	3	7	7	5	6	1	3	4	4	7	6	7	8	5	4	4	4	2	1	3	2	3	4	4	3	V
251	Briza media	2	4	2	2	2	2	2	2	2	2	2	2	2		2	1	3	1	3	3	4		3	2	3	2	3	2	3	3	4	2	2	4	4	4	3	V
800	Lotus corniculatus	1				2	1	2	2	2	2	2	2	2	2	1	3	4	2	2	3	2	2	2	2	3	3	3	2	3	2	4	3		3	3	3		V
973	Plantago lanceolata	2	2	2		3	1		2	2	1		1	1	1	2	1	2	1	1	2		2	1	2	2	1		3	2	1	3	3	2	2	2	2	2	V
574	Festuca ovina	2	3	3		6	6	3		4	5	5		3		5	3	8	1	2	2	3			3	5	6	6	4	3	3	3	5	3	3	3	3	3	V
1245	Sesleria albicans	2	6	2	3	2	4	9	4	8	5	9	1		9		9	2	7	7	8	7			8	3	8	8	1		8		1	1	6	8	8	6	V
1053	Sanguisorba minor	5		4	3	4	6	2	6		3	4	1	3	2	3	3	4	4	2	3	3	4	2	1	4	2		5	4	1			4			2	2	V
654	Helianthemum nummularium	7	7	8	9	8	4	5	6	8	4	3	1	4	5			2	7	4	2	3	5	5		7			8	8	1			6					IV
995	Polygala vulgaris						1				1	2	1	1			1	2	1	1	2	3	1	2	1	2	3	2	2	1	2			1	1	2	1	1	IV
655	Avenula pratensis			2					8		7	4	2						3	3	2	8		1	4	4	5	5	8	5	4	8	8	6	7	7	7	6	IV
371	Centaurea nigra	2	2	3	3	4	1		2		2	2				1	1	2	3	2	2	2	2	4					2	2	1		1	2					IV
1205	Scabiosa columbaria	2	2	2		2	2	1		2	2	3	1			3	1	2		1	2	1	1	1	2	1					2						1	2	IV
1305	Succisa pratensis		2	3	2	2	2		2	2		2							3	2	2				3	3	3	3	3	3	3	3		2			2	3	III
1914	Pseudoscleropodium purum						2	3	3	2			2	2					1			2	3	2		2	2	2	2	1	1	3	3	3	3	1	1		III
1600	Ctenidium molluscum						3	3	2			3		2		2		2	3	3	2	2			2	2				3	2	2		3	3	3	2	2	III
2611	Crataegus monogyna (g)				1	1	1						1	1			1	1	1	1		1	1	3			1		1	1	1	3	1	1	1			1	III
769	Leontodon hispidus						2	2	1		1		2	1		2	1	2	1	1		2	2		2			3			2		2			3	2	3	III
786	Linum catharticum		3		1	2	1													1	2	1			3	3	3	3	2	2	3	3	3	3		3	3	3	III
968	Pimpinella saxifraga	2		2		2	1	2		1	1		1			2	2	1		2	2	1	1			1	2		1		1	2							III
576	Festuca rubra	6		6	3	5	4	6					3	3		5	3	3						1	2	2			4	5	1		2					2	III
976	Plantago media	1				2			1	1	3	2	2	2			1			1	1		1		2	1		2			2			1			3	3	III
1333	Thymus praecox arcticus		2		2	1														2	1				6	4	2	4		3	4	4	2	2	3	4	5	4	III
1349	Trifolium pratense	1		2		2	2		3				2	2	2		3							2			3		3	2		2	3	2	1	2			III
1445	Calliergon cuspidatum						4		3	3	3		2	2		3		3				3	4		2					3	2	2	3	2	1	1			III
104	Achillea millefolium	2		3		2	1		2	2				2	1			1						1		1			3	2		2	2	1			1		III
288	Campanula rotundifolia						1						1	2			1			3	1	2			1	2		2			1	3	2	1		2	2	1	III
465	Dactylis glomerata	2		1	1					1	1			1		1						1	1						1	1		4	2	1	3				III
788	Listera ovata						1		2	1		1	1				2	2	1	1	2	2	1	1						2	1								III
1807	Plagiomnium undulatum						1		2				2	1		2		1	1			1				1					2	3	2	1	2	1			III
2615	Fraxinus excelsior (g)																	1					2	2	2	1	1	1	1	1	1	1	1	1		1	1		III
247	Brachypodium sylvaticum						1			1	1		1	1	1	7	1	2	2			1	4	5										1					II
1056	Primula veris									1		1	2	2	1	1		1					1	1	1		1					1	2	1					II
1059	Prunella vulgaris	2					1						2	1		2		1									1		1			3	3	2	2	2			II
1423	Viola hirta		1				2		2	2	2	3	2		2		1	2					3	3									1						II
1695	Fissidens taxifolius						3				3	2		2	1	2			1				2	2	2								2	1	1				II
256	Bromus erectus						1		2		3		10	8		4								1		2	3	3		2	2								II
613	Galium verum	2				2		2		3			3	2			3					3	4	2												1		1	II
1429	Viola riviniana									1			2			2		1	1	1		1	2	2								3	3	1					II
174	Anthyllis vulneraria										1	1							1	3	4				2	5					1						3	5	II
746	Koeleria macrantha			1		3																1					1	2	2						2	2	2	2	II
1411	Vicia cracca					2				1				1	1							1	1	1				1				3				2			II
372	Centaurea scabiosa			2	3	2			1	1									4	2		2		4															II
1346	Trifolium medium			2			1						2				2	2						2			2	3						1					II
2982	Taraxacum seedling/sp	1	1	1						1							1	1														1		1	1				II
466	Dactylorhiza fuchsii											1							1			1	1		1	1		2		2									II
587	Fragaria vesca	1												1		3		2					2	3								1			1				II
1519	Brachythecium rutabulum			1						2	1		2	1								1					2							1					II
1677	Eurhynchium praelongum						1	3	3		1	1		2		1	2																						II
1940	Rhytidiadelphus squarrosus																												2	1	1	3	2	2	1	2			II
661	Heracleum sphondylium					1												1					1					2					1	1	1				I
2639	Ulex europaeus (g)			1																	1				1					3	4						1	2	I
702	Hypericum pulchrum																	1		2	2		1								1			1					I
2754	Rosa canina (g)	1														2	1		1				1	1															I
2999	Viola seedling/sp													1	1		2						1				1			1									I
234	Stachys officinalis					1					3							1			1								2										I
384	Cerastium fontanum triviale			2		2																									2		1				1		I
575	Festuca pratensis					2										1		1					1	5															I
758	Lathyrus pratensis										1													1								2	2		1				I
1136	Rubus fruticosus agg.	4	3						1				1											4															I
1249	Danthonia decumbens																			1							1								1		2	3	I
1493	Barbula recurvirostra																									1				1	1							2	I
1566	Campylium chrysophyllum						2				3			2											2														I
1688	Fissidens cristatus						1										1			1										2									I
2003	Thuidium tamariscinum						3																					1				1			2				I
2610	Corylus avellana (g)																									1				1			1	1					I
532	Equisetum arvense																															2	3		4				I
568	Euphrasia officinalis agg		1																												1					1			I
649	Gymnadenia conopsea											1																1			1								I
675	Hieracium 'indeterminate'																		1	1				1															I
743	Knautia arvensis						1		2	2																													I
784	Linum perenne anglicum						7		7										7																				I
1239	Senecio jacobaea			1																												1				1			I
1350	Trifolium repens			1											1																	1							I
1522	Brachythecium velutinum								3														3	2															I
1795	Plagiomnium rostratum										3			2																				1					I
2760	Rubus fruticosus agg (g)																1		1				2																I
113	Agrimonia eupatoria													2									1																I
122	Agrostis stolonifera																															1		2					I
230	Bellis perennis	1																																					I
419	Cirsium vulgare																																1		2				I
445	Crataegus monogyna (s)															2							1																I
528	Epipactis atrorubens																			2	1																		I

	Relevé number	112	113	114	115	116	121	122	124	125	126	127	128	129	130	132	134	136	137	138	139	140	141	142	144	148	149	150	151	152	153	154	155	157	158	159	160	161	
573	Festuca gigantea	4																																		2				I
619	Gentianella amarella																			1																1			I
680	Holcus lanatus																															1	2						I
965	Hieracium pilosella group					1																														1			I
1050	Potentilla reptans												2																				2						I
1086	Ranunculus bulbosus																															1	2						I
1106	Rhinanthus minor													1				3																					I
1356	Trisetum flavescens			1		1																																	I
1363	Ulex europaeus (s)	4	4																																				I
1401	Veronica officinalis																															2			1				I
1682	Eurhynchium swartzii																		2			2																	I
1683	Fissidens adianthoides																			1											1								I
2628	Quercus robur (g)																																1		1				I
2822	Cirsium sp																								1								1						I
3192	Dactylorhiza sp.								1									1																					I
118	Elymus repens																							2															I
167	Angelica sylvestris																																1						I
168	Antennaria dioica																			2																			I
184	Arabidopsis thaliana	1																																					I
185	Arabis hirsuta	1																																					I
362	Carlina vulgaris																								1														I
373	Centaurium erythraea																											1											I
431	Conopodium majus																																1						I
475	Daucus carota															1																							I
656	Avenula pubescens					2																																	I
975	Plantago maritima																								1														I
1051	Potentilla sterilis																																1						I
1123	Rosa pimpinellifolia																1																						I
1339	Tragopogon pratensis	1																																					I
1396	Veronica chamaedrys																																2						I
1487	Barbula fallax													1																									I
1490	Barbula hornschuchiana																	1																					I
1513	Brachythecium glareosum													1																									I
2807	Bryum sp																	1																					I
3065	Weissia sp										1																												I
	Number of species per sample	28	16	26	13	30	37	15	28	26	29	22	32	37	15	27	29	37	29	33	25	31	35	35	29	28	25	24	25	31	37	36	43	38	31	27	25	24	

Table 4 *Briza media* grassland

Relevé number	4	5	6	10	11	14	15	16	17	18	19	22	29	30	31	32	34	35	41	42	43	44	45	46	47	51	52	53	54	55	56	57	62	63	75	78	79	80	81	84	85	86	89	90	91	93	94	97	100	103	104	108	109	111	
Soil pH	7.8	7.7	7.9	8.0	8.2	8.1	8.2	8.1	8.2	8.3	8.2	8.0	7.6	8.2	8.1	7.9	8.0	7.8	7.8	8.0	8.3	8.0	8.2	7.8	8.3	8.0	7.9	7.7	7.0	8.5	8.3	7.9	8.4	8.4	8.3	7.9	7.9	7.8	7.9	7.7	7.7	8.0	7.8	7.9	8.1	8.4	8.4	8.2	7.8	8.0	8.2	7.8	7.9	8.2	
Soil depth (centimetres)	9	14	4	3	5	10	11	10	3	2	2	6	6	10	10	13	15	6	5	6	2	4	5	4	2	6	15	11	15	4	5	10	2	6	6	5	6	4	9	10	10	10	16	10	5	7	6	6	6	6	11	10	10	5	
Scrub density (all species)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Bare ground (%)	0	0	8	50	0	0	0	0	50	20	20	20	25	60	50	0	40	0	0	0	5	0	0	0	0	0	5	0	0	85	80	0	0	0	40	0	5	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	
251 Briza media	2	3	3	5	6	8	5	8	3	4	3	1			3	2	2	3	8	6	4	7	8	6	3	3	3	2	2	1	2	2	6	4		6	4	5	3	5	8	5	5	3	6	4	7	2	6	3	4	8	7	5	V
323 Carex flacca	2	3		1	8	7	3		1	5	2		7	4	2	2		2	1	3	3	2	2	2	6	3	8	2	2	1		3	8	4	1	2	6	7	1	6	7	2	8	2	2	5	5	2	3	7	6	5	3	4	V
800 Lotus corniculatus	4	4	3	3	5	6	4	7	2	5		4			3	3		3	5	6	4	4	8	7	4	4	3	3	2	1		3	6	5	2	7	7	5	7	7	3	8	4	5	4	4	8	4	4	4		5	6		V
371 Centaurea nigra	2	2	1	2	2		2	4	2	2	3	2	2			1	3	1	5	3	3	3	3	3	1	3	3	4	4	1	1	4	3	3		1	1		2	2	3		2	4	3	2	2	2	2	2		4	3		V
769 Leontodon hispidus	1	1		1	2	5	3	2		2	1		3	1		2	2	1			1	1		3	2		2	2	1	1		2			2	3	3	3	4	3	3	2	4	3	3	2	3	2	3	3	2	2	2		IV
965 Hieracium pilosella group	3	3	3	5	3	2	2	3	5	5	8	1			1	5	3	3	1	2	1	2		1	2	4	2	1	2		1	4	3	2	3		1		2	1		1	3	4	1	3				1	3	2			IV
973 Plantago lanceolata			1	3	3	3	2	2	1		1	1	1				2	2	3	1	1	1	2	2		1		2	3				1			2	1	2	2	3	1	2	3		2	1	2	2	4	1		2	2	2	IV
466 Dactylorhiza fuchsii	3	2			2	1	1	1		1	1		2	3	1			1	1	2		1	1	1			1							1		2	3	3	2	2	2			1	1	1	1		1		1		1		III
675 Hieracium 'indeterminate'					1	1		1	1	2		1	1			2	3	1		1	2				2	3	1	1	2	3	2	2	1	3	3		1		1				2	3	3	2				1	2				III
1349 Trifolium pratense					1	3	3	2		1	2		2					1	1	2		3	2	3	2			1	2								1	3	2	2	3	4	1		1		3	2	4	3		2	3	3	III
2611 Crataegus monogyna (g)		1	1	1	2	1	1	1	1	1	1		1			1	1	1	1			1	1			1					1	1	1	1	1					1	1	1			1		1			1	1				III
576 Festuca rubra				2	1	6			2	2									7	6		5	3	4	2		1	2	3						1								3	3	4	2		4	5	4	3	6	5	6	III
1600 Ctenidium molluscum	2	1	1	2	2	5	2	2				1								5						3	2	2	2			6	3	4		2				3			4	3	3		2			3	3	2			III
465 Dactylis glomerata		2	1	1		1		2	1	1	1								1				1						2				1						1	4	2	3	1	1	3	1	1	3	3	1				1	III
1333 Thymus praecox arcticus	2	2	4	5	7		9			4	2	3		4		2			1	5	7	1	1	2	3					1	5	1																		4	3	1		1	III
1445 Calliergon cuspidatum						2	2	2										4	6			3	2	2			2	2	2							1	2	2	4	2	3	3				2	3	2	2			2	1		III
1056 Primula veris	1	0			2					1		1					1	1	1	1			1			2		1	2			3	1	1					2	1	2				1	1			1				1		III
1566 Campylium chrysophyllum		1								2	1	2	3					2			3				3			2				1	1			1	2	1	1	1	2	2		1	2	1	2				1				III
661 Heracleum sphondylium		1	1			1	3	2		2		1						1				2	1	1				2	2					1					1	1	1					1		2	1			1	1		III
1059 Prunella vulgaris			1		1	2							3				1					1				3	2	2	1		1	2	1	1	2	1	1				2	2	2			1							1		III
1205 Scabiosa columbaria													1							1		2														1	1	2	2	3	2	2	2	2	3	3			1	2	2	3	1	1	II
372 Centaurea scabiosa				2				2			1						2		2	1		1						4	1										5	1	2		2	2	3	1		2	2			2			II
844 Medicago lupulina							3	3			3							2	1		5	3	1	2			1	1	2	1							1					3			1	1				2				6	II
995 Polygala vulgaris				2	1			3		1									1	2			1		1	1		1		2	2	2	2	1												1				1	2			1	II
786 Linum catharticum										1		1		1	1	1					1					1				1		1			2								1	1	3	2	2			1		2	2		II
1305 Succisa pratensis	2	2	2		1		1			2			2	1	1	2											2					2		1		1				1	2	1		2											II
362 Carlina vulgaris		3	2	1	3			2		2		1														1				1			2	2									1	2	1	2				1	1				II
568 Euphrasia officinalis agg												2						1	2		1	1		1	1							1	1	1	2							1	1		1					3		2		3	II
104 Achillea millefolium													1			2		2	2	1	1	1	2	1	1												1		2			1						3		2		2			II
574 Festuca ovina						1			2										4	5	2												1		3						2	5		3	2	3		6	8			3	2		II
2982 Taraxacum seedling/sp				1			1		1	1	1		1				1						1				1				1	1				1		1				1							3					1	II
288 Campanula rotundifolia														1	1		1									3				3	2	3			1				2	1						2			1	1	3		2		II
579 Festuca ovina/rubra (vegetativ	1	4											4	4	4	3	3	4								2				2						1	2	3	2	2														II
1053 Sanguisorba minor	1	2										2	3	1		1	4	1	1		1											4		4															1				2		II
403 Leucanthemum vulgare								4								1	1					1		2	1				1										1	1	1	1				1		1							II
587 Fragaria vesca				1			1		2		2	3						3											2	2					3					1	2				1		1								II
373 Centaurium erythraea								1			1	2	2	3	2			1			2									3	2				2															1					II
1245 Sesleria albicans													2	1	1		2				2				5										1															8	8	3	4	3	II
2760 Rubus fruticosus agg (g)				1	1		1		2		1					1		1	1	1				1																	1	1													II
256 Bromus erectus																3	1	1								4	3		3	2	2	4	6	7																					II
475 Daucus carota		2	2	1	2		1	3	3	2	3										1	2																																	II
976 Plantago media					3								1					4		2		1	2	1																										2	2	1		1	II
656 Avenula pubescens								1																		3	7	6	7	3	2	4									2								5						I
743 Knautia arvensis				1			1		1		2					2																1			1				1								1					1		I
746 Koeleria macrantha														3	2		2	2	5	2	2	4			1																									2					I
3065 Weissia sp												2		1																1					3	1				1		1				2						1		2	I
247 Brachypodium sylvaticum										1	1								1	1			1										1	1											2	1								I
654 Helianthemum nummularium																	1		1	4					2	3			1	1			5	3																				I
1411 Vicia cracca								1			1	1						1		1																				1	2	3						2						I
2754 Rosa canina (g)		1		1	1		2	1	1	1	1																					1																						I
655 Avenula pratensis																						7		3	1				1												4					1	5	2						I
1360 Tussilago farfara							1		1					1																2	1				2	1	3																	I
1695 Fissidens taxifolius										2								1					2									1								1											1	2	2		I
391 Epilobium angustifolium	1								1		1	1		2		1		1																																					I
230 Bellis perennis				1					1		3											1																												2				4	I
649 Gymnadenia conopsea					1														1		1	1			1	1																												I
706 Hypochoeris radicata														1	1																					2	2			1														1	I
1050 Potentilla reptans																	1		3							1	1		2						3																				I
1086 Ranunculus bulbosus					1	1		1																																										2			2	3	I
1106 Rhinanthus minor																1													1							3	2	3		3															I
1665 Encalypta streptocarpa												2		2																												1	2	2						1				I
2807 Bryum sp												1			4						1												1		2											1								I
680 Holcus lanatus																						1	6	5																						1						2		I
702 Hypericum pulchrum												2							2	2			1												2																				I
758 Lathyrus pratensis												2					1												1												1	1													I
1239 Senecio jacobaea									1		1																															1								1				2	I
575 Festuca pratensis																											2	2		1	1																								I
701 Hypericum perforatum																					2	1	1	2																															I
1807 Plagiomnium undulatum																																			1								2	1									2		I
2605 Betula pubescens (g)																									1	1							2		1																				I
2607 Betula pendula (g)																										1							4	1																1					I
174 Anthyllis vulneraria			1						1	1																																													I
460 Cynosurus cristatus																																								1			1							1					I
970 Pinguicula vulgaris																																				3	3	3																	I
975 Plantago maritima																																																		1	4			1		I
981 Poa annua																																																			1			2	2	I
1167 Salix aurita																																	2	1	1																				I
1168 Salix caprea (s)																			3							2								1																						I
1346 Trifolium medium																																										1						1						1		I
1401 Veronica officinalis							1					1								1																																			I
1487 Barbula fallax																																					1					1								1					I
1493 Barbula recurvirostra											1																				1															2									I
2639 Ulex europaeus (g)																				1					1										2																				I
2999 Viola seedling/sp												2										1													1																				I
118 Elymus repens																																																	2	1						I
122 Agrostis stolonifera																							3		1																														I
234 Stachys officinalis																																								2											1				I

	Relevé number	4	5	6	10	11	14	15	16	17	18	19	22	29	30	31	32	34	35	41	42	43	44	45	46	47	51	52	53	54	55	56	57	62	63	75	78	79	80	81	84	85	86	89	90	91	93	94	97	100	103	104	108	109	111
384	Cerastium fontanum triviale																											2																										2	I
477	Deschampsia cespitosa cespitos																														1				1																				I
528	Epipactis atrorubens																																2	1																					I
788	Listera ovata																		1																											2									I
914	Ononis repens													1								5																																	I
968	Pimpinella saxifraga															1																													3										I
1043	Potentilla anserina																											2	1																										I
1081	Ranunculus acris																																																3	2					I
1136	Rubus fruticosus agg.																										1																					1							I
1158	Sagina procumbens													1	1																																								I
1350	Trifolium repens																																																	2				1	I
1396	Veronica chamaedrys																																																2				1		I
1426	Viola odorata		1																													1																							I
1490	Barbula hornschuchiana												1																						1																				I
1571	Campylium stellatum												1														2																												I
1666	Encalypta vulgaris																									3							1																						I
1677	Eurhynchium praelongum																																			2									2										I
1683	Fissidens adianthoides						1																																					1											I
1688	Fissidens cristatus																					1																							1										I
1914	Pseudoscleropodium purum																		1																	1																			I
1940	Rhytidiadelphus squarrosus																																																2				2		I
2183	Marchantia polymorpha																																		1		2																		I
2615	Fraxinus excelsior (g)																																	1												1									I
2631	Salix caprea (g)												1																					1																					I
2703	Cephaloziella sp																																		3							1													I
2819	Cephalozia sp																																1					1																	I
3282	Seligeria sp.														3																				3																				I
123	Agrostis capillaris																													1																									I
127	Ajuga reptans																																																			1			I
185	Arabis hirsuta														1																																								I
445	Crataegus monogyna (s)																							1																															I
543	Erigeron acer											1																																											I
613	Galium verum																																																	7					I
619	Gentianella amarella											1																																											I
700	Hypericum montanum											2																																											I
783	Linaria vulgaris																																																				1		I
876	Molinia caerulea																																		2																				I
918	Ophrys apifera																								1																														I
920	Orchis mascula																	1																																					I
988	Poa pratensis																	3																																					I
1095	Ranunculus repens																																																			2			I
1122	Rosa canina agg.		1																																																				I
1169	Salix cinerea (s)																		1																																				I
1259	Silene vulgaris																							1																															I
1356	Trisetum flavescens																																																					1	I
1429	Viola riviniana																																																				1		I
1486	Barbula cylindrica																								1																														I
1510	Brachythecium albicans																																																					2	I
1514	Brachythecium mildeanum																																					1																	I
1519	Brachythecium rutabulum																																																	1					I
1522	Brachythecium velutinum																																		1																				I
1562	Homalothecium lutescens																																										3												I
1621	Dicranella varia																																																		1				I
1795	Plagiomnium rostratum																																																2						I
2110	Conocephalum conicum																																														1								I
2150	Leiocolea badensis																																				1																		I
2167	Lophocolea bidentata																																																2						I
2180	Lophozia ventricosa																	1																																					I
2614	Fraxinus excelsior (s)																											1																											I
2709	Trifolium seedling/sp	1																																																					I
2721	Poa sp																																									2													I
2735	Ranunculus seedling/sp																																							1															I
3255	Ulmus minor (s)																																	1																					I

Number of species per sample 14 21 17 22 25 18 25 25 22 26 27 29 22 19 17 21 21 32 32 27 23 32 25 24 26 24 21 24 28 22 17 25 29 26 32 23 24 16 21 32 25 30 22 21 29 30 20 20 28 38 21 25 31 24 0