A comparison of magnesian limestone grassland seres, with particular reference to factors affecting the colonisation of a regraded spoil slope at Raisby quarry, CO. Durham

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A comparison of magnesian limestone grassland seres, with particular reference to factors affecting the colonisation of a regraded spoil slope at Raisby Quarry, Co. Durham

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Summary

1. Four sites were studied at Raisby Quarry Nature Reserve, Co. Durham. A regraded magnesian limestone spoil slope, a 50 year old abandoned quarry floor, a semi-natural magnesian limestone grassland and an area of the limestone grassland cleared of scrub 5 years ago. The species composition of the four sites were compared.

2. Nine years after regrading, the spoil slope still supports very little vegetation. Four transects were set up, running along the top, the bottom, the eastern side and the western side of the slope. Environmental factors thought to be influencing the colonisation of the slope were investigated.

3. It was assumed that the emergence of seedlings was the crucial stage determining the percentage plant cover during colonisation. The amount of bare ground in each quadrat was most strongly correlated with an increase in the pH of the soil and a decrease in the number of seedlings that emerged. Highly alkaline soils reduce the availability of minerals to the plant, reducing growth. A reduction in root growth increases a plant's susceptibility to desiccation. A more northerly aspect, a lower organic content and a steeper slope were also correlated with reduced vegetation cover.

4. Significantly more vegetative cover was found in quadrats nearer the top of the slope. This was because of the lower pH and higher organic content found at the top of the slope and also because nutrient runoff from the adjacent arable field enhanced growth.

5. DECORANA and TWINSPAN analysis showed the species composition of the quadrats from the regraded spoil to be strongly influenced by the vegetation immediately surrounding the slope. Species more typical of grassland were spreading down from the top of the slope and scrub has established from adjacent woodland at the bottom of the slope.

6. DECORANA and TWINSPAN analysis showed the species composition of the four sites to be very different. The regraded spoil contained a high proportion of wind-dispersed species able to colonise the slope but very few 'desirable' species, presumably because these have poor powers of dispersal. The quarry floor is less vegetated than the limestone grassland and therefore is important for supporting rare species intolerant of denser vegetation. The scrub-cleared area still supports species typical of shaded habitats although some magnesian limestone species are starting to recolonise.

7. Implications for management are discussed.

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Chapter 1

Introduction

1.1 Magnesian limestone

1.1.1 Distribution

Permian magnesian limestone extends, albeit patchily, along the east of England from Tyne and Wear in the north down to Nottingham in the south. In County Durham it is the predominant rock covering some 596 km^2 in a roughly triangular shape. On its western side, the limestone forms an escarpment up to 60m high in places, behind which the magnesian limestone slopes away to the east to form the East Durham Plateau (Pettigrew, 1980).

1.1.2 Composition

Magnesian limestone rock is mainly composed of calcium carbonate but, unlike carboniferous limestone, it contains a higher content of the mineral dolomite, up to 15%. Dolomite is composed of calcium magnesium carbonate (Pettigrew, 1980).

1.1.3 Botanical significance

Most of the magnesian limestone is covered with glacial drift of varying depths. Where the rock lies close to the surface, weathering and decomposition of minerals in the soil causes the formation of a thin rendzina soil. This has a species rich flora associated with it (Alexander, 1980).

In Co. Durham the magnesian limestone supports a unique flora of the Association Seslerio-Helichtotrichetum (Shimwell, 1968). *Sesleria albicans** is the dominant or co-dominant grass in this communiity. The flora found on the magnesian limestone of Co. Durham is important because it links the Festuco-Brometea limestone grasslands of the south with the Elyno-Seslerietea Arctic-alpine grasslands of Europe and north Scotland (Shimwell, 1969). Therefore there are found on the magnesian limestone species such as *Bromus erectus*, *Linum anglicum*** and *Ophrys apifera* existing at their absolute northern limit and species such as *Epipactis atrorubens* (Plate 6), *Primula farinosa* and *Antennaria dioica* living towards their absolute southern limits (Doody, 1980). The grassland also supports the common rockrose,

* Nomenclature of grasses follows that of Hubbard (1992).
** Nomenclature of dicotyledons follows that of Clapham, Tutin & Warburg (1962).

Helianthemum nummularium (Plate 5), which is the food plant of a butterfly found only in east Durham, the Durham Argus Brown (*Alicia artaxerxes salmacis* (Steph.)).

1.2 Quarrying

1.2.1 Uses of magnesian limestone

Magnesian limestone has been quarried for a few hundred years but it is only since the last century that there has been a dramatic increase in demand for the limestone due to industrial growth. Magnesian limestone was used as a flux in blast furnaces, for making 'Doloma' for the steel production industry and 'Magnesia' for the chemical industry. Now the main use for the magnesian limestone quarried in Co. Durham is in the civil engineering industry, where it is used as road fill, and in agriculture, where it is used for liming (Percy, 1980).

1.2.2 The quarrying process - a brief outline

Initially the soil is removed to expose the limestone which is then blasted. After blasting the stone is transported to the primary crushing plant for crushing, and then the stones are screened and graded by size. Stones which are too large for their intended use are crushed further and rescreened. Stone which does not meet the requirements for use is moved to waste heaps, which are therefore composed of crushed soft raw magnesian limestone.

1.2.3 Implications for flora

In order to reach the magnesian limestone for quarrying the soil and associated vegetation above it must be stripped off. Together with farming, both of which have risen sharply over the last 40 years (Richardson, Davis & Evans, 1980), this has now left only relicts of natural and semi-natural areas of the original magnesian limestone grassland. There are still plenty of reserves of magnesian limestone left in the county and as the limestone is of great economic importance to the area it can be expected that quarrying will continue for many decades to come.

However abandoned and restored quarries, of which there are many, have the potential to become important refuges for flora (Doody, 1977; Humphries, 1980; Richardson *et al*, 1980) and many, of which the study site at Raisby Quarry was one, have now been designated as SSSI's (Humphries, 1980).

1.3 Raisby Quarry Nature Reserve (NZ 335354)

1.3.1 History

Raisby Quarry, lying 107 - 137m above sea level, is situated on the western Lower Magnesian Limestone escarpment, approximately 4 miles south east of Durham City. It was opened in 1830 and has been worked continuously since 1847 (Booy, 1975). The working face is extensive, being 800 yards long and up to 40 yards high in places (Richardson *et al*, 1980).

An area of the quarry, covering 10.01 hectares, has been set aside as a Nature Reserve. Part of it, Raisby Hill Grassland was first notified as a SSSI in 1957. Since 1978 it has been managed by Durham Wildlife Trust and was re notified as a SSSI in 1984.

1.3.2 Description of the study site

Fig. 1 shows the four areas of the Nature Reserve where the project was carried out - a regraded spoil slope, an abandoned quarry floor, an area of semi-natural magnesian limestone grassland and an area of the grassland cleared of scrub approximately 5 years ago. The site has a north to north-western aspect and is currently geographically isolated from other areas of magnesian limestone grassland. A disused mineral railway running along the northern side of the study areas serves as a wildlife corridor, otherwise the Nature Reserve exists "as an island of semi natural vegetation surrounded by quarry and agricultural land" (Durham Wildlife Trust, 1991).

Temperatures recorded at Durham University Observatory, 9 km away and 60 m lower than Raisby Quarry, show a mean January monthly temperature of 2.5 °C and a mean monthly July temperature of 15 °C, with a mean annual rainfall of 650 mm (Durham Wildlife Trust, 1991).

The waste heaps used to be a flat top feature until they were regraded by cut and fill methods using existing materials in the late summer of 1986 (P. Gladwin, pers. comm.). The resultant spoil slope is not included within the SSSI but has been allowed to recolonise naturally since regrading occurred. It is intended that a range of stages of colonisation will be maintained from scrub through to bare ground (Durham Wildlife Trust, 1991) but at the moment the a lot of the slope is still very bare (Plates 2, 3 and 4). Situated above the regraded spoil is an arable field which was restored after quarrying by regrading, subsoiling and topsoiling. On the eastern side of the regraded slope studied, there is an area of spoil that was regraded several years previously and now has a well-established area of scrub towards the bottom. At the bottom of the slope there is an area of woodland.

The small abandoned quarry (Plate 1) was left to naturally recolonise approximately 50 years ago. It is flat area of exposed hard dolomite (Richardson *et al*, 1980) that now supports a shallow layer of friable soil. *Bromus erectus* and *Sesleria albicans* are the dominant species, with *Carex flacca*, *Briza media*, *Lotus corniculatus*, *Helianthemum nummularium*, *Hieracium pilosella*, *Sanguisorba minor* and *Thymus drucei* also fairly common. The quarry floor supports six species of orchid and is an especially important site for *Epipactis atrorubens*, *Coeloglossum viride* and *Gymnadia conopsea* which are species with a fairly restricted distribution. Monitoring has shown that the vegetative cover has gradually increased with time, the grasses predominating (Durham Wildlife Trust, 1991). The quarry floor is surrounded on three sides by woodland. In 1991 the quarry floor was fenced off and scrub clearance carried out (P. Gladwin, pers. comm.). Scrub is especially invading the spoil slope on the southern side of the quarry floor (marked as a slope in fig. 1).

The semi-natural magnesian limestone grassland lies on a steep slope in clearings within invading *Crataegus monogyna* scrub. There is also a problem with invasion by *Ulex europaeus*. Allchin (1993) identified the grassland as of the subcommunity *Bromus erectus*, differing from the main *Sesleria* community found in Co. Durham because of the frequent occurrence of *B.erectus*. *Stachys officinalis*, *Listera ovata* (Plate 7), *Linum catharticum* and *Campanula rotundifolia* also occur more frequently than in *Sesleria* communities and there is a lack of *H.nummularium*. Other species found in the magnesian limestone grassland include *Molinia caerulea*, *Gymnadia conopsea*, *Pimpinella saxifraga* and *Lotus corniculatus* (Durham Wildlife Trust, 1991). Management of the grassland involves coppicing and grazing to control scrub invasion. Since autumn 1992 cattle have been allowed onto the grassland for two months, twice a year (autumn and spring).

The final area of the Nature Reserve to be studied in the project was an area of the magnesian limestone grassland which had been cleared of *C.monogyna* scrub approximately 5 years ago in an attempt to increase the size of the grassland at the bottom of the slope. The scrub is estimated to have been present for approximately 30 years beforehand.

1.4 Aims of the Project

The first aim of the project was to determine if any environmental factors were affecting the natural colonisation of the regraded magnesian limestone spoil slope. Also I wanted to investigate whether the magnesian limestone grassland and/or the quarry floor were acting as species pools for the colonisation of the regraded spoil. I therefore looked at whether there was a change in species composition on the regraded slope along a gradient of closeness to the magnesian limestone grassland and quarry floor.

Secondly I wanted to see if a seed bank in the regraded spoil was helping in the colonisation of the regraded slope by investigating what numbers and species of seedlings established themselves and how this was influenced by the environmental factors.

Finally, I was interested in comparing the vegetation of the four sites to see if the vegetation from the regraded spoil, the quarry floor and the scrub-cleared area were approaching the perceived desirable type of the magnesian limestone grassland.

Plate 1. The Quarry Floor at Raisby Hill Grassland, SSSI

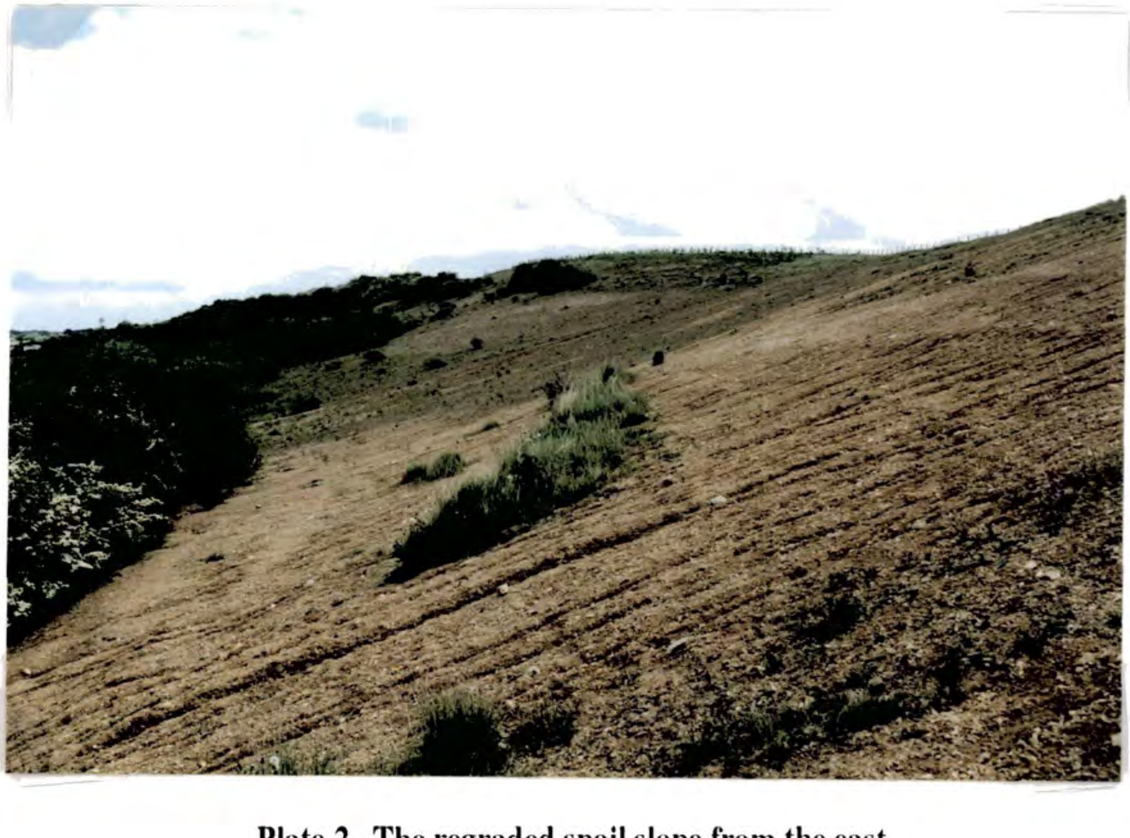


Plate 2. The regraded spoil slope from the east

Plate 3. The regraded spoil from the west

Plate 4. The regraded spoil from the west showing the grassland adjacent to the arable field at the top

Plate 5. ***Helianthemum nummularium*** **- the common rockrose (Quarry floor)**

Plate 6. ***Epipactis atrorubens*** **- the dark red helleborine (Quarry floor)**

Plate 7. ***Listera ovata*** **- common twayblade (Quarry floor)**

Plate 8. ***Dactylorhiza purpurella*** **- the northern marsh orchid (regraded spoil)**

Fig. 1. The four sites studied at Raisby Quarry Nature Reserve

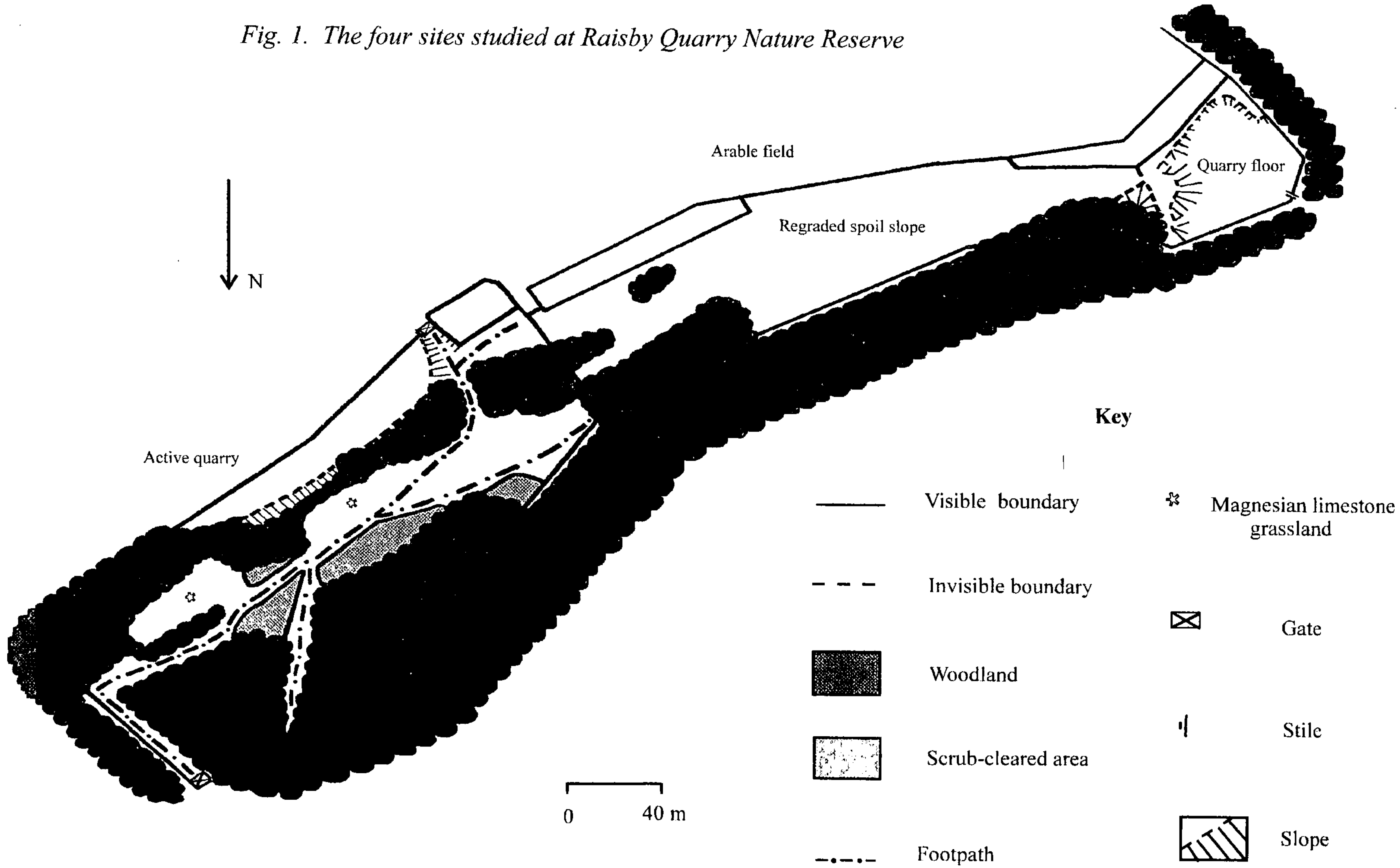
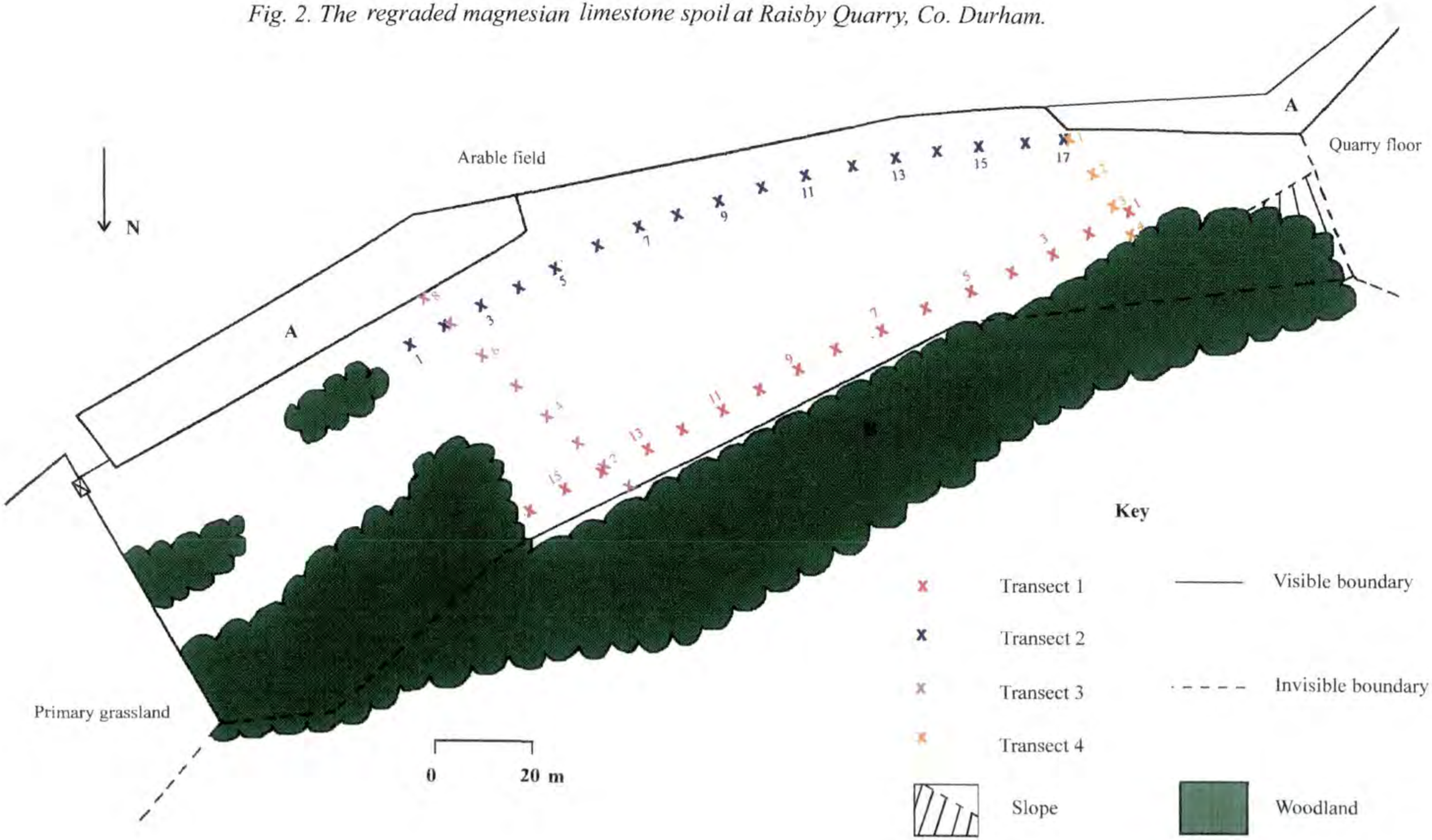


Fig. 2. The regraded magnesian limestone spoil at Raisby Quarry, Co. Durham.



Chapter 2

Materials & Methods

2.1 The study area on the regraded spoil

Four transects were set up on the regraded spoil site roughly forming a rectangle with transects 1 and 2 running along the slope (bottom and top respectively) and transects 3 and 4 running up and down on either side (east and west respectively - see fig. 2). Every 10 m along each transect a 2 x 2 m quadrat was marked out with stones and numbered as in fig. 2. There were 45 quadrats in all.

Table 1. Table showing the length of and number of quadrats to be found in each transect on the regraded spoil

	Length (m)	Number of quadrats
Transect 1	150m	16
Transect 2	160m	17
Transect 3	70m	8
Transect 4	30m	4

2.2 Environmental variables affecting revegetation of the regraded slope

The following environmental factors were compared with the amount of bare ground in each quadrat.

2.2.1 pH and organic content of the soil

To see if there was a relationship between vegetation cover and edaphic factors, the soil pH and organic content of each quadrat was analysed. At each quadrat four soil samples (one at each corner of the quadrat) to a depth of 5 cm were taken using a corer (diameter of 0.001 m^2) and thoroughly mixed. The soil was passed through a 2 mm sieve to standardise the samples by removing larger stones.

Approximately 10 g of the soil was weighed out and made into a paste with 25 ml of distilled water. The paste was stirred thoroughly and left to stand for 1-2 hours, occasionally being stirred during this period. An electrode was then used to determine the pH. Because the first investigation showed a marked difference in pH between vegetated and unvegetated quadrats further soil samples were taken as before. Two cores were taken at each of 16 sites along the slope, eight in vegetated areas and eight in relatively bare areas. The majority of the samples were taken towards the top of the slope to minimise the effects of leaching from the top to the bottom of the slope.

To investigate the organic content of the soil it was first weighed and then oven dried overnight at 60 °C. The samples were reweighed and approximately 2.5 g placed in a crucible and left in a muffle furnace for 4 hours at 550 °C. The samples were then reweighed and the percent of organic content of the soil in each quadrat calculated.

2.2.2 Slope

To the eye it looked as though the slope gradient may influence the ability of the plants to establish themselves, perhaps because of leaching effects, water runoff or gravitational effects on the soil.

The slope steepness for each quadrat was measured using a clinometer. It was thought that the steepness of the slope immediately above each quadrat was likely to have affected the characteristics of the quadrat itself, therefore the readings were taken about 5 m above the quadrat along transects 1, 3 and 4. Most of the quadrats along transect 2 were situated just below the flat bank at the top of the slope which was not included in the measurements. Therefore the readings, although they gave an accurate value for the gradient of the quadrat itself, did not take into account the fact that the quadrats were situated at the top of the slope along transect 2. Four readings were taken at each quadrat and the average used. The clinometers were accurate to within 0.5 - 1°.

2.2.3 Aspect

Aspect was also taken into consideration as the eastern and western halves of the slope faced slightly different directions. The average of three readings taken on either side of the 'bend', which occured between quadrats 6 and 7 along transect 1 and between quadrats 9 and 10 along transect 2, was used.

2.3 Seedling studies

In order to see which seedlings managed to establish themselves and in what numbers, soil was collected from each quadrat as before at the end of April. At each quadrat eight samples were taken using a corer (with a diameter of 0.001 m^2) around the edges (so that vegetation within the quadrat would not be affected) down to a depth of 5 cm and brought back to the lab and kept in a refrigerator for up to a week. Then the soil from each quadrat was sieved using a 2 mm sieve to remove large stones, roots and surface vegetation. Seed trays (21 x 17 cm) were lined with paper to stop soil being washed out on watering and then soil from each quadrat was added to different trays to a depth of 2 cm. The seed trays were labelled and kept in a greenhouse with natural light / dark routines and temperatures, and regularly watered so that the soil did not dry out. Later it was noted that the trays did not hold water for long, thus necessitating the lining of the seed tray holders with plastic. Three control trays consisting of magnesian limestone, autoclaved to kill seeds present in the soil, were also placed in the greenhouse so that any seedlings germinating from seeds that had blown onto the trays from within the greenhouse could be eliminated from the investigation. Seedlings started emerging after a couple of weeks and thereafter the number of seedlings present in each tray were counted on a weekly basis. When possible the seedlings were identified using Chancellor (1966) and Hanf (1983). When the seedlings had been identified, they were removed from the trays.

2.4 Comparison of the vegetation from the four sites

Quadrats were surveyed during June and July 1995, recording all shrubs, grasses, herbs, mosses and bare earth with the Domin Scale (Rodwell, 1992). All 45 of the quadrats on the regraded spoil were surveyed. The quarry floor was divided into four by eye and three randomly placed quadrats surveyed in each quarter, making a total of 12 in all. As the primary grassland exists in two separate clearings the nine quadrats surveyed were distributed between them. The area of grassland recently cleared of scrub / woodland was situated at the bottom of the primary grassland and six quadrats were randomly placed within this. The total number of quadrats surveyed was 72.

2.5 Multivariate Analysis

2.5.1 DECORANA (Detrended Correspondence Analysis)

DECORANA is an ordination programme that extracts the principal axes of variation within the data set based upon eigenvector values. The result is an ordination diagram with similar samples clustered together and dissimilar samples more distant from one another (Hill, 1979a).

2.5.2 TWINSPAN (Two-way Indicator Species Analysis)

TWINSPAN acts by repeatedly dividing the samples and then the species into two groups on the basis of the relative abundance of certain indicator species (pseudospecies) which are the most strongly differential species. The levels of abundance of a species used to define a pseudospecies are called the pseudospecies cut levels, the following five being used for the analyses in this study, 0, 3, 4, 5 and 7 on the Domin scale. Each sample is given an indicator score of +1 for every positive indicator and -1 for every negative indicator leading to the sample group being divided near to the middle of the principal axis into a 'negative' group and a 'positive' group (Hill, 1979b). The maximum level of divisions chosen was six and the minimum group size for division was five.

Chapter 3

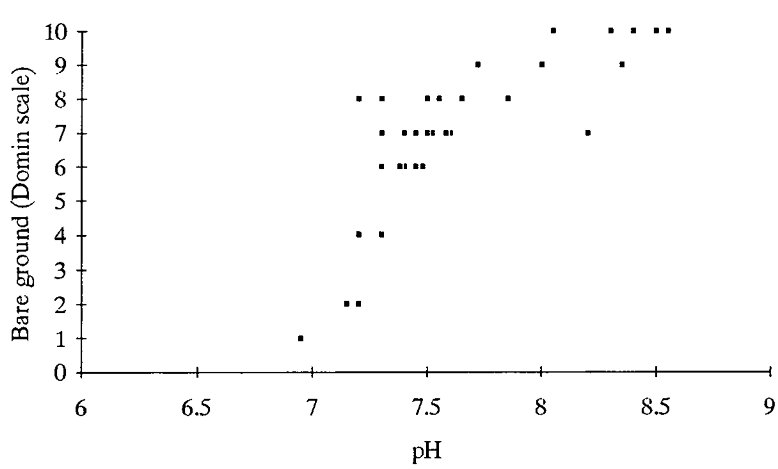
Results

3.1 Factors affecting the vegetation cover of quadrats

The environmental variables aspect, pH and percentage organic content of the soil, amount of bare ground, distance from the top and distance from the magnesian limestone grassland for each quadrat were correlated using the Spearman rank correlation. Fig. 3 shows the Spearman rank correlation coefficients (r_s) for all the data, the critical values for a two-tailed distribution at the 5%, 1% and 0.1% significance levels are given at the top of the table. As with all the data analysed in the study, any result with a p value greater than 0.05 was not considered significant. The data in full can be found in the Appendix. It can be seen that many of the variables are correlated.

3.1.1 pH

Fig. 4. Graph showing the relationship between pH and the amount of bare ground in each quadrat



The amount of bare ground present in each quadrat was most strongly positively correlated with the pH of the soil ($r_s = 0.811$, $n = 43$, $p < 0.001$). The graph in fig. 4 shows a sharp increase in the amount of bare ground as the pH rises above pH 7.3. At pH > 8.0 the amount of bare ground reaches ten on the Domin scale.

Fig. 3. Spearman rank coefficients of correlation for environmental variables

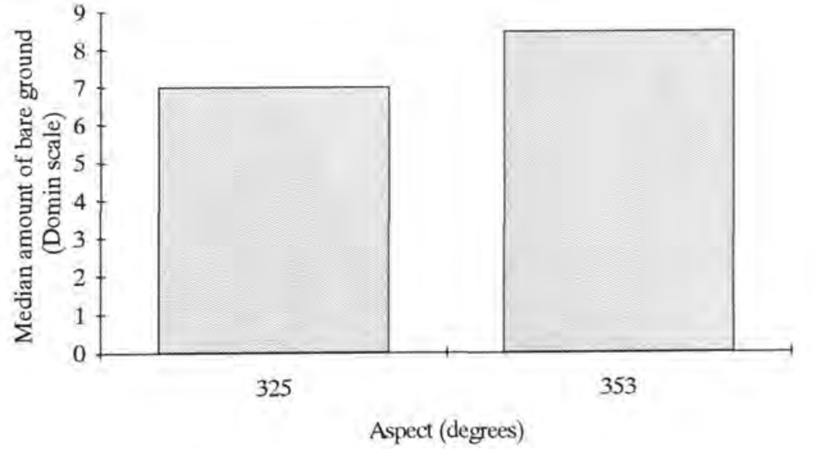
Critical values of the Spearman rank correlation (n=43), $\alpha(2)$ 0.05 = 0.301 (a), $\alpha(2)$0.01= 0.391 (b), $\alpha(2)$ 0.001= 0.490 (c)

	Bare ground	**pH**	**Organic content**	**Slope**	**Aspect**	**Distance from top**	**Distance from primary grassland**	**Number of seedlings**
Bare ground	1	-	-	-	-	-	-	-
pH	0.811^{c}	1	-	-	-	-	-	-
Organic content	-0.310^{a}	-0.398^{a}	1	-	-	-	-	-
Slope	0.442^{b}	0.341^{a}	0.081	1	-	-	-	-
Aspect	0.495^{c}	0.464^{b}	0.465^{b}	0.415^{b}	1	-	-	-
Distance from top	0.458^{b}	0.523^{c}	-0.513^{c}	0.292	0.037	1	-	-
Distance from primary grassland	0.522^{c}	0.450^{b}	0.077	0.154	0.862^{c}	-0.048	1	-
number of seedlings	-0.747^{c}	-0.718^{c}	-0.359^{a}	-0.373^{a}	-0.081	-0.513^{c}	-0.300	1

3.1.2 Aspect

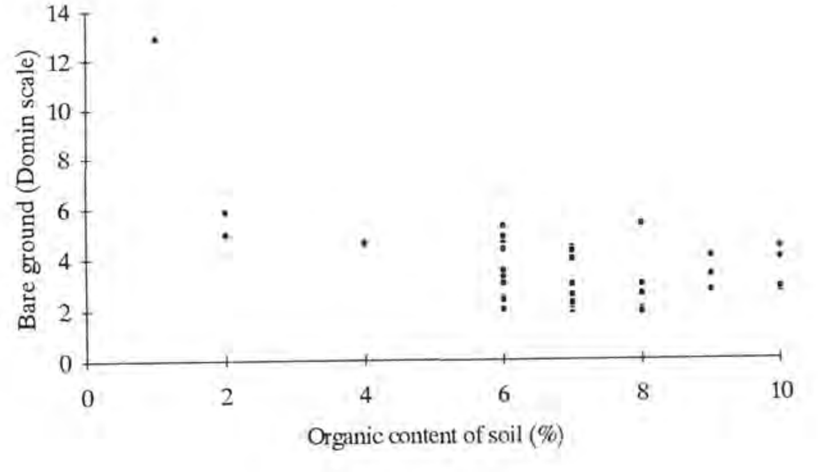
There was a strong positive correlation between aspect and the amount of bare ground ($r_s = 0.495$, $n = 43$, $p < 0.001$) as seen in fig. 5. At the more northerly aspect of 353° there was more bare ground in each quadrat. The median Domin value (the mean was not used as the Domin scale is not linear) for the amount of bare ground at aspect 325° was 7 and at 353° was 8.5.

Fig 5. Barchart showing the relationship between aspect and the median amount of bare ground measured on the Domin scale



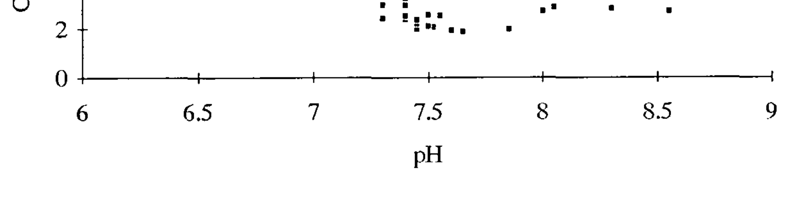
3.1.3 Organic content

Fig. 6. Graph showing the relationship between the organic content of the soil and the amount of bare ground in each quadrat



As may be expected there was a significant negative correlation between the amount of bare soil and the organic content of the soil in each quadrat (r_s = -0.310, n = 43; $p < 0.05$) as can be seen in fig. 6. With increasing amounts of bare ground there was a corresponding lowering of the soil organic content presumably because there is less vegetation present to enter into the soil on dying and less organic matter to encourage plant development. As the amount of bare soil shows a significant positive correlation with pH as previously discussed it would be expected that as the organic content decreases (with increasing amounts of bare ground) then there will be a negative correlation with pH. This is indeed the case and pH is significantly negatively correlated with the organic content of the soil in each quadrat (r_s = -0.398, n = 43; $p < 0.05$) as shown in fig. 7. At lower pH values the soil tends to have a higher organic content. The quadrat with an organic content of 12.88%, almost no bare ground and a pH of 6.95 may influence the correlation somewhat as the values are on the extremes of the data set in all cases. Quadrat 8 from transect 3 consisted of a high amount of vegetation, mainly grass and moss, and was situated on the flat bank at the top of the slope.

Fig. 7. Graph showing the relationship between pH and the organic content of the soil in each quadrat



3.1.4 Slope

Slope angle was significantly positively correlated with both pH and therefore, as could be expected, the amount of bare ground, but more strongly with the latter (r_s = 0.341, n = 34, $p < 0.05$; r_s = 0.442, n -= 43, $p < 0.01$ respectively). The steeper the slope (which ranged from 10° to 21.75°) on the regraded spoil the higher the pH and correspondingly the more bare ground there was. However, the data from quadrat 8 from transect 3 may once again have influenced the results.

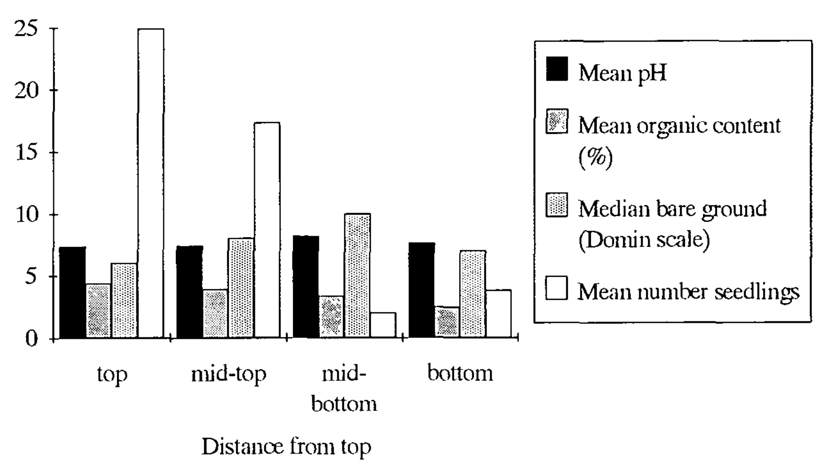
3.1.5 Distance from the magnesian limestone grassland

The distance from the magnesian limestone grassland was very highly positively correlated with aspect ($r_s = 0.862$, $n = 43$, $p < 0.001$) as the slope nearer the grassland had an aspect of 325°. Therefore there were similar positive correlations for pH and organic content with distance from the grassland ($r_s = 0.450$, $n = 43$, $p < 0.01$; $r_s = 0.522$, $n = 43$, $p < 0.001$ respectively) as there were with aspect.

3.1.6 Distance from the top of the slope

The distance from the top of the slope seemed to play an important part in the amount of bare ground and the number of seedlings emerging. The distance from the top was measured on a scale from 0 - 3 (0 being at the top, 3 at the bottom) as there were different numbers of quadrats in transects 3 and 4 running up and down the slope. The distance of a quadrat from the top of the slope was highly positively correlated with the pH and amount of bare ground ($r_s = 0.523$, $n = 43$, $p <0.001$; $r_s = 0.458$, $n = 43$, $p < 0.01$) within it and negatively correlated with the organic content of the soil ($r_s = -0.513$, $n = 43$, $p < 0.001$) as can be seen in fig. 8. Quadrats further down the slope had a higher pH and a corresponding increase in the amount of bare soil and a decrease in the organic content of the soil.

Fig. 8. Barchart showing the relationship between the number of seedlings emerging and the amount of bare ground and the pH and organic content of the soil at different distances from the top of the slope



3.2 Comparisons of soil pH.

3.2.1 Vegetated and bare patches on the regraded spoil slope

Following on from the previous section, where there was shown to be a very high positive correlation between pH and the amount of bare ground, the differences in pH between vegetated and bare areas on the slope were looked at in more detail. Table 2 shows the pH values, with their respective means and standard errors, of eight samples each selected from a vegetated and unvegetated area. The areas were selected by eye and all samples were taken in one morning. A Mann-Whitney U test comparing the pH of the two sample sets showed a highly significant difference between the sample sets ($U = 4.5$, $n_1 = 8$, $n_2 = 8$, $p = 0.0038$). That is, there was a significantly higher pH from samples with no vegetation compared with vegetated samples.

Table 2. Comparisons of the pH readings obtained from the eight vegetated and eight bare areas

Area	pH bare ground	pH vegetated ground
1	9.10	8.00
2	8.30	7.85
3	8.13	7.75
4	8.40	7.95
5	8.35	7.78
6	7.85	7.70
7	8.53	7.95
8	8.35	7.98
Mean (± s.e)	8.38 (± 0.136)	7.87 (± 0.044)

3.2.2 Comparison between the regraded spoil and the other three sites

Table 3 shows the mean pH values (± s.e) of the regraded spoil, the quarry floor, the magnesian limestone grassland and the area cleared of scrub. The mean pH values of the regraded spoil and the quarry floor were similar being 7.59 (±0.063) and 7.55 (±0.038) respectively. They were higher than the pH values obtained from the magnesian limestone grassland and scrub-cleared areas (7.22 ±0.034 and 7.27 ±0.030 respectively). A Kruskal-Wallis 1-way ANOVA carried out on the pH values obtained from all four sites showed that there was a highly significant difference in pH values between the four groups ($\chi^2 = 24.2$, $df = 3$, $p < 0.0001$). Further analysis using the

Mann-Whitney U test to determine between which samples the differences occurred showed there to be a significant difference in pH between the regraded spoil and magnesian limestone grassland ($U = 32$, $n_1 = 45$, $n_2 = 9$, $p = 0.0001$), the regraded spoil and scrub-cleared area ($U = 31$, $n_1 = 45$, $n_2 = 6$, $p = 0.0035$) the quarry floor and magnesian limestone grassland ($U = 1$, $n_1 = 12$, $n_2 = 9$, $p = 0.0001$) and the quarry floor and scrub-cleared area ($U = 1$, $n_1 = 12$, $n_2 = 6$, $p = 0.0009$). There was no significant difference between the pH's of the regraded spoil and the quarry floor or the magnesian limestone grassland and the scrub-cleared area. This last result is especially encouraging as it shows that the presence of scrub has not irretrievably acidified the soil. Both the magnesian limestone grassland and the scrub-cleared area are more vegetated than either the quarry floor or regraded spoil and are therefore likely to have a higher organic content in their soil (although this was not measured) and therefore a lower pH. As the quarry floor still has a relatively high pH it is indicative of a relatively low amount of organic matter in the soil and that therefore, even after 50 years, a humic soil has not formed. Therefore it can be expected to take many years with the regraded spoil too.

Table 3. Table showing the mean and standard error values of the pH for the four sites

Site	Mean pH (± s.e)
Regraded spoil	7.59 (± 0.063)
Quarry floor	7.55 (± 0.038)
Magnesian limestone grassland	7.22 (± 0.034)
Scrub-cleared area	7.27 (± 0.030)

3.3 <u>Factors affecting seedling germination</u>

The total number of seedlings that emerged in each tray, representing each quadrat, was included in the Spearman rank correlation (fig. 3) as a measure of seeds in the seed bank. The number of seedlings emerging in each tray was used (i) to try and explain the occurrence of bare ground on the regraded slope and (ii) to look at the effect that the environmental variables have on seedling establishment.

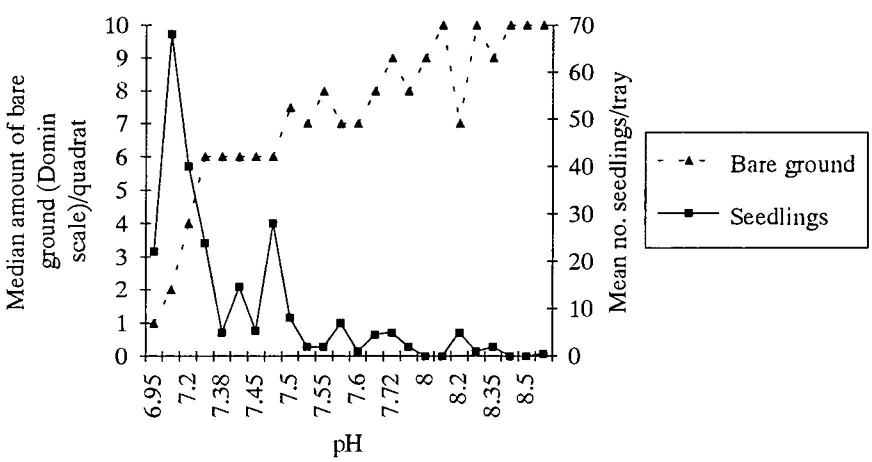
3.3.1 The amount of bare ground

The number of seedlings emerging in each tray was highly correlated with the amount of bare ground present in the corresponding quadrat ($r_s = -0.747$, $n = 43$, $p < 0.001$). Bare ground exists because seeds fail to germinate, seedlings germinate but fail to establish themselves or because the seeds are not present to start with.

3.3.2 pH

The number of seedlings emerging in each tray was highly negatively correlated with the pH of the soil in the representative quadrat (r_s = -0.718, n = 43, $p < 0.001$). Fig. 9 shows that, except for the first point, the number of seedlings emerging in the trays generally decreases as the amount of bare ground in each quadrat and pH increases. Very high numbers of seedlings were recorded emerging in trays representing quadrats 2 from transect 2 and 7 from transect 3 (68, seedlings), quadrat 3 from transect 2 (83 seedlings) and quadrat 6 from transect 3 (46 seedlings) with corresponding amounts of bare ground being 2, 2, 4 and 4 respectively on the Domin scale. The number of seedling emerging in each tray decreases sharply as the pH of the representative quadrat increases. Above about pH 7.5 very few seedlings emerged. The trays with the highest number of seedlings (as before) had pH's of 7.2, 7.2, 7.3 and 7.2 respectively.

Fig.9. Graph showing the relationship between pH, the mean number of seedlings emerging in each tray and the median amount of bare ground in the corresponding quadrat



3.3.3 Organic content

The number of seedlings emerging in each tray was significantly negatively correlated with the organic content of the soil (r_s = -0.359, n = 43; $p < 0.05$). That is, as the organic content of the soil increased the number of seedlings emerging decreased. It would be expected that the number of seedlings would increase with an increasing organic content as this would mean that there were more nutrients and water available to the seedling for growth. However, if you look at the negative correlation between seedling emergence and pH and bare ground (see sections 3.3.1 and 3.3.2), both of which are negatively correlated with organic content, then it follows that seedling emergence should be positively correlated with organic content. Reasons for the seeming anomaly is that both organic content and seed distribution within the soil are patchily distributed (Risch, 1992) and therefore the soil taken for organic analysis may have been taken from an area with a lower than average organic content for that area. Alternatively, soil taken for seedling studies may have contained higher than average numbers of seedlings for that area. More replicates were probably needed to negate this effect.

3.3.4 Distance from the top of the slope

The number of seedlings emerging in each tray was highly negatively correlated with the distance down the slope of the representative quadrat (r_s = -0.513, n = 43, $p < 0.001$). The further from the top the quadrat was, the fewer the seedlings that emerged in the tray. This is illustrated in fig. 8.

3.4 Factors affecting the distribution of selected species

To look more closely at which environmental variables influenced the distribution of selected species on the regraded spoil chi-square analysis was undertaken for these species, on a presence or absence basis, and each of the environmental variables discussed in section 3.1. Species found on the regraded spoil were chosen either because they are typical calcareous grassland species or they were used as indicator species for the TWINSPAN divisions (see section 3.6.2). The species chosen were *Thymus drucei*, *Salix* sp., *Betula* sp., *Leontodon hispidus*, *Lotus corniculatus*, *Medicago lupulina*, *Plantago lanceolata*, *Potentilla reptans*, *Senecio* sp. and *Arrhenatherum elatius*. Table 4 gives the results of the chi-square analyses with the corresponding degrees of freedom and significance levels.

3.4.1 *Thymus drucei*

Significantly more *T.drucei* was found than expected at an aspect of 325° compared with an aspect of 353° (X^2 = 79.2, df = 1, $p < 0.01$) and thus was also significantly more likely to be found on the slope closer to the magnesian limestone grassland than expected (X^2 = 29.0, df = 2, $p < 0.01$). The presence of *T.drucei* was also significantly favoured by a pH of between 6.95 and 7.50 (X^2 = 4.68, df = 1, $p < 0.05$) and a soil organic content of between 0 and 2.5 % (X^2 = 8.63, df = 2, $p < 0.05$). There was no significant effect of the distance from the top of the slope or the slope angle itself on *T.drucei* distribution.

Table 4. Chi square values from testing the relationship between environmental variables and selected species

Environmental variable	Species	Chi-square value	Degrees of freedom	Significant
pH	Thymus drucei	4.68	1	5%
	Salix caprea	0.74	1	N.S.
	Betula pendula	2.17	1	N.S.
	Leontodon hispidus	2.79	1	N.S.
	Lotus corniculatus	6.50	1	5%
	Medicago lupulina	5.02	1	5%
	Plantago lanceolata	8.94	1	1%
	Potentilla reptans	3.04	1	N.S.
	Senecio sp.	2.20	1	N.S.
	Arrhenatherum elatius	7.27	1	1%
% organic matter	T.drucei	8.63	2	5%
	S.caprea	23.1	2	1%
	B.pendula	15.0	2	1%
	L.hispidus	0.18	1	N.S.
	L.corniculatus	5.17	2	5%
	M.lupulina	7.74	2	5%
	P.lanceolata	2.94	2	N.S.
	P.reptans	1.21	2	N.S.
	Senecio sp.	10.7	2	1%
	A.elatius	8.58	2	5%
Slope	T.drucei	3.83	2	N.S.
	S.caprea	0.17	2	N.S.
	B.pendula	1.75	2	N.S.
	L.hispidus	7.18	1	1%
	L.corniculatus	1.84	1	N.S.
	M.lupulina	15.3	1	1%
	P.lanceolata	9.92	1	1%
	P.reptans	4.64	1	5%
	Senecio sp.	1.65	2	N.S.
	A.elatius	0.75	2	N.S.
Aspect	T.drucei	79.2	1	1%
	S.caprea	15.7	1	1%
	B.pendula	6.80	1	1%
	L.hispidus	1.46	1	N.S.
	L.corniculatus	0.16	1	N.S.
	M.lupulina	1.20	1	N.S.
	P.lanceolata	0.42	1	N.S.
	P.reptans	0.42	1	N.S.
	Senecio sp.	3.38	1	N.S.
	A.elatius	0.38	1	N.S.
Distance from magnesian limestone grassland	T.drucei	29.0	2	1%
	S.caprea	12.7	2	1%
	B.pendula	8.08	2	5%
	L.hispidus	0.35	1	N.S.
	L.corniculatus	0.12	1	N.S.
	M.lupulina	0.56	2	N.S.
	P.lanceolata	1.49	2	N.S.
	P.reptans	4.98	2	N.S.
	Senecio sp.	0.02	2	N.S.
	A.elatius	6.72	2	5%

Table 4. (continued). Chi square values from testing the relationship between environmental variables and selected species

Environmental variable	Species	Chi-square value	Degrees of freedom	Significant
Distance from top	T.drucei	4.89	2	N.S.
	S.caprea	23.7	2	1%
	B.pendula	19.4	2	1%
	L.hispidus	3.02	1	N.S.
	L.corniculatus	9.72	1	1%
	M.lupulina	16.8	2	1%
	P.lanceolata	17.8	1	1%
	P.reptans	10.3	2	1%
	Senecio sp.	10.7	2	1%
	A.elatius	9.60	2	1%

3.4.2 *Salix* sp.

Salix sp. were significantly more likely to be present at the bottom of the slope than expected (χ^2 = 23.7, df = 2, p < 0.01) and on soil with an organic content of between 0 and 2.5 % (χ^2 = 23.1, df = 2, p < 0.01). Aspect also seemed to play a part in influencing *Salix* distribution as *Salix* was found significantly more often than expected at an aspect of 325° compared with 353° (χ^2 =15.7, df = 1, p < 0.01). Therefore *Salix* was also significantly more common than expected on the slope nearer to the magnesian limestone grassland (χ^2 = 12.7, df = 2, p < 0.01). The pH of the soil and slope steepness both had no significant effect on the presence of *Salix* sp.

3.4.3 *Betula* sp.

Betula sp. were significantly more common than expected at the bottom of the slope compared with higher up the slope (χ^2 = 19.4, df = 2, p < 0.01). They were also more likely to be found on soil with an organic content of less than 2.5 % (χ^2 = 15.0, df = 2, p < 0.01) and at an aspect of 325° (χ^2 = 6.80, df = 1, p < 0.01). This meant that they were also found significantly more often than expected nearer to the magnesian limestone grassland than to the quarry floor (χ^2 = 8.08, df = 2, p < 0.05). Slope angle and the pH of the soil had no significant effect on *Betula* distribution.

3.4.4 *Leontodon hispidus*

The only environmental factor found to significantly increase the frequency of occurrence of *L.hispidus* was slope steepness (χ^2 = 7.18, df = 1, p < 0.01). *L.hispidus* seemed to prefer a slope of less than 18°.

3.4.5 *Lotus corniculatus*

The frequency of occurrence of *L.corniculatus* was significantly higher than expected at a pH of between 6.95 and 7.50 ($\chi^2 = 6.50$, df = 1, $p < 0.05$) and at an organic content of 4 % or more ($\chi^2 = 5.17$, df = 1, $p < 0.05$). It was also significantly more often than expected found towards the top of the slope than at the bottom ($\chi^2 = 9.72$, df = 1, $p < 0.01$). None of slope steepness, aspect or distance from the magnesian limestone grassland significantly affected its distribution.

3.4.6 *Medicago lupulina*

M.lupulina was found significantly more often than expected when the pH was between 6.95 and 7.50 ($\chi^2 = 5.02$, df = 1, $p < 0.05$) and at an organic content of at least 4 % ($\chi^2 = 7.74$, df = 2, $p < 0.05$). It was also significantly more likely to be found right at the top of the slope than anywhere else ($\chi^2 = 16.82$, df = 2, $p < 0.01$) and on a less steep slope (less than 18°) ($\chi^2 = 15.26$, df = 1, $p < 0.01$). Aspect and distance from the magnesian limestone grassland had no significant effect on *M.lupulina* distribution.

3.4.7 *Plantago lanceolata*

P.lanceolata occurred significantly more often than expected at a pH of between 6.95 and 7.50 ($\chi^2 = 8.94$, df = 1, $p < 0.01$) and at a slope of less than 18° ($\chi^2 = 9.92$, df = 1, $p < 0.01$). It was also found significantly more often than expected towards the top of the slope compared with the bottom ($\chi^2 = 17.8$, df = 1, $p < 0.01$). None of the other environmental variables had a significant effect on *P.lanceolata* distribution.

3.4.8 *Potentilla reptans*

The only two environmental variables to significantly affect the distribution of *P.reptans* were the slope angle ($\chi^2 = 4.64$, df = 1, $p < 0.05$) and distance from the top ($\chi^2 = 10.3$, df = 2, $p < 0.01$). *P.reptans* occurred more often than expected right at the top of the slope and on a slope of less than 18°.

3.4.9 *Senecio* sp.

Senecio sp. were found significantly more often than expected where the organic content of the soil was higher than 4 % ($\chi^2 = 10.7$, df = 2, $p < 0.01$) and right at the top of the slope ($\chi^2 = 10.7$, df = 2, $p < 0.01$). The other environmental variables did not cause *Senecio* sp. to show a significantly different distribution to what would be expected.

3.4.10 *Arrhenatherum elatius*

A.elatius was found significantly more often than expected where the pH was less than 7.50 ($\chi^2 = 7.27$, df = 1, $p < 0.01$) and where the organic content was higher than 4 % ($\chi^2 = 8.58$, df = 2, $p < 0.05$). It was also found significantly more often than expected at the top of the slope ($\chi^2 = 9.60$, df = 2, $p < 0.01$) and on either side of the slope compared with the middle ($\chi^2 = 6.72$, df = 2, $p < 0.05$). Neither aspect nor slope angle caused a significantly different distribution of *A.elatius*.

3.5 Seed bank studies

Overall very few seedlings grew from the soil samples taken, a total of 619 from 45 trays making an average of 13.8 per tray. As it was very difficult to identify the seedlings that did grow most of them were noted as being an 'unknown dicotyledon' or an 'unknown grass' (for the results in full, including the species identified, see the Appendix). Of the unknown grasses, most were of a single species. Only one of the control trays contained seedlings which were identified as being *Poa* sp. and *Oxalis* sp. Therefore these seedlings, if present in the other trays, were discounted. The total number of seedlings emerging from each tray was used for analysis . Table 5 shows the number of seedlings found in the trays and the mean number (± s.e) of seedlings found per tray along each transect. Each tray corresponds to a quadrat.

Most seedlings, a total of 382, emerged in trays from transect 2 especially in trays from quadrats 2, with 68 seedlings, 3, with 83 seedlings and 4 with 35 seedlings (NB. quadrat 2 along transect 2 was the same as quadrat 7 along transect 3 as they occurred at the transect 2 and transect 3 intersect). Quadrats from transect 1 had an average of 2.88 (± 0.85) seedlings emerging per tray, quadrats from transect 2 had an average number of 22.5 (± 5.78) seedlings emerging per tray, quadrats from transect 3 contained an average of 19.6 (± 10.1) seedlings a tray and quadrats from transect 4 an average of 8.40 (± 8.33) seedlings a tray. Mann-Whitney U tests carried out on the results showed that transect 1 had a significantly lower mean number of seedlings emerging per tray compared with transect 2 ($U = 23.0$, $n_1 = 16$, $n_2 = 17$, $p < 0.0001$) and transect 3 ($U = 28.5$, $n_1 = 16$, $n_2 = 8$, $p < 0.03$) but no significant differences were found in the mean number of seedlings emerging per tray from the other transects.

One reason for the low number of seedlings emerging from the trays is that even though washing out of the soil through watering had been considered and preparations made for it in the experimental design, this did still occur and obviously seeds will have been washed out along with the soil. The thinner layer of soil resulting from this also had another effect on the viability of the seeds as there was therefore a tendency for the soil to dry out very quickly and in the very warm weather experienced in the summer of

1995 the greenhouses got very hot inside. Drought is one of the main causes for the failure of seedlings to establish themselves (Davison, 1964).

Table 5. The number of seedlings emerging from each tray with the mean (± s.e) per tray for each transect.

	Number of seedlings emerged			
Tray number	**Transect 1**	**Transect 2**	**Transect 3**	**Transect 4**
1	0	21	5	26
2	1	68	2	5
3	0	83	2	2
4	0	35	11	1
5	0	21	1	-
6	0	15	46	-
7	2	28	68	-
8	7	3	22	-
9	2	4	-	-
10	1	5	-	-
11	2	16	-	-
12	5	8	-	-
13	10	8	-	-
14	4	6	-	-
15	4	7	-	-
16	8	28	-	-
17	-	26	-	-
Mean (± s.e)	2.88 (± 0.85)	22.5 (± 5.78)	19.6 (± 10.1)	8.50 (± 8.33)

The total number of seedlings emerging in each tray was used as a variable in the correlations with the environmental variables as discussed in section 3.3.

3.6 Multivariate analysis

The quadrats or species situated towards the end of the axes are the best indicators of ecological gradients.(**EXPAND**) Quadrats 2 and 4 along transect 1 on the regraded spoil site were not included in the DECORANA or TWINSPAN analyses as these two quadrats contained no vegetation.

3.6.1 DECORANA

3.6.1.1 Ordination of species and quadrats from all four sites

A total of 70 samples and 136 species were used in the ordination. Table 6 displays the eigenvalues of the four principal axes of variation shown by DECORANA. The first two axes result in nearly 87% of the total variation to be seen whilst axes 3 and 4 only contribute to 29%. Therefore, only axes 1 and 2 will be considered in the ordination of quadrats and species from all 4 sites.

Table 6. Eigenvalues of the four principal axes of variation in quadrat and species data from all four sites

Axis	Eigenvalue
1	0.555
2	0.311
3	0.162
4	0.126

Fig. 10 shows the DECORANA ordination of all quadrats along the first and second principal axes of variation. Four distinct clusters of quadrats can be seen. These correspond to the regraded spoil site (1 - 43), the quarry floor (44 - 55), the magnesian limestone grassland (56 - 64) and the area cleared of scrub (65 - 70). The actual quadrat represented by each number can be found in the Appendix. Axis 1 accounts for the main variation (56.1%) seen between the regraded slope, the quarry floor and the magnesian limestone grassland site. Quadrats from the regraded spoil are found towards the negative end of axis 1 and quadrats from the magnesian limestone grassland are found towards the more positive end of axis 1. Quadrats from the quarry floor are situated in between, although closer to quadrats from the magnesian limestone grassland than the regraded spoil. Axis 2 seems to account for more of the differences seen between the area cleared of scrub and both the quarry floor and magnesian limestone grassland. The quadrats from the scrub-cleared area are situated further towards the positive end of axis 2.

Fig. 11 shows the DECORANA ordination of species from all four of the sites. The species abbreviations are given in full in the Appendix. Species plotted towards the more positive end of the first axis include *Pimpinella saxifraga, Sesleria albicans, Listera ovata, Stachys officinalis, Campanula rotundifolia* and *Viola hirta.* These species were frequently to commonly found on the magnesian limestone grassland. Species plotted towards the more negative end of the first axis included *Leucanthemum vulgare, Tripleurospermum inodorum, Holcus lanatus, Bryum* sp.*** and *Salix caprea* and were mostly found on the regraded spoil slope. These species are associated with

*** Nomenclature of bryophytes follows that of Smith (1978)

Fig. 10. Ordination of quadrats from all four sites

Axis 1 vs Axis 2

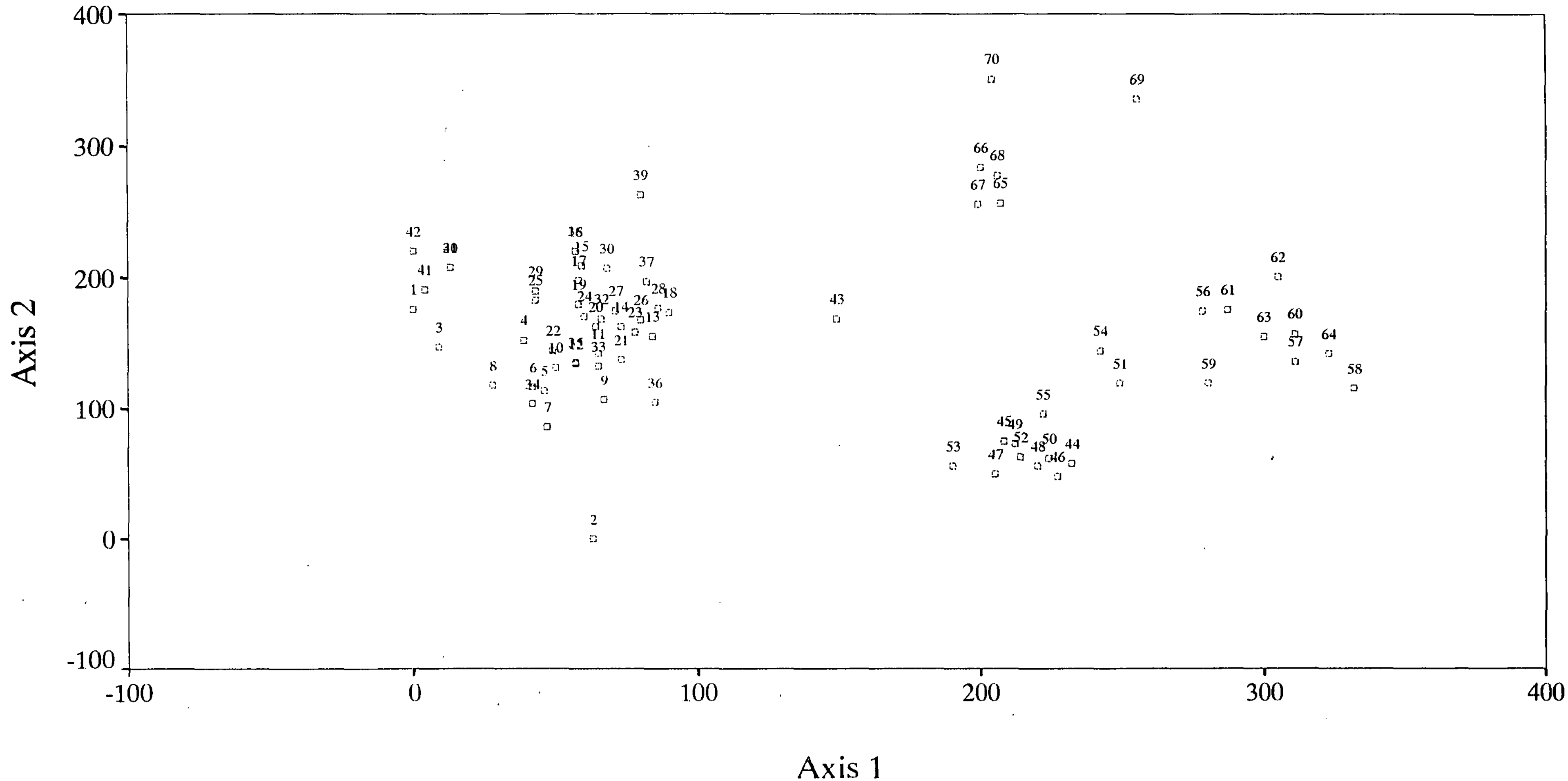
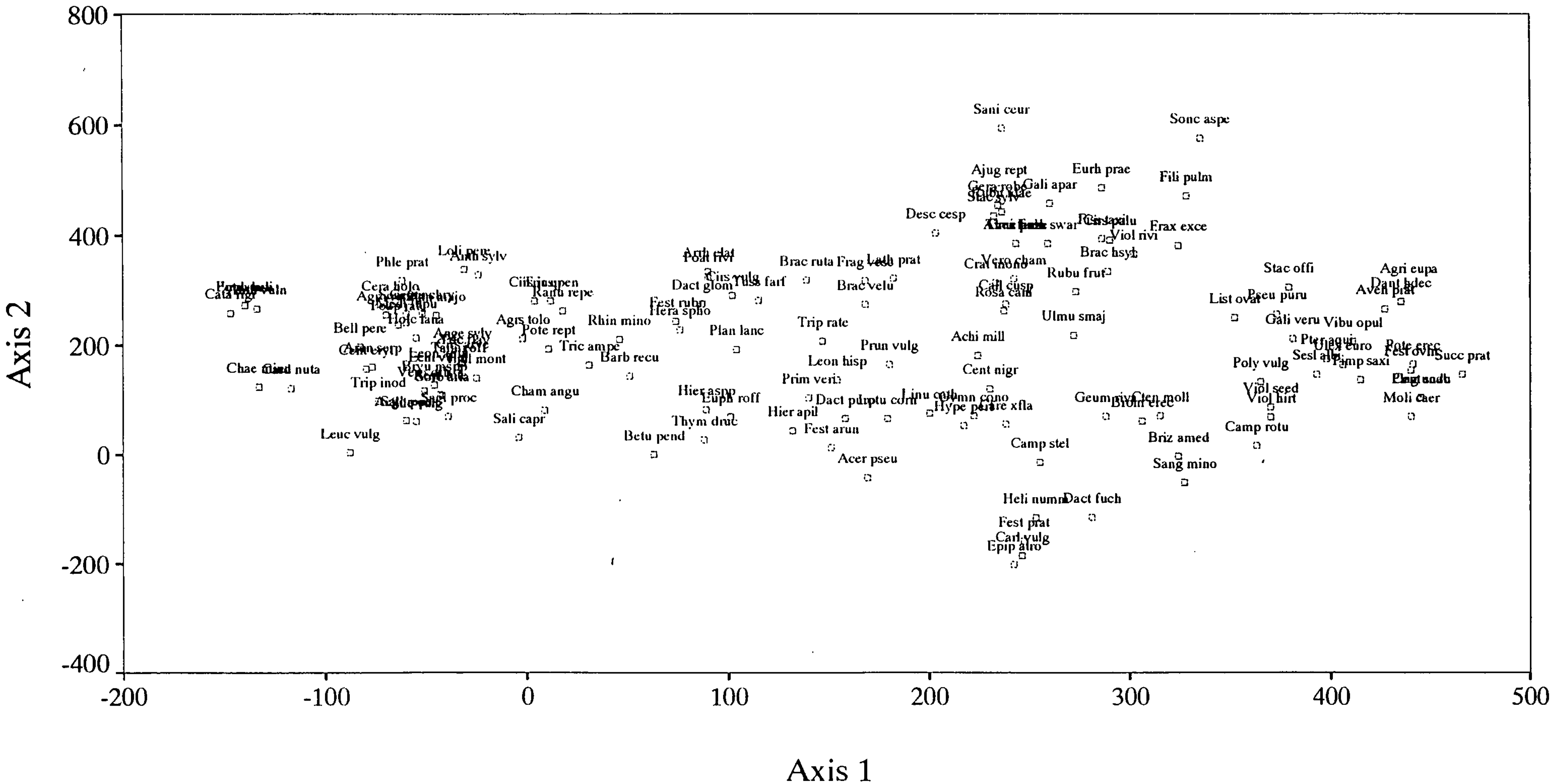


Fig. 11. Ordination of species from all four sites

Axis 1 vs Axis 2



primary succession and are common on disturbed areas such as wasteland. Species plotted in the middle of the axis include *Leontodon hispidus*, *Plantago lanceolata*, *Prunella vulgaris*, *Primula veris* and *Centaurea nigra*, all of which prefer meadow or grassland habitats although they do occur elsewhere (Graham, 1988).

The species plotted towards the more positive end of Axis 2 include *Ajuga reptans*, *Eurhynchium praelongum*, *Deschampsia cespitosa*, *Galium aparine*, *Viola riviniana* and *Veronica chamaedrys* which are characteristic of woodland or shaded habitats and were mainly found in the quadrats from the scrub-cleared area. Species plotted towards the more negative end of the second axis include *Helianthemum nummularium*, *Dactylorhiza fuchsii*, *Sanguisorba minor*, *Epipactis atrorubens*, *Carlina vulgaris* and *Acer pseudoplatanus*. These species tend to compete better on short turf where conditions of stress may prevail which excludes other, usually more competitive, species.

The first axis may therefore be related to variation in the successional stage of development to a magnesian limestone grassland. The second, to succession from open to shaded habitats.

3.6.1.2 Ordination of species and quadrats from the regraded spoil site

Table 7 shows the eigenvalues of the four principal axes of variation calculated by DECORANA. The first two axes account for over 57% of the total variation whist axes 3 and 4 only account for 19%. Therefore only the first two axes were considered for the ordination plots of quadrats and species from the regraded magnesian limestone spoil.

Table 7. Eigenvalues of the four principal axes of variation in the quadrat and species data from the regraded spoil site

Axis	Eigenvalue
1	0.358
2	0.215
3	0.112
4	0.078

Fig. 12 shows the DECORANA ordination of the quadrats from the regraded spoil site. Towards the more positive end of the first axis the majority of the quadrats are from transect 1 (2 - 13), the first five quadrats of transect 3 (32 - 36) and the

Fig. 12. Ordination of quadrats from the regraded spoil slope

Axis 1 vs Axis 2

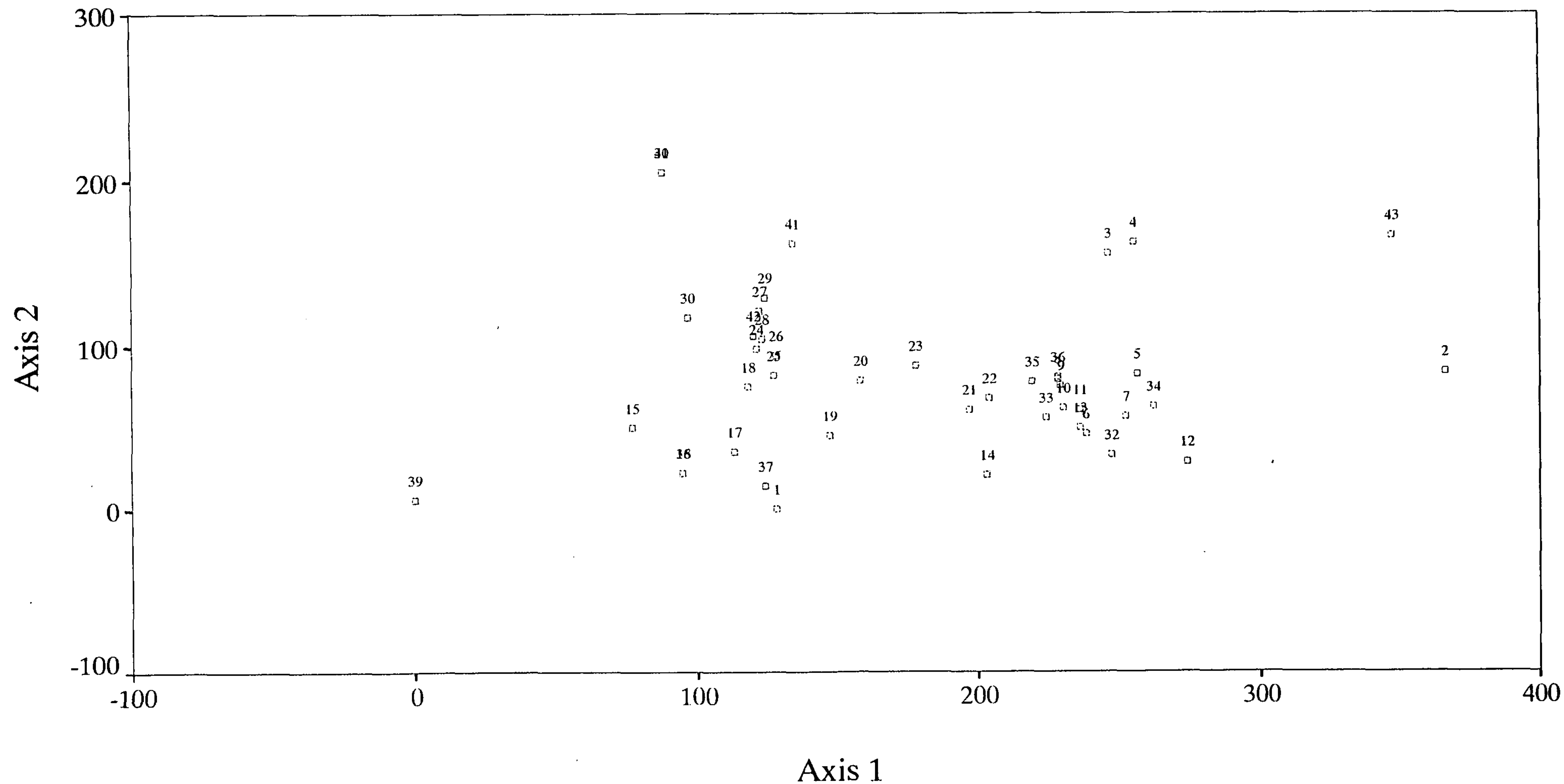
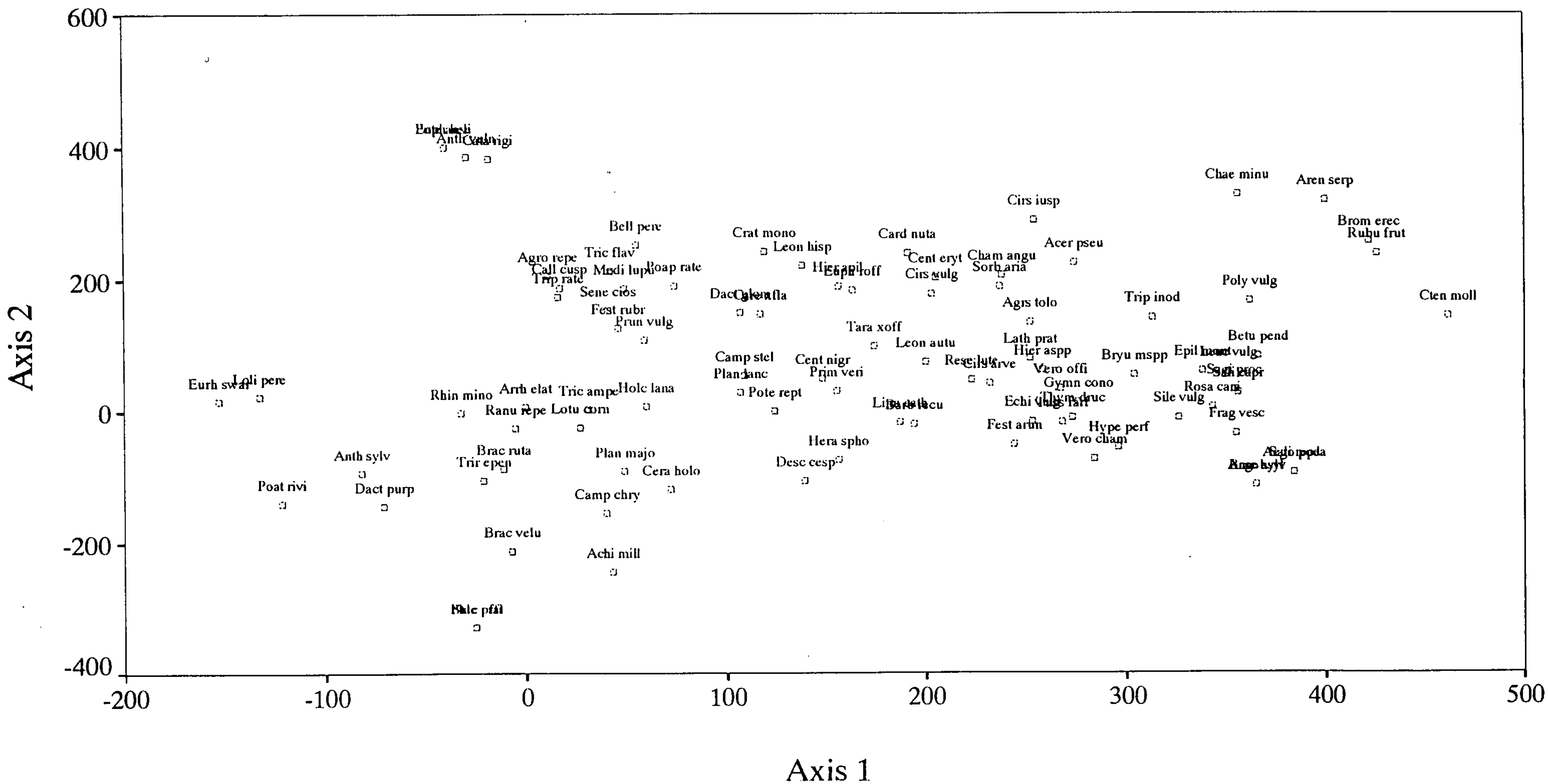


Fig. 13. Ordination of species from the regraded spoil slope

Axis 1 vs Axis 2



bottom-most quadrat of transect 4 (43). Towards the more negative end of axis 1 points representing quadrats from transect 2 (15 - 18, 24 - 31)), the last three quadrats of transect 3 (37 - 39) and the first three quadrats from transect 4 (40 - 42) have been plotted. As fig. 2 illustrates, transect 1 was situated at the bottom of the slope, transect 2 at the top of the slope, transect 3 on the eastern side of the slope (running from bottom to top) and transect 4 on the western side of the slope (running from top to bottom). The main cause of variation between the quadrats may therefore be their relative distance from the top of the slope.

Towards the more positive end of axis 2, quadrats 5 and 6 from transect 1 (3 and 4), quadrat 17 from transect 2 (31) and quadrats 1, 2 and 4 from transect 4 (40, 41 and 43) have been plotted. These are all found on the western side of the regraded slope nearer to the quarry floor. Towards the negative end of axis 2, quadrats 1, 14 and 16 from transect 1 (1, 12 and 14), quadrats 2 and 3 from transect 2 (16 and 17), and quadrats 1, 6, 7, and 8 from transect 3 (32, 37, 38 and 39) have been plotted. With the exception of 1/1, all these quadrats lie on the eastern side of the regraded spoil slope nearer to the magnesian limestone grassland. Therefore the second most important source of variation between the quadrats may be their relative distance from either the magnesian limestone grassland or the quarry floor.

Fig. 13 shows the DECORANA ordination of the species from the regraded spoil along axes 1 and 2. Towards the more positive end of the first axis lie species such as *Fragaria vesca*, *Salix repens*, *S.caprea*, *Betula pendula*, *Brachypodium sylvaticum*, *Polygala vulgaris*, *Chaenorhinum minus* (L.), *Leucanthemum vulgare*, *Bromus erectus* and *Rosa canina* all of which were primarily found towards the bottom of the slope. There is a tendency for the species to be associated with woodland or shaded habitats although there are obvious exceptions such as *B.erectus* and *L.vulgare*. Towards the more negative end of axis 2, species such as *Poa trivialis*, *Lolium perenne*, *Catapodium rigidum*, *Anthyllis vulneraria*, *Trifolium repens*, *Brachythecium rutabulum*, *Brachythecium velutinum*, *Trifolium pratense*, *Rhinanthus minor* and *Anthyllis sylvestris* are found. These species were generally found towards the top of the regraded slope and are more typically associated with grassland habitats.

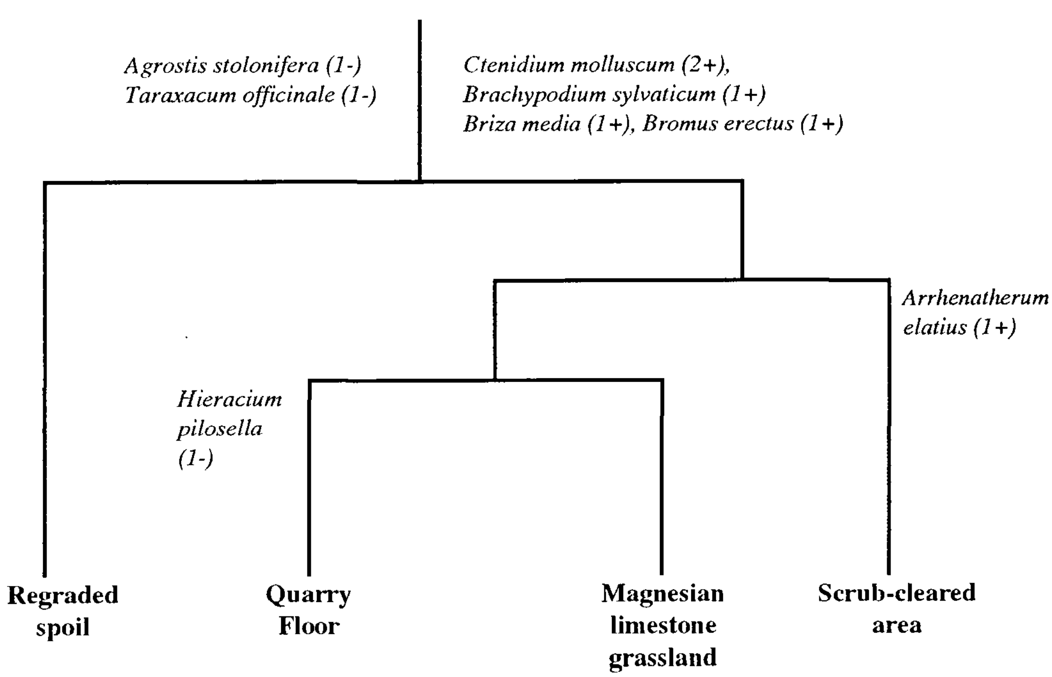
Towards the more positive end of axis 2, species found mainly on the western side of the slope have been plotted such as *C.rigidum*, *A.vulneraria*, *Bellis perennis*, *Crataegus monogyna*, *C.minus*, *B.erectus* and *Arenaria serpyllifolia*. Towards the more negative end of the second axis, species found on the eastern side of the slope have been plotted such as *B.velutinum*, *D.cespitosa*, *V.chamaedrys*, *B.sylvaticum* and *Campylium chrysophyllum*.

3.6.2 TWINSPAN

3.6.2.1 TWINSPAN division of quadrats from all four sites

Fig. 14 shows a dendrogram of the first three divisions made by TWINSPAN on the quadrat data based on the indicator species and pseudospecies cut levels as shown. The pseudospecies cut levels used (0, 3, 4, 5 and 7 on the Domin scale) correspond to 1, 2, 3, 4 and 5 respectively in the figure. At the first division, all 29 quadrats from the quarry floor, the magnesian limestone grassland and the scrub-cleared area (the 'positive' side) were separated from the quadrats from the regraded spoil (the 'negative' side). The positive indicators used for the division (with the pseudospecies cut level) were the moss *Ctenidium molluscum* (2), *Briza media* (1), *Bromus erectus* (1) and *Brachypodium sylvaticum* (1). The negative indicator species used (with the pseudospecies cut level) were *Agrostis stolonifera* (1) and *Taraxacum officinale* agg. (1). The second division split the six quadrats from the scrub-cleared area from the quadrats from the magnesian limestone grassland and quarry floor on the basis that they contained *Arrhenatherum elatius*. Finally, the nine quadrats from the magnesian limestone grassland were divided from the 12 quadrats of the quarry floor on the basis that they did not contain any *Hieracium pilosella*.

Fig 14. Dendrogram showing the first three TWINSPAN divisions of quadrats from all four sites with the indicator species used in the divisions. Pseudospecies cut levels are in brackets.



3.6.2.2 TWINSPAN division of quadrats from the regraded spoil site

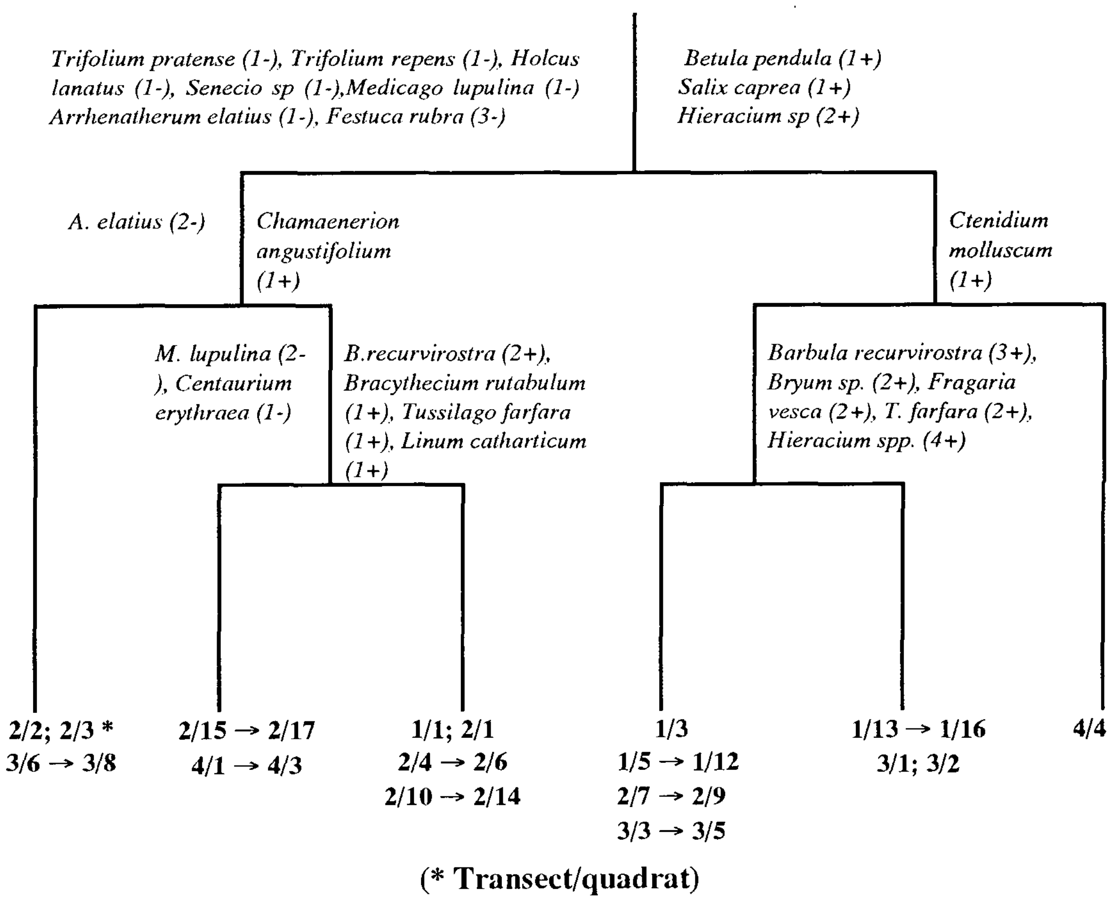
Fig. 15 shows the first few divisions made by TWINSPAN on the quadrat data from the regraded spoil site. The indicator species and pseudospecies cut levels (levels as in section 3.4.2.1) used are displayed in the figure. The first division separated quadrats generally nearer to the bottom of the slope (i.e. all the quadrats from transect 1 with the exception of quadrat 1, quadrats 7 to 9 from transect 2, quadrats 1 to 5 from transect 3 and quadrat 4 from transect 4) from quadrats nearer to the top of the slope (i.e. quadrat 1 from transect 1, most of the quadrats from transect 2, quadrats 6 to 8 from transect 3 and quadrats 1 to 3 from transect 4). The indicator species and pseudospecies cut levels used were *Hieracium* sp. (2+), *Betula pendula* (1+), *Salix caprea* (1+), *Senecio sp.* (1-), *M.lupulina* (1-), *Trifolium pratense* (1-), *Trifolium repens* (1-), *Holcus lanatus* (1-), *Arrhenatherum elatius* (1-) and *Festuca rubra* (3-). This generally supported the DECORANA ordinations of quadrats and species from the regraded slope along the first principal axis which had the quadrats from nearer the top of the slope and species more typical of grassland habitats towards one end of the axis and quadrats from nearer the bottom and species more typical of woodland or scrub towards the other end of the axis.

After this division there was no clear pattern to explain why quadrats had been grouped together. When the group of quadrats from towards the bottom of the slope were split up, quadrat 4 from transect 4 is separated from the rest as it contained *Ctenidium molluscum* and the others did not. This could be from an outcrop of magnesian limestone rock adjacent to the quadrat. A TWINSPAN division of the remaining 21 quadrats split quadrats from the bottom eastern side of the slope (i.e. quadrats 13 to 16 from transect 1 and quadrats 1 and 2 from transect 3) from the rest using *Bryum* sp. (2+), *Barbula recurvirostra* (3+), *Fragaria vesca* (2+), *Tussilago farfara* (2+) and *Hieracium* sp. (4+) as indicator species with their associated pseudospecies cut levels. (NB. bottom eastern corner of the slope studied was near established scrub leading to shade tolerant species such as *F.vesca* becoming established and perhaps more moisture and nutrients in the soil to favour higher numbers of plants and bryophytes.)

When the group of quadrats towards the top of the slope were divided up by TWINSPAN, quadrats from the top eastern side of the slope with the exception of the first quadrat from transect 2 (i.e. quadrats 2 and 3 from transect 2 and quadrats 6 to 8 from transect 3) were separated from the rest, using *A.elatius* (2-) and *Chamaenerion angustifolium* (1+) as indicator species with their associated pseudospecies cut levels. TWINSPAN divided the remaining 16 quadrats up into two groups using *M.lupulina* (2-), *Centaurium erythraea* (1-), *Brachythecium rutabulum* (1+), *B.recurvirostra* (2+), *T.farfara* (1+) and *Linum catharticum* (1+) as the indicator species The group on the more negative side of the division consisted of the quadrats from the top western side of the spoil slope (i.e. quadrats 15 to 17 from transect 2 and quadrats 1 to 3 from transect 4).

Further TWINSPAN divisions of the quadrats from the regraded spoil therefore tend to follow the DECORANA ordinations along the second principal axis and groups quadrats according to their relative positions across the slope.

Fig 15. Dendrogram showing the first four TWINSPAN divisions of quadrats from the regraded spoil site with the indicator species used in the divisions. Pseudospecies cut levels are in brackets.



Chapter 4

Discussion

4.1 Factors affecting the percentage vegetation cover of quadrats

The amount of bare ground found in each quadrat was most highly correlated with the pH of the soil. In calcareous soils the maximum pH is limited by the chemical equilibrium between carbon dioxide, carbonate and bicarbonate ions and cannot exceed a pH of 8.5. Soils with a higher pH usually have free sodium carbonate (Bannister, 1976). Soil pH can have direct and indirect effects on plants. Mobilisation of nitrogen and sulphur falls at pH > 8.0 and at pH > 8.8 the toxicity of hydroxide ions increases (Bannister, 1976). At pH > 7.5 the availability of calcium, zinc, potassium, phosphorus and boron falls. Alkalinity also causes a decrease in the availability of iron, manganese and copper (Black, 1968) and at pH > 7.3 biological activity in the soil falls. However, although pH influences plant distribution it is also true that plants change the pH of the soil beneath them (McCulloch, 1975; Hodgkin, 1984).

The amount of bare ground in the quadrats was also positively correlated with distance from the top of the slope. This could be for several reasons. Firstly, the pH of the soil increased towards the bottom of the slope and therefore for reasons discussed above plant growth may have been inhibited. Secondly essential nutrients may have influenced plant growth and vegetation cover in quadrats in different areas of the slope, especially where it joins agricultural land. For limestone grassland, plant-available water, phosphorus and nitrogen are the decisive limiting factors for plant growth (Humphries, 1977). Most limestone quarry materials have less than 100 ppm/g of total nitrogen which is inadequate for the growth of most plants (Humphries, 1977). Quarry spoil is also known to contain low concentrations of inorganic phosphorus and potassium and high concentrations of calcium and magnesium (Richardson & Evans, 1986). High levels of calcium decrease the solubility of phosphate thereby decreasing its availability to plants. Phosphorus deficiency can cause the older leaves and stems of plants to turn reddish (Bannister, 1976), symptoms which were observed in many of the plants on the regraded spoil slope. Mineral nutrient stress limits the root growth of many species, therefore making them more susceptible to drought (Grime & Curtis, 1976). Therefore plant growth may be severely limited generally through the study site but enhanced nearer the top of the slope due to nutrient-enriched surface runoff from the adjacent arable field.

A decrease in vegetative cover was also associated with a decrease in the organic content of the soil. Leaching of nutrients can be a problem if there is little organic matter present in the soil to retain the ions (Grunwald, Iverson & Szafoni, 1988). Organic matter also enables the soil to retain more water (Anderson, 1927). Drought can have a large impact on the percentage vegetation cover of a site. During the 1976 drought the amount of bare ground in a chalk grassland increased from a summer average of 5.5% to 39% (Hopkins, 1978). Water is also important as it is the medium in which the mineral ions are transported and therefore desiccation decreases the mobility of these ions (Bannister, 1976).

Quadrats on steeper slopes had less vegetative cover associated with them. Steeper slopes would cause more surface runoff of water, nutrient leaching and soil erosion.

Of the two aspects measured on the regraded spoil the more northerly facing one was correlated with an increased amount of bare ground. South facing slopes receive more radiant energy and therefore warm quicker in spring leading to a longer period for plant growth. This could account for the greater vegetation cover. However, in the summer, soils on south-facing slopes may dry out more. (Grunwald *et al*, 1988) and so can be expected to support less vegetation. The reasons for the relationship found with aspect are therefore not exactly clear.

The assumption is that the number of seedlings emerging in each tray reflects the number of seeds present in the soil sample.

The number of seedlings emerging in each tray was highly correlated with the amount of bare ground in the representative quadrat. An explanation for this correlation is that where there were fewer plants there were fewer seeds in the soil and therefore fewer seedlings to emerge. This demonstrates that seeds are not evenly distributed over the regraded slope. Therefore the low number of seeds could partly account for the low amount of plants developing in a quadrat. This still leaves the important question of why plants have become established in some quadrats and not others and it is assumed that the establishment of seedlings, once they have germinated, is the crucial stage determining the percentage plant cover during the colonisating phase. The same factors which affect the amount of vegetation (discussed previously) are also likely to affect the establishment of seedlings. In addition there is also evidence that shows the presence of bare ground is itself detrimental for seedling establishment as a lack of vegetation on the surface of the soil allows extremes of temperatures (Grunwald et al, 1988) and frost damage to occur. Ryser (1993) concluded that physical hazards such as drought and frost heave control seedling survival more than competition on open sites. For example, *Primula veris* seedlings need the shelter of neighbouring plants for their successful establishment because this decreases the amount of drought damage and frost heave experienced (Ryser, 1993). The roots of established plants stabilise the soil against frost heave. Temperature is likely to affect seedling establishment by influencing the balance between photosynthesis and respiration. Seedlings usually have a relatively high respiration : photosynthesis ratio and are therefore especially sensitive to temperature extremes (Bannister, 1976). High temperatures are also associated with desiccation in seedlings, especially on bare ground because of evaporation (Anderson, 1927).

High pH values were also associated with low numbers of seedlings emerging. High pH values have direct and indirect effects on plants as discussed in section 4.1 and also are associated with a decrease in the organic matter content of soil. As already discussed, organic matter is the main source of mineral nutrients for plants and it also enables the soil to retain more water (Anderson, 1927). Before germination can take place, seeds must be able to take up relatively large amounts of water (Etherington, 1975). Therefore increased germination and consequential seedling establishment is facilitated with increasing amounts of organic material. (Humphries, 1977). A lack of organic matter can lead to the surface of the soil drying out, a process that is detrimental to newly established seedlings as they only have very shallow roots (Davison, 1964).

The lower part of the slope were associated with lower numbers of seedlings emerging, possibily because higher pH's were found towards the bottom of the slope, but also because of the suspected nutrient runoff from the arable field at the top. If minerals are not available to the seedling when its reserves run out then it will suffer from decreased root growth thus making the seedling more susceptible to drought (Bannister, 1976).

Steeper slopes were associated with fewer seedlings emerging, but once again this could be explained by the higher pH and more bare ground found on the steeper slopes. Humphries (1977) noted that as quarry materials lack a physical resemblance to soil in their structure they are more easily eroded by wind and water. Therefore the establishment of vegetation on unstable slopes is prevented by the removal or burial of seeds and seedlings. Soil movement can also expose roots to desiccation and frost damage or damage the aerial shoots. Towards the bottom of the regraded spoil, especially on the western side of the slope, there are deep runnels caused by surface water runoff and soil has been washed downhill (pers. observation). This soil would engulf newly established seedlings but this runoff was not studied.

Another cause of seedling death is the failure to form mycorrhizas (Fenner, 1987). Gay, Grubb & Hudson (1982) found that seedlings of most species they studied formed mycorrhizas within two weeks of their germination and that these mycorrhizas led to increased growth. On phosphate-deficient soils Mosse and Hayman (1971) found that the extent of infection of seedlings varied greatly from place to place, probably because there was less fungi in the soil.

4.2 Multivariate analysis

4.2.1 Regraded site

Colonisation can be considered to be the successful outcome of two independent processes, that of dispersal and of establishment. Firstly, species have to arrive at the site. The only species to arrive will be those with the appropriate powers of dispersal. Immediately adjacent species will have a good chance of reaching the site, but species from further away will only reach if they have long-distance dispersal mechanisms (Bradshaw, 1983; Jefferson and Usher, 1986). Pioneer species tend to have similar dispersal methods, most have light wind-dispersed seeds (Grime, 1979).

The DECORANA ordination along the first principal axis and the first TWINSPAN division generally separated the quadrats from the top of the slope from those nearer the bottom. Quadrats from the bottom of the slope tended to have more woodland/scrub species within them whilst quadrats nearer the top had a higher number of grasses and grassland dicotyledon species growing within them. As can be seen from fig. 2, the species assemblage found growing within quadrats bears a strong resemblance to the vegetation immediately surrounding the regraded spoil slope. At the bottom of the slope there is an area of woodland (labelled 'B' on fig. 2) consisting of *Salix*, *Betula*, *Fraxinus excelsior*, *Acer pseudoplatanus* and *Crataegus monogyna*. The grassland adjacent to the arable field at the top (labelled 'A' on fig. 2) consists of species such as *Arrhenatherum elatius*, *Poa trivialis*, *Primula veris*, *Rhinanthus minor*, *Trifolium* sp. and *Centaurea nigra*.

DECORANA ordinations and TWINSPAN divisions also cluster the quadrats according to which side of the regraded slope they occurred. The aspect of the slope (the western side faced a more northerly direction) and the surrounding vegetation may be the environmental factors causing this. The bottom eastern corner of the regraded slope studied was next to an area of scrub containing mostly *Salix* sp., *Betula* sp., *C.monogyna*, *Tussilago farfara* and *Fragaria vesca* which has established since that part of the slope was regraded some years (actual date unknown) before the section of slope studied. This was reflected in the vegetation found in quadrat 16 from transect 1 which was situated right next to the scrub area. The distribution of *T.drucei* was most significantly associated with the eastern side of the slope perhaps because its growth and flowering is generally better on south facing slopes (Pigott, 1955).

To conclude, it would appear therefore that the vegetation immediately surrounding the regraded slope is acting as the main seed source for the colonisation of the slope.

Once seeds arrive they will only be able to colonise the site if the species is adapted to the special conditions found at the site, e.g. the physical and chemical factors. (They will also be able to colonise the site if they evolve adaptations to the extreme conditions). The relatively open site will favour species that do not withstand competition. As already discussed, the soils are skeletal and contain few of the requirements needed by plants (Humphries, 1980; Bradshaw, 1983). Booy (1975) analysed the screened dolomite waste heaps at Raisby quarry and found that the levels of available nitrogen, phosphorus and potassium were much lower than those considered necessary for good plant growth.

The species found towards the top of the slope will be subjected to a less extreme environment compared with those found towards the bottom of the slope. At the top of the slope the soil has a lower pH, a higher organic content and is probably enriched with nutrients from the arable field. The first TWINSPAN division divided the quadrats towards the top of the slope ('positive' side) from those towards the bottom ('negative' side) using *Trifolium* sp., *Festuca rubra*, *Holcus lanatus*, *Senecio* sp., *Medicago lupulina* and *Arrhenatherum elatius* as 'positive' indicator species and *Salix* sp., *Betula* sp. and *Hieracium* sp. as 'negative' indicator species.

Of the species found towards the top of the slope *Trifolium* sp. have a high phosphate requirement and don't survive in tall vegetation (Humphries, 1977). *Trifolium* sp. also cannot tolerate severe frost or droughts (Grime *et al*, 1988). Growth of *Festuca rubra* is limited by low amounts of available nitrogen in the soil (Lloyd & Pigott, 1967). Grasses such as *Poa trivialis* found at the top of the slope may be deterred from colonising the bare areas further down the slope as they are fairly shallow-rooted and thus are not tolerant of drought (Grime *et al*, 1988). Similarly, *Rhinanthus minor* was found to be absent from droughted habitats in the Sheffield region (Grime *et al*, 1988). *Primula veris* seedlings need the shelter of neighbouring plants for their successful establishment because this decreases the amount of frost heave and drought damage experienced (Ryser, 1993). *Arrhenatherum elatius* is susceptible to nitrogen stress. A lack of nutrients limits its root penetration and therefore makes it more susceptible to drought (Grime & Curtis, 1976). The subspecies *bulbosum*, which was most often found on the regraded spoil, is very sensitive to frosts (Pfitzenmeyer, 1962) and therefore is not suited for bare ground. Therefore the spread of these species further down the slope will be limited until suitable conditions are reached by the gradual incorporation of organic matter into the soil.

Of the species found towards the bottom of the slope *Salix* sp. and *Betula* sp. are fairly shallow-rooted but they can still tap sufficient amounts of water for their survival as they have efficient root systems. (Locket 1945). Seeds of scrub species have larger reserves of nitrogen and phosphorus and therefore are initially almost independent of the nutrient supply from the soil (Lloyd & Pigott, 1967). *Betula* sp. has a good chance of establishment on bare soil (Grime *et al*, 1988) but the seeds, being wind-dispersed, are very small and therefore more prone to drought. Establishment of seedlings of *Salix* is limited to gaps in vegetation (Grime *et al*, 1988). *Hieracium* sp. are known to have wind blown seeds and have long tap roots, thus making them suitable for colonising less suitable environments. Lloyd & Pigott (1967) found that *C.monogyna* was not good at colonising open sites with poor soils which may help to explain why *C.monogyna* was only present as seedlings and not as established shrubs.

Generally those species able to cope with drought conditions because they have a good root system, e. g. *Plantago lanceolata* (Sagar & Harper, 1964), *Hieracium* sp. and *T. officinale* (Grime *et al*, 1988), are tolerant of frost, e. g. *P.lanceolata* (Grime *et al*, 1988), *T.drucei* (Grime *et al*, 1988), or are tolerant of low nutrient levels, e. g. *Tussilago farfara* (Myerscough & Whitehead, 1966) were found in quadrats at all distances down the slope.

4.2.2 All sites

DECORANA and TWINSPAN analysis of the quadrat data showed the four areas surveyed to be very different with respect to their vegetation.

The regraded spoil did not contain the majority of species to be found on either the magnesian limestone grassland or the quarry floor. However, calcareous grassland species such as *Rhinanthus minor*, *Prunella vulgaris*, *Thymus drucei*, *Gymnadia conopsea*, *Medicago lupulina*, *Lotus corniculatus*, *Leontodon hispidus* and *Hieracium pilosella* were present. The most frequently found mosses were *Bryum* sp. and *Barbula recurvirostra*. Many of the species found were wind-blown colonising species such as *Salix* sp., *Taraxacum officinale* agg., *Hieracium* sp., *Betula* sp., *L.hispidus*, *Tussilago farfara* and *Agrostis stolonifera* as predicted for primary colonisers by Grime (1979).

Agrostis stolonifera often grew where no other species were found. It is defined as a competitive-ruderal by Grime (1979), most abundant where there are no tall growing plants. It can survive on soils with a pH > 8 and reproduces both by wind-dispersed seeds and vegetatively by stolons (Grime *et al*, 1988). Vegetative reproduction by means of stolons or rhizomes has advantages for the establishment of new plants in inhospitable environments as the offspring can receive nutrients from the parent plant whilst they become established. Regeneration by means of stolons also has advantages for colonisation over stony ground as the offspring is supported by the parent until they reach a substrate suitable for growth. Besides *A.stolonifera*, *H.pilosella*, *Fragaria vesca* and *Potentilla reptans* regenerate by means of stolons.

If a species does not grow on a site it is not known whether this is because it has not reached the site or whether it has not been able to become established. In this case the harsh conditions found on the regraded slope may have curtailed the establishment of many incoming species unable to cope with (or adapt to) them. Most of the species found had long tap roots, were nitrogen fixers (e.g. *L.corniculatus*), had low seedling requirements for external nutrients or were stoloniferous.

It has previously been found that for most grassland species the majority of seeds settle within 1m from the parent plant (Verkaar, Schenkeveld & van de Klashorst, 1983). Humphries, (1980) also found that a species may not be able to reach a site because it cannot colonise the intermediate areas. The regraded spoil is separated from both the quarry floor and the magnesian limestone grassland by areas of scrub (see fig. 1), although only a fairly narrow band of scrub exists between the quarry floor and the regraded spoil. Therefore, those species with poor dispersal abilities such as *Sesleria albicans* (Dixon, 1982), *Bromus erectus* (Lloyd & Pigott, 1967) and *Pimpinella saxifraga* (Grime *et al*, 1988) and/or are poor competitors in more productive environments are unlikely to reach the regraded spoil for a very long time, if at all. The Leblanc waste heaps near Bolton had a surface pH of between 8 and 9 which is the same as the more alkaline areas of the regraded spoil. Even after 100 years the sites were very open because of the extreme soil characteristics and the limited immigration of suitably adapted species. Once some of these species had been introduced to the site they were able to establish viable populations (Ash, Gemmell and Bradshaw, 1994).

The quarry floor has shallow soil with a mean pH not significantly different from that of the regraded spoil. There are still considerable gaps present in the vegetation and even 50 years after abandonment the vegetation on the quarry floor does not match that of the magnesian limestone grassland. The dominant grass was *Bromus erectus* (found in all 12 quadrats) and *Briza media* and *Festuca rubra* were also fairly common. *Sesleria albicans* was found in only half the quadrats surveyed. Frequently found dicotyledons included *L.corniculatus*, *M.lupulina*, *T.drucei*, *C.nigra*, *Campanula rotundifolia*, *L.hispidus*, *Sanguisorba minor*, *H.pilosella*, *Helianthemum* *nummularium* and *Carlina vulgaris*. The most abundant moss was *Ctenidium molluscum*. The shallow soil is probably subject to drought periods in the summer and therefore the species most suitable for the site are those possessing a long tap root to absorb subsoil moisture, e.g. *H.pilosella*, *T.drucei*, *L.corniculatus*, *M.lupulina* and *S.minor* (Grime *et al*, 1988). It is also a very important site for species such as *H.nummularium*, *C.vulgaris*, *T.drucei*, *Epipactis atrorubens* and other orchids which are out-competed by the taller, denser vegetation found on the limestone grassland. *L.hispidus* is also out-competed as its seeds cannot germinate in shade cast by taller vegetation (Silvertown, 1980). Because the site suffers from relatively little disturbance (mainly fires and trampling by people) and the shallow soils generally result in few nutrients and little water being available, many of the species occupying the quarry floor are stress-tolerators as defined by Grime (1979).

The quadrat data from surveying the magnesian limestone grassland indicated that this was a well vegetated site containing a high frequency and abundance of *S.albicans* (found in all nine quadrats), and also *B.erectus*, *B.media*, *Festuca ovina*, *Centaurea nigra*, *Listera ovata*, *C.rotundifolia*, *Gymnadia conopsea*, *Potentilla erecta*, *Pimpinella saxifraga* and *C.molluscum*. *F.ovina* is probably more commonly found on the limestone grassland rather than on the quarry floor (where it was only found in one quadrat) because it is susceptible to drought on shallow soils (Grime *et al*, 1988). *P.erecta* and *Stachys officinalis* also have a requirement for moister habitats (Grime *et al*, 1988) and so were restricted to the grassland. *H.pilosella*, which was used as the indicator species in the TWINSPAN division for separating quadrats from the quarry floor and the limestone grassland, was not present in the grassland, presumably as it is out-competed by the taller denser vegetation found there. In places the grassland was becoming invaded by *Ulex europaeus* and *Crataegus monogyna*.

The area of the magnesian limestone grassland recently cleared of 30 year old scrub still retained many species more typical of shaded or disturbed habitats such as *Geranium robertianum*, *Sanicula europaea*, *Fragaria vesca*, *Ajuga reptans*, *Rubus idaeus* and *Rubus fruticosus*. *C.monogyna* was also vigorously regenerating from the coppiced stools. The presence of scrub has been shown to enrich the soil beneath it with organic matter (McCulloch, 1975; Hodgkin, 1984) which will allow more competitive plants such as *A.elatius* to gain an advantage over stress-tolerators. However, there were signs that some species more typical of calcareous grassland were starting to recolonise the area such as *L.ovata*, *S.albicans* and *B.erectus* and there was no significant difference to be found between the pH of the scrub-cleared area and that of the magnesian limestone grassland. It can be expected that it will take a while for some of the shade-tolerant species to be eliminated from the scrub-cleared areas as some species, such as *G.robertianum* and *Pteridium aquilinum*, are predicted to have a persistent seed bank (Grime, *et al*, 1988). By coppicing the hawthorn, areas of grassland have been opened up allowing regeneration by those species with a persistent seed bank. Gaps in the grassland will also allow colonisation by ruderals.

4.3 General Discussion

A decrease in the amount of vegetation cover found in quadrats was correlated with a higher pH, a lower organic content, a more northerly aspect, presence on a steeper slope, nearness to the bottom of the slope and the emergence of fewer seedlings. This last correlation is indicative of poor seed stock being linked to low vegetation cover.

The vegetation found in the quadrats was also influenced by the vegetation immediately surrounding the regraded slope. Quadrats nearer the top of the slope contained species associated with the area of grassland adjacent to the arable field. Species found in the quadrats nearer the bottom of the slope were more associated with woodland and scrub, reflecting the presence of both around the edge of the slope at the bottom. The species found on either side of the spoil slope were less strongly differentiated. Few species from either the quarry floor or the magnesian limestone grassland had colonised the regraded spoil. This is probably because the environmental conditions found on the spoil are too harsh, combined with the poor dispersal abilities of those species characteristic of the quarry floor and limestone grassland. Gibson & Brown (1991) found the species composition in a recent grassland was strongly related to the distance from an ancient grassland source and concluded that ancient grassland species can only colonise quickly if they are adjacent to the site.

Species colonising the regraded spoil slope tend to be wind-dispersed and are defined by Grime (1979) as being Competitors, Ruderals or of an intermediate strategy (e g. CSR, competitive-ruderals, stress tolerant-competitors and stress-tolerant ruderals). Ruderals are potentially fast growing, short-lived plants which produce vast numbers of seeds. Competitors such as *A.elatius* and *Salix* sp. are defined as "...exploiting conditions of low stress and disturbance". CSR strategists such as *P.lanceolata* and *F.vesca* have evolved to cope with habitats where competition, stress and/or disturbance are constant features. Stress is defined by Grime (1979) as a factor causing a decrease in plant photosynthesis, such as a constant lack of nutrients or water. Disturbance is defined as a factor causing the actual destruction of a plant or part of a plant, such as frost or grazing.

The majority of species found on the magnesian limestone grassland and on the quarry floor are stress-tolerators (Grime, 1979). Grime (1979) defines stress-tolerating plants as being from areas of high stress and low disturbance. The species that are best adapted to the low nutrient concentrations found in calcareous soils are either potentially fast growing species that adapt to slow their growth or those species that are intrinsically slow-growing thereby lowering their nutrient requirements (Grime & Hunt, 1975). These species tend to optimise their tolerance by extending their growing season or by having flexible mineral absorption rates (Rorison, 1990). By using relatively little of the mineral resource available, if more minerals enter the soil they can be kept as a reserve for use in the future (Grime, 1979).

4.4 Management proposals

4.4.1 Regraded spoil slope

The regraded spoil slope is of potential importance for linking the magnesian limestone grassland with the quarry floor, thus decreasing their isolation and increasing the size of the nature reserve and its conservation value. Many studies have shown that larger reserves contain a higher diversity of species and are less prone to catastrophic declines in species numbers (Diamond & May, 1981).

The regraded spoil slope suffers from a lack of nutrients and probably water in the soil. Some areas of the slope also had high pH values (pH's as high as 9.1 were measured). However some species, mainly associated with grassland, are gradually spreading from the top of the slope downwards. Plants are abundant in the runnels which probably receive water and nutrient runoff from the arable field at the top. Therefore at present this is enhancing the colonisation of the slope. However, if more stress-tolerant calcicolous species become established in the future the runoff of nutrients from the arable field may become detrimental to their survival. It would favour the establishment of more competitive species which would exclude the stress-tolerators.

There have been many studies supporting the addition of NPK fertilisers to quarry waste to obtain a quicker cover of vegetation (Booy, 1975; Richardson & Evans, 1986). Without it it has been known to take over 50 years for similar sites to become colonised (Humphries, 1980). No fertilisers have been applied to the regraded spoil at Raisby but the nutrient runoff from the arable field may help to counter this.

The slippage of soil is more of a problem and could be a serious barrier to the establishment of seedlings towards the bottom of the slope on the western side. Even though the slopes have been regraded and are no longer considered to be steep, the runoff from adjacent areas is washing out soil and causing deep runnels to form which is detrimental for the establishment of vegetative cover. Booy (1975) suggested that the addition of organic material to the spoil slopes at Coxhoe quarry would decrease the amount of erosion caused by rainwater runoff, but there is no experimental evidence to support this.

There is a lack of 'desirable' species from the quarry floor and the magnesian limestone grassland colonising the slope, probably because many have poor dispersal mechanisms. There are areas of scrub, relatively productive habitats, separating the three sites which would prove to be an additional barrier to dispersal. Colonisation of the slope may also be curtailed because the environmental conditions are not yet right. One way of hastening colonisation would be to collect and sow seeds of species such as *S.albicans* and *B.erectus* at the top of the slope and they may then spread downslope along the runnels. From Ash *et al* (1994) it is clear that many species could grow in seemingly inhospitable conditions if only they could reach the site first. Previous studies have shown *Sesleria* to be a very successful colonist if found adjacent to the area for colonisation. At Highland House, an abandoned quarry in Co. Durham, there was a wide belt of *S.albicans* around the edge of the quarry resulting in *Sesleria* becoming a very successful colonist of the quarry, especially on the soft rock. At Bishop Middleham No. 2 quarry, less than 2 miles from Highland House, there was no *Sesleria* in the surrounding rim flora and this corresponded with a complete lack of *Sesleria* within the quarry itself (Richardson *et al*, 1980).

In contrast to Richardson (1956), who found no sites where tree species were amongst the first species colonising magnesian limestone waste heaps, at the bottom of the regraded slope scrub species such as *Salix* and *Betula* are colonising without there being a grassland successional stage first. This may mean that the grassland species may never become established and scrub will establish straight away. At the moment the shrubs growing on the soil may be important for enriching the soil with organic material which will allow new species to colonise in the future. Care must be taken that the scrub does not invade the whole of the site, although the EN policy is for a mixture of successional states thus increasing habitat, and hence, species diversity.

The area of grassland adjacent to the arable field contains many species typically found in calcareous grasslands such as *R.minor*, *L.corniculatus*, *M.lupulina*, *T.repens* and *C.nigra* . Whether these species arrived by natural means or were sown is unclear but they are starting to spread down the slope. *L.corniculatus* forms cushions which can be 1 or 2 cm higher than the surrounding ground and contain small particles of soil. Therefore *L.corniculatus* is important in three ways for the development of vegetative cover. Firstly it increases the amount of available nitrogen in the soil as it is a legume and can fix atmospheric nitrogen. It can also trap wind blown material and on dying it enriches the soil with organic matter. (Usher, 1979).

To conclude, it is important to keep monitoring the regraded spoil. The quarry floor has become an important refugia with time. With luck and appropriate management in another 40 years the regraded slope may be also.

4.4.2 Quarry floor

The quarry floor suffers from trampling by people, fire sites, litter and scrub encroachment. It is important to keep the very open conditions for the retention of species such as *H.nummularium*, *E.atrorubens*, *C.viride* and other orchids. The vegetation of the magnesian limestone site is taller and denser and, although more typical of magnesian limestone flora, excludes these rare species. The quarry floor at Raisby supports the highest number of *E.atrorubens* in Co. Durham making it an extremely important site for conservation.

4.4.3 Magnesian limestone grassland

The main threat to the magnesian limestone grassland is that of scrub encroachment. Hodgkin (1984) found evidence that the presence of hawthorn caused an increase in soil fertility, enriching it with nitrates and phosphates. Hawthorn changes the pH, organic content and moisture content of the top soil and may thereby favour the growth of other species, although this may be a feature of long-term scrub development (McCulloch, 1975; Rizand *et al*, 1989). At Thrislington Nature Reserve in Co. Durham, invasion by hawthorn was shown to decrease the pH of the magnesian limestone soil along with the amount of exchangeable calcium and magnesium. The amount of organic matter in the soil was increased (McCulloch, 1975).

The grazing regime now implemented should decrease the scrub starting to recolonise the site. The additional removal of gorse is needed as it acidifies the top layer of the soil, reducing the advantages of calcicolous species over more competitive species. From the results found in this investigation (i.e. the soil pH from the scrub-cleared area is not significantly different from that of the magnesian limestone grassland, and that there are some species more typical of magnesian limestone grassland recolonising the scrub-cleared area) it is not yet too late to clear additional woodland from the magnesian limestone site and, as a potential seed source is immediately adjacent, there is a good chance of magnesian limestone flora colonising more of the scrub-cleared area. Unpermitted grazing by horses was observed on the grassland this summer (pers. observation) which will damage the flora, flowering at the time, if allowed to continue in subsequent years. The site is also popular with people walking their dogs and has a number of well-used footpaths throughout.

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APPENDIX - Species composition and abundance (Domin scale) of all quadrats

				Appendix 1 - Species composition and abundance (Domin scale) of all quadrats											
		Acerpseu	Achimill	Aegopoda	Agrieupa	Agrorepe	Agrstolo	Ajugrept	Angesylv	Anthsylv	Anthvuln	Arenserp	Arrhelat	Avenprat	Avenpube
	Quadrat														
Transect 1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	6	1	0	0	0	0	4	0	0	0	0	1	0	0	0
	7	0	0	0	0	0	5	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	2	0	0	0	0	0	1	0	0
	9	1	0	0	0	0	2	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	4	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	3	0	0	0	0	0	0	0	0
	12	0	0	0	0	0	5	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	2	0	0	0	0	0	0	0	0
	14	0	0	1	0	0	4	0	0	0	0	0	0	0	0
	15	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	4	0	0	1	0	0	1	0	0
Transect 2	1	0	0	0	0	2	5	0	0	0	0	0	1	0	0
	2	0	0	0	0	0	5	0	0	1	0	0	5	0	0
	3	0	0	0	0	0	5	0	0	0	0	0	4	0	0
	4	0	0	0	0	0	4	0	0	0	0	0	1	0	0
	5	0	0	0	0	0	5	0	0	1	0	0	2	0	0
	6	0	0	0	0	0	6	0	0	0	1	0	0	0	0
	7	0	0	0	0	0	5	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	5	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	6	0	0	0	0	0	0	0	0
	10	0	0	0	0	2	6	0	0	0	0	0	0	0	0
	11	0	0	0	0	2	6	0	0	0	0	0	2	0	0
	12	1	0	0	0	0	6	0	0	0	0	0	0	0	0
	13	0	0	0	0	2	5	0	0	0	0	0	2	0	0
	14	0	0	0	0	2	4	0	0	0	0	0	2	0	0
	15	1	0	0	0	2	6	0	0	0	0	0	1	0	0
	16	0	0	0	0	5	5	0	0	0	0	0	2	0	0
	17	0	0	0	0	1	4	0	0	0	7	0	2	0	0
Transect 3	1	0	0	0	0	0	4	0	1	0	0	0	0	0	0
	2	0	0	0	0	0	1	0	0	0	0	0	4	0	0
	3	0	0	0	0	0	4	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	6	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	2	0	0	0	0	0	0	0	0
	6	0	1	0	0	0	4	0	0	1	0	0	5	0	0
	7	0	0	0	0	0	5	0	0	1	0	0	5	0	0
	8	0	0	0	0	0	0	0	0	4	0	0	8	0	0
Transect 4	1	0	0	0	0	1	4	0	0	0	7	0	2	0	0
	2	0	0	0	0	0	2	0	0	0	0	0	1	0	0
	3	0	0	0	0	4	4	0	0	0	0	0	2	0	0
	4	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Quarry floor	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Mag. limestone	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
grassland	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	1	0	0	0	0	0	0	0	0	4	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scrub-cleared	1	0	0	0	0	0	5	0	0	0	0	0	2	0	2
area	2	0	0	0	0	0	4	0	0	0	0	0	6	0	0
	3	0	0	0	0	0	4	0	0	0	0	0	4	0	0
	4	0	0	0	0	0	4	2	0	0	0	0	4	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	4	0	0
	6	0	0	0	0	0	2	1	0	0	0	0	2	0	0

Appendix 1 - Species composition and abundance (Domin scale) of all quadrats

Barbrecu	Bellpere	Betupend	Bracruta	Bracvelu	Brachsyl	Brizamed	Bromerec	Bryumspp	Callcusp	Camprotu	Campchry	Campstel	Cardnutc	Carexfla	Carlvulg
0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	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	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	2	0	0	0	0	2	3	0	0	0	0	0	0	0
3	0	5	0	0	0	0	0	2	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	2	0	0	0	1	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	2	0	0	0	0	1	0	0	0	0	0	0	1	0
3	0	2	0	0	0	0	0	3	0	0	0	0	0	1	0
4	0	3	0	0	0	0	0	4	0	0	0	0	0	0	0
4	0	2	0	0	0	0	0	3	0	0	0	0	0	1	0
4	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0
5	0	4	2	0	0	0	0	3	0	0	3	0	0	0	0
3	0	0	3	0	0	0	0	0	3	0	3	0	0	0	0
3	0	0	4	2	0	0	0	0	0	0	3	0	0	0	0
4	0	0	4	0	0	0	0	2	0	0	4	0	0	0	0
4	2	0	4	0	0	0	0	0	3	0	0	3	0	4	0
3	0	0	3	0	0	0	0	0	0	0	1	0	0	3	0
4	0	1	3	0	0	0	0	0	3	0	3	0	0	2	0
3	0	0	3	0	0	0	0	0	0	0	0	0	0	2	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	2	0
3	2	0	1	0	0	0	0	0	1	0	0	0	0	3	0
3	2	0	1	0	0	0	0	3	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	2	1	0	0	0	0	2	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0
3	0	0	0	0	0	0	0	2	2	0	0	0	0	4	0
2	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0
0	1	0	0	2	0	0	0	3	4	0	3	0	0	0	0
0	2	0	0	0	0	0	0	0	1	0	0	0	0	1	0
3	0	2	0	0	2	0	0	3	0	0	0	0	0	1	0
4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	4	0	0	0	0	0	2	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
3	0	0	4	2	0	0	0	0	0	0	3	0	0	2	0
3	0	0	4	2	0	0	0	0	0	0	3	0	0	0	0
3	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	1	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	1	0	0	0	2	7	0	0	2	0	3	0	5	1
0	0	0	0	0	0	2	8	0	0	1	0	2	0	4	0
0	0	0	0	0	0	4	8	0	0	0	0	0	0	5	2
3	0	1	0	0	1	2	5	0	0	2	0	0	0	4	4
0	0	1	0	0	2	5	5	0	0	1	0	3	0	5	1
0	0	1	0	0	0	5	5	0	0	3	0	3	0	4	1
0	0	1	0	0	1	5	7	0	0	3	0	4	0	4	1
0	0	1	0	0	1	5	5	0	3	1	0	4	0	4	0
0	0	1	0	0	0	4	5	0	0	1	0	2	0	4	0
5	0	4	0	0	2	4	6	0	0	0	0	0	0	4	2
3	0	1	4	0	0	4	6	0	0	0	0	3	0	2	0
0	0	0	2	0	0	5	6	0	0	0	0	0	0	4	0
3	0	0	0	0	4	4	7	0	3	2	0	0	0	5	0
0	0	0	0	0	1	5	5	0	2	3	0	2	0	2	0
0	0	0	0	0	0	2	4	0	2	3	0	0	0	5	0
0	0	0	0	0	1	4	5	0	4	3	0	5	0	5	0
0	0	0	0	4	1	4	5	0	4	3	0	0	0	5	0
3	0	0	3	0	4	2	7	0	3	2	0	0	0	4	0
0	0	0	0	0	2	2	6	0	4	0	0	0	0	4	0
0	0	0	0	0	2	4	7	0	2	3	0	0	0	5	0
0	0	0	0	0	2	4	5	0	4	3	0	0	0	2	0
0	0	0	0	0	5	0	2	0	9	0	0	2	0	5	0
0	0	0	4	0	5	0	4	0	0	0	0	0	0	2	0
0	0	0	0	0	2	1	2	0	5	0	0	0	0	0	0
3	0	0	5	0	4	0	4	0	5	0	0	0	0	0	0
0	0	0	5	0	5	0	2	0	0	0	0	0	0	0	0
0	0	0	0	0	4	0	1	0	0	0	0	0	0	0	0

Appendix 1 - Species composition and abundance (Domin scale) of all quadrats

Catarigi	Centnig	Centscab	Centery	Ceraholo	Chaeminu	Chamangu	Cirspalu	Cirsiusp	Cirsvulg	Cirsarve	Cratmond	Cruclaev	Ctenmol	Dactglom	Dactfuc
0	0	0	0	0	0	1	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	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	3	1	0	0	0	0	1	0	0	0	0
0	0	0	1	0	3	2	0	2	0	0	0	0	0	1	0
0	2	0	3	0	0	1	0	1	0	0	0	0	0	0	0
0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	2	0	0	1	0	0	0	0	2	0
0	0	0	1	0	0	1	0	0	0	0	0	0	0	2	0
0	2	0	1	0	0	1	0	0	0	0	1	0	0	1	0
0	1	0	1	0	0	1	0	0	1	4	0	0	0	3	0
0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
0	1	0	1	0	0	2	0	0	0	0	0	0	0	2	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0
0	1	0	1	1	0	0	0	0	0	0	0	0	0	2	0
0	1	0	0	1	0	0	0	0	0	0	0	0	0	4	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	1	1	0	2	0	0	0	0	0	0	0	2	0
0	0	0	1	0	0	1	0	0	2	0	1	0	0	1	0
0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0
0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0
0	0	0	3	0	0	2	0	0	0	0	1	0	0	2	0
0	1	0	0	0	0	2	0	0	0	0	0	0	0	2	0
0	0	0	0	0	0	2	0	0	0	0	1	0	0	2	0
0	1	0	0	0	0	1	0	0	0	0	1	0	0	4	0
0	0	0	2	1	0	2	0	0	0	0	1	0	0	2	0
0	4	0	1	0	0	1	0	1	0	0	1	0	0	2	0
2	1	0	2	0	0	1	0	1	0	0	1	0	0	2	0
0	0	0	1	1	0	1	0	0	1	0	0	0	0	2	0
0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0
0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0
0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
0	4	0	1	1	0	0	0	0	0	0	0	0	0	2	0
0	1	0	1	1	0	0	0	0	0	0	0	0	0	2	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0
2	1	0	2	0	0	1	0	1	0	0	1	0	0	2	0
1	0	0	1	0	3	2	0	0	1	0	0	0	0	2	0
0	0	0	1	1	0	0	0	0	2	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
0	2	0	0	0	0	1	0	0	0	0	1	0	8	0	0
0	1	0	0	0	0	1	0	0	0	0	1	0	7	0	0
0	2	0	0	0	0	0	0	0	0	0	1	0	7	0	0
0	2	0	0	0	0	0	0	0	0	0	1	0	5	0	1
0	4	0	0	0	0	0	0	0	0	0	0	0	8	0	0
0	2	0	0	0	0	1	0	0	0	0	1	0	5	0	0
0	2	0	0	0	0	1	0	0	0	0	2	0	7	1	0
0	2	0	0	0	0	0	0	0	0	0	1	0	8	2	0
0	2	0	0	0	0	1	0	0	0	0	1	0	7	0	1
0	4	0	0	0	0	1	0	0	0	0	0	0	8	1	1
0	4	0	0	0	0	1	0	0	0	0	4	0	8	1	0
0	4	0	0	0	0	0	0	0	0	0	2	0	7	2	0
0	5	0	0	0	0	0	1	0	0	0	2	0	7	0	0
0	4	1	0	0	0	0	0	0	0	0	1	0	8	0	0
0	4	0	0	0	0	0	0	0	0	0	0	0	9	0	0
0	5	0	0	0	0	0	0	0	0	0	1	0	4	0	0
0	4	0	0	0	0	0	0	0	0	0	2	0	4	0	0
0	5	0	0	0	0	0	0	0	0	0	5	0	7	0	0
0	4	0	0	0	0	0	0	0	0	0	1	0	4	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	6	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	7	0	1
0	4	0	0	0	0	0	1	0	1	0	7	2	4	4	0
0	1	0	0	0	0	0	0	0	4	0	7	0	4	4	0
0	7	0	0	0	0	0	1	0	1	0	7	0	4	2	0
0	0	0	0	0	0	0	0	0	0	0	4	0	4	2	0
0	0	0	0	0	0	0	1	1	0	0	4	0	5	0	0
0	0	0	0	0	0	0	0	0	0	0	5	0	0	4	0

Appendix 1 - Species composition and abundance (Domin scale) of all quadrats

Dactpurp	Danthdec	Desccesp	Echivulg	Epilmont	Epipatro	Euphheli	Euphroff	Eurhprae	Eurhswar	Festarun	Festovin	Festprat	Festrubr	Filipulm	Fisstaxi
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	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	1	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0
0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0
0	0	0	0	1	0	0	3	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	4	0	0
0	0	0	0	1	0	0	3	0	0	0	0	0	2	0	0
0	0	0	1	2	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0
0	0	0	1	1	0	0	0	0	0	4	0	0	0	0	0
1	0	0	0	1	0	0	0	0	2	0	0	0	4	0	0
0	0	2	0	0	0	0	2	0	0	1	0	0	7	0	0
0	0	0	1	0	0	0	2	0	0	0	0	0	7	0	0
0	0	1	0	0	0	0	1	0	0	0	0	0	5	0	0
0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	2	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	2	0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	3	0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	2	0	3	0	0	0	4	0	0
0	0	0	0	0	0	1	2	0	0	0	0	0	5	0	0
0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	2	0	0	0	0	2	0	0	1	0	0	4	0	0
0	0	2	0	0	0	0	2	0	0	1	0	0	7	0	0
0	0	0	0	0	0	0	0	0	5	0	0	0	5	0	0
0	0	0	0	0	0	1	2	0	0	0	0	0	5	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	2	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	3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1
0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	3	0	3	0	0	2	0	0	0	0	0
0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
1	0	0	0	0	0	0	0	0	3	0	0	2	0	0	0
0	0	0	0	0	1	0	3	0	0	2	0	0	1	0	0
0	0	0	0	0	0	0	2	0	0	2	0	0	5	0	0
0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	2	0	0	2	0	0	4	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	2	0	0	1	2	0	4	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	2
0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	4	0	0	1	0
0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0
0	0	0	0	0	0	0	0	0	3	0	4	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	6	0	2	0	0	0	2
0	1	0	0	0	0	0	0	0	2	0	4	0	0	0	2
0	0	0	0	0	0	0	0	0	2	0	5	0	0	0	0
0	0	4	0	0	0	0	0	0	2	0	0	0	5	0	3
0	0	1	0	1	0	0	0	0	8	0	0	0	0	0	4
0	0	6	0	0	0	0	1	2	4	0	0	0	0	0	0
0	0	6	0	0	0	0	0	0	0	0	0	0	2	0	3
0	0	8	0	0	0	0	0	3	8	0	0	0	0	6	2
0	0	7	0	0	0	0	0	0	9	0	0	0	4	4	3

		Appendix 1 - Species composition and abundance (Domin scale) of all quadrats													
Fragvesc	Fraxexce	Galiapar	Galiveru	Gerarobe	Geumriva	Gymncono	Helinumm	Heraspho	Hierapil	Hieraspp	Holclana	Hypeperf	Lathprat	Leonautu	Leonhisp
0	0	0	0	0	0	0	0	1	0	0	1	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	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	1	0	0	0	0	0
1	0	0	0	0	0	0	0	0	1	2	0	0	0	0	1
0	0	0	0	0	0	0	0	1	1	4	0	0	0	0	1
1	0	0	0	0	0	0	0	0	1	4	1	0	0	0	1
0	0	0	0	0	0	0	0	1	2	4	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	4	1	1	0	0	2
0	0	0	0	0	0	0	0	0	2	4	0	1	0	0	2
2	0	0	0	0	0	0	0	1	2	4	0	1	0	0	1
2	0	0	0	0	0	2	0	2	2	5	0	1	0	0	2
5	0	0	0	0	0	0	0	2	1	6	0	2	0	1	0
5	0	0	0	0	0	2	0	0	2	4	0	0	0	1	1
6	0	0	0	0	0	0	0	1	0	5	0	0	0	0	0
0	0	0	0	0	0	0	0	2	1	2	2	0	0	0	0
0	0	0	0	0	0	0	0	2	2	2	1	0	0	0	0
1	0	0	0	0	0	0	0	2	1	2	4	0	0	0	2
0	0	0	0	0	0	0	0	1	4	1	4	0	0	0	1
0	0	0	0	0	0	1	0	2	1	2	4	1	0	0	2
0	0	0	0	0	0	1	0	1	5	4	1	0	0	0	2
0	0	0	0	0	0	0	0	0	1	4	0	1	1	0	2
0	0	0	0	0	0	1	0	1	0	2	1	0	0	0	2
0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	2
0	0	0	0	0	0	0	0	0	0	2	4	0	0	1	4
0	0	0	0	0	0	0	0	1	2	2	4	0	0	1	1
0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	2
0	0	0	0	0	0	0	0	2	4	4	1	0	0	1	4
0	0	0	0	0	0	1	0	0	2	2	2	0	0	0	4
0	0	0	0	0	0	0	0	0	1	2	2	0	0	0	2
0	0	0	0	0	0	0	0	0	4	2	1	0	0	0	4
0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	4
4	0	0	0	0	0	1	0	1	0	4	0	1	0	0	1
0	0	0	0	0	0	0	0	1	2	5	0	0	0	0	1
0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0
0	0	0	0	0	0	0	0	1	2	4	0	0	0	0	1
0	0	0	0	0	0	0	0	0	2	4	0	1	0	0	0
0	0	0	0	0	0	0	0	5	1	5	0	3	0	0	1
0	0	0	0	0	0	0	0	2	2	2	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	4
0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	2
0	0	0	0	0	0	0	0	2	0	0	1	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	1	0	2	2	0	1	0	0	0
0	0	0	0	0	0	0	0	1	2	4	0	1	0	0	1
0	0	0	0	0	0	0	4	0	4	4	0	2	0	0	1
0	0	0	0	0	0	0	2	1	4	4	0	1	0	0	1
0	0	0	0	0	0	0	2	0	2	4	0	1	0	0	1
0	0	0	0	0	0	1	1	0	2	2	0	0	0	0	2
0	0	0	0	0	0	2	0	0	4	4	0	0	0	0	1
2	0	0	0	0	4	2	0	0	2	2	0	1	0	0	2
0	0	0	0	0	0	0	6	1	2	2	0	2	0	0	2
0	0	0	0	0	0	0	6	0	4	2	0	1	0	0	2
1	5	0	0	0	0	1	4	1	2	1	0	0	0	0	0
0	1	0	0	0	1	2	5	0	5	4	0	1	0	0	0
1	0	0	1	0	0	0	0	1	0	0	0	2	0	0	4
0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	1
0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	1
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	4
0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	2	0	0	0	0	0	2	0	0	2
0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	4
2	0	0	0	1	0	0	0	1	0	2	0	1	2	0	0
5	0	2	0	2	1	0	0	1	0	2	0	0	0	0	2
2	0	0	0	1	0	0	0	1	0	4	0	0	0	0	4
4	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
4	5	1	0	0	0	0	0	1	0	1	0	0	0	0	0
4	1	0	0	2	0	0	0	1	0	0	0	0	0	0	0

Appendix 1 - Species composition and abundance (Domin scale) of all quadrats

Leucvulg	Linucath	Listovat	Lolipere	Lotucorn	Medilupu	Molicaer	Phleprat	Pimpsaxi	Plagundu	Planlanc	Planmajo	Poaprate	Poatrivi	Polyvulg	Poteanse
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	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	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	1	0	0	0	0	2	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	1	1	0	0	0	0	1	0	1	0	0	0
2	2	0	0	0	0	0	0	0	0	2	0	0	0	1	0
1	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
0	1	0	0	5	4	0	0	0	0	3	0	0	0	0	0
0	1	0	4	6	4	0	0	0	0	2	0	0	0	0	0
0	1	0	0	2	4	0	1	0	0	4	0	4	2	0	0
0	3	0	0	5	4	0	0	0	0	2	0	2	0	0	0
0	1	0	0	0	4	0	0	0	0	3	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0	2	0	3	0	0	0
1	1	0	0	0	2	0	0	0	0	4	0	4	0	0	0
0	1	0	0	0	1	0	0	0	0	2	0	1	0	0	0
0	0	0	0	1	0	0	0	0	0	3	0	2	0	0	0
0	0	0	0	1	0	0	0	0	0	4	0	2	0	0	0
0	1	0	0	4	2	0	0	0	0	1	0	2	0	0	0
0	1	0	0	4	1	0	0	0	0	4	1	2	0	0	0
0	2	0	0	4	2	0	0	0	0	2	0	2	0	0	0
0	0	0	0	2	2	0	0	0	0	2	0	2	0	0	0
0	0	0	0	4	1	0	0	0	0	2	0	1	0	0	0
0	0	0	0	0	4	0	0	0	0	2	0	2	0	0	0
0	0	0	0	0	4	0	0	0	0	2	0	4	0	0	0
0	0	0	0	0	4	0	0	0	0	1	0	3	0	0	1
0	0	0	1	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	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	3	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0
0	1	0	0	0	2	0	0	0	0	2	1	0	2	0	0
0	1	0	0	2	4	0	1	0	0	4	0	4	2	0	0
0	2	0	7	4	0	0	0	0	0	4	0	2	5	0	0
0	0	0	0	0	4	0	0	0	0	1	0	3	0	0	1
0	0	0	1	0	4	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	4	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	4	0	0	0	0	0	0	0	0	0	1	0
0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	6	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0
0	3	0	0	4	0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	2	0	0	0	1	0	2	0	0	0	0	0
0	2	0	0	4	0	0	0	0	0	2	0	0	0	0	0
0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0
0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0
0	3	1	0	1	0	1	0	1	0	2	0	0	0	0	0
0	3	0	0	0	0	6	0	0	2	0	0	0	0	0	0
0	3	2	0	0	0	5	0	2	0	0	0	0	0	1	0
0	2	0	0	4	0	4	0	2	0	4	0	0	0	1	0
0	3	0	0	0	0	0	0	2	0	1	0	0	0	2	0
0	3	0	0	0	0	0	0	2	0	0	0	0	0	2	0
0	2	0	0	4	0	0	0	2	0	2	0	0	0	2	0
0	2	0	0	2	0	0	0	0	0	2	0	0	2	0	0
0	3	0	0	0	0	0	0	2	0	1	0	0	0	0	0
0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0
0	0	1	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	0	0	0	0	0	0	0	0	0	0

		Appendix 1 - Species composition and abundance (Domin scale) of all quadrats													
												Sagiproc			
Poteerec	Poterept	Primveri	Prunvulg	Pseupuru	Pteraqui	Ranurepe	Reselute	Rhinmino	Rosacani	Rubufrut	Rubuidae		Salicapr	Salirepe	Sangmino
												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	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	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	5	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	7	0	0
0	1	1	0	0	0	0	0	0	0	0	0	0	4	0	0
0	1	1	0	0	0	2	0	0	1	0	0	1	4	0	0
0	1	0	0	0	0	0	0	0	2	0	0	0	4	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	4	1	0
0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
0	2	1	0	0	0	0	0	0	1	0	0	0	4	0	0
0	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0
0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	2	2	0	0	0	1	1	4	0	0	0	0	0	0	0
0	0	2	0	0	0	1	0	1	0	0	0	0	0	0	0
0	4	0	0	0	0	0	0	1	0	0	0	0	1	0	0
0	2	4	0	0	0	0	1	0	0	0	0	0	1	0	0
0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0
0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0
0	2	2	1	0	0	0	0	1	0	0	0	0	0	0	0
0	4	4	0	0	0	0	0	1	0	0	0	0	0	0	0
0	1	2	4	0	0	0	0	2	0	0	0	0	0	0	0
0	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0
0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	1	0	0	0	0	0	0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0	8	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0
0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	2	0	4	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0		0	0	0
												0			
0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0	1	0	1	0	0	0	0	0	0	2	0	0	0	0	4
0	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	1	0	2	0	0	0	0	2	1	0	0	0	1	0	0
0	0	2	1	0	0	0	0	0	1	0	0	0	2	0	4
0	2	2	2	5	0	0	0	0	1	1	0	0	0	0	5
0	0	2	2	0	0	0	0	0	1	2	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	2
0	1	0	0	4	0	0	0	0	0	4	0	0	0	0	1
0	0	0	0	1	0	1	0	0	0	1	0		2	0	0
												0			
2	0	0	2	3	0	0	0	0	1	2	0	0	0	0	1
3	0	1	0	2	4	0	0	0	5	1	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5
0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	5
2	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0
2	0	2	1	3	0	0	0	0	0	1	0	0	0	0	0
0	1	0	1	4	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0
2	0	0	0	4	0	0	0	0	0	0	0		0	0	0
												0			
0	0	1	2	0	0	0	0	0	5	4	1	0	0	0	0
0	2	0	0	2	0	0	0	0	4	7	1	0	0	0	0
0	0	0	2	0	1	0	0	0	5	0	0	0	0	0	0
0	0	0	2	2	0	0	0	0	0	1	4	0	0	0	0
0	0	0	0	2	0	0	0	0	1	5	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	1		0	0	0

		Appendix 1 - Species composition and abundance (Domin scale) of all quadrats													
Saniceur	Senecios	Seslalbi	Silevulg	Soncaspe	Sorbaria	Stacoffi	Stacsylv	Succprat	Tripinod	Taraxoff	Thuitama	Thymdruc	Tricflav	Tricampe	Triprate
0	0	0	0	0	0	0	0	0	0	1	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	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0
0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	1	0	0	0	0	0	1	1	0	4	0	0	0
0	0	0	4	0	0	0	0	0	0	2	0	5	0	0	0
0	0	0	1	0	0	0	0	0	1	2	0	4	0	0	0
0	0	0	4	0	0	0	0	0	0	2	0	6	0	0	0
0	0	0	5	0	0	0	0	0	2	4	0	5	0	0	0
0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	0
0	0	0	4	0	0	0	0	0	0	1	0	3	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	0
0	0	0	1	0	0	0	0	0	0	2	0	2	0	0	2
0	2	0	0	0	0	0	0	0	2	2	0	1	0	0	2
0	2	0	1	0	0	1	0	0	0	2	0	2	0	0	0
0	1	0	0	0	0	0	0	0	0	2	0	4	0	0	1
0	0	0	0	0	0	0	0	0	0	2	0	4	0	1	1
0	1	0	0	0	0	0	0	0	0	1	0	6	0	0	1
0	1	0	0	0	0	0	0	0	0	2	0	5	0	0	0
0	0	0	4	0	0	0	0	0	0	2	0	7	0	0	0
0	0	0	1	0	1	0	0	0	1	2	0	5	0	0	0
0	0	0	1	0	1	0	0	0	0	1	0	4	0	0	0
0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2
0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2
0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	2
0	1	0	0	0	0	0	0	0	0	1	0	0	2	0	4
0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2
0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	2
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4
0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
0	0	0	0	0	0	0	0	0	1	1	0	4	0	0	0
0	1	0	0	0	0	0	0	0	0	1	0	3	0	0	2
0	0	0	0	0	0	0	0	0	2	0	0	4	0	0	0
0	0	0	1	0	0	0	0	0	2	1	0	3	0	0	0
0	0	0	0	0	0	0	0	0	1	1	0	4	0	0	0
0	2	0	1	0	0	0	0	0	0	2	0	4	0	0	1
0	2	0	1	0	0	1	0	0	0	2	0	2	0	0	0
0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	4
0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	1
0	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	4	0	0	0	0	0	0	0	0	0	7	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	7	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	1	0	2	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	2
0	0	6	0	0	0	4	0	0	0	0	0	1	0	0	4
0	0	8	0	0	0	1	0	5	0	0	0	0	0	0	2
0	0	7	0	0	0	0	0	1	0	0	0	0	0	0	4
0	0	8	0	0	0	4	0	5	0	0	0	0	0	0	0
0	0	6	0	0	0	4	0	0	0	0	0	0	0	0	1
0	0	7	0	0	0	5	0	0	0	0	0	0	0	0	0
0	0	6	0	0	0	4	0	0	0	0	0	0	0	0	0
0	0	8	0	0	0	2	0	5	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0
0	0	0	0	0	0	0	4	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
0	0	4	0	0	0	1	1	0	0	1	0	0	0	0	0
0	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0

	Appendix 1 - Species composition and abundance (Domin scale) of all quadrats								
Trirepen	Tussfarf	Ulexeuro	Ulmusmaj	Verocham	Verooffi	Vibuopul	Violhirt	Violrivi	Violseed
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	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0
0	1	0	0	0	2	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0
0	5	0	0	0	2	0	0	0	0
0	6	0	0	0	0	0	0	0	0
0	4	0	0	0	1	0	0	0	0
0	2	0	0	2	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
4	2	0	0	0	0	0	0	0	0
4	4	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0
2	2	0	0	0	2	0	0	0	0
2	2	0	0	0	1	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0
1	1	0	0	0	1	0	0	0	0
1	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
1	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	5	0	0	0	1	0	0	0	0
0	2	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	0
4	2	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
1	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	0	0	0	0
2	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	0	0	0	0
0	1	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	2	2	3
0	2	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	2	0	0	0	1	1	1
0	0	0	1	0	0	0	1	0	0
1	0	4	0	0	0	0	2	4	0
0	2	0	0	1	0	0	1	0	2
0	0	1	0	0	0	2	1	0	1
0	0	2	0	0	0	2	2	1	0
0	0	0	0	0	0	1	0	0	0
0	0	4	0	0	0	0	0	4	0
0	0	0	0	2	0	2	0	2	3
0	0	4	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0	2	0
0	4	0	0	0	0	0	0	4	0
0	4	0	1	4	0	0	0	4	0
1	4	0	0	0	0	0	0	4	0
0	7	0	0	0	0	1	0	4	0
0	0	0	0	0	0	0	0	5	0
0	8	0	0	0	0	0	0	4	0

APPENDIX - Explanation of species abbreviations found in DECORANA ordinations

Acer pseu	*Acer pseudoplatanus*
Achi mill	*Achillea millefolium*
Aego poda	*Aegopodium pcdagraria*
Agri eupa	*Agrimonia eupatoria*
Agro repe	*Agropyron repens*
Agrs tolo	*Agrostis stolonifera*
Ajug rept	*Ajuga reptans*
Ange sylv	*Angelica sylvestris*
Anth vuln	*Anthyllis vulneraria*
Aren serp	*Arenaria serpyllifolia*
Arrh elat	*Arrhenatherum elatius*
Aven pube	*Avenula pubescens*
Barb recu	*Barbula recurvirostra*
Bell pere	*Bellis perennis*
Betu pend	*Betula pendula*
Brac ruta	*Brachythecium rutabulum*
Brac velu	*Brachythecium velutinum*
Brac bsyl	*Brachypodium sylvaticum*
Briz amed	*Briza media*
Brom erec	*Bromus erectus*
Bryu mspp	*Bryum* spp.
Call cusp	*Calliergon cuspidatum*
Camp rotu	*Campanula rotundifolia*
Camp chry	*Campylium chrysophyllum*
Camp stel	*Campylium stellatum*
Card nuta	*Carduus nutans*
Care xfla	*Carex flacca*
Carl vulg	*Carlina vulgaris*
Cata rigi	*Catapodium rigidum*
Cent nigr	*Centaurea nigra*
Cent scab	*Centaurea scabiosa*
Cent eryt	*Centaurium erythraea*
Cera holo	*Cerastium holosteoides*
Chae minu	*Chaenorhinum minus*
Cham angu	*Chamaenerion angustifolium*
Cirs palu	*Cirsium palustre*
Cirs vulg	*Cirsium vulgare*
Cirs arve	*Cirsium arvense*
Crat mono	*Crataegus monogyna*
Cruc laev	*Cruciata laevipes*
Cten moll	*Ctenidium molluscum*
Dact glom	*Dactylis glomerata*
Dact fuch	*Dactylorhiza fuchsii*
Dact purp	*Dactylorhiza purpurella*
Dant hdec	*Danthonia decumbens*
Desc cesp	*Deschampsia cespitosa*
Echi vulg	*Echium vulgare*
Epil mont	*Epilobium montanum*
Epip atro	*Epipactis atrorubens*
Euph heli	*Euphorbia helioscopia*
Euph roff	*Euphrasia officianalis* agg
Eurh prae	*Eurhynchium praelongum*
Eurh swar	*Eurhynchium swartzii*
Fest arun	*Festuca arundinacea*
Fest ovin	*Festuca ovina*
Fest prat	*Festuca pratensis*
Fest rubr	*Festuca rubra*
Fili pulm	*Filipendula ulmaria*
Fiss taxi	*Fissidens taxifolius*
Frag vesc	*Fragaria vesca*
Frax exce	*Fraxinus excelsior*
Gali apar	*Galium aparine*
Gali veru	*Galium verum*
Gera robe	*Geranium robertianum*
Geum riva	*Geum rivale*
Gymn cono	*Gynmadenia conopsea*
Heli numm	*Helianthemum nummularium*
Hera spho	*Heracleum sphondylium*
Hier apil	*Hieracium pilosella*
Hier aspp	*Hieracium* spp.
Holc lana	*Hypericum perforatum*
Hype perf	*Lathyrus pratensis*
Lath prat	*Leontodon autumnalis*
Leon autu	*Leontodon hispidus*
Leon hisp	*Leucanthemum vulgare*
Leuc vulg	*Linum catharticum*
Linu cath	*Linum catharticum*
List ovat	*Listera ovata*
Loli pere	*Lotus corniculatus*
Lotu corn	*Medicago lupulina*
Medi lupu	*Medicago lupulina*
Moli caer	*Molinia caerulea*
Phle prat	*Phleum pratensis*
Pimp saxi	*Pimpinella saxifraga*
Plag undu	*Plagiomnium undulatum*
Plan lanc	*Plantago lanceolata*
Plan majo	*Plantago major*
Poap rate	*Poa pratensis*
Poat rivi	*Poa trivialis*
Poly vulg	*Polygala vulgaris*
Pote anse	*Potentilla anserina*
Pote erec	*Potentilla erecta*
Pote rept	*Potentilla reptans*
Prim veri	*Primula veris*
Prun vulg	*Prunella vulgaris*
Pseu puru	*Pseudoscleropodium purum*
Pter aqui	*Pteridium aquilinum*
Ranu repe	*Ranunculus repens*
Rese lute	*Reseda lutea*
Rhin mino	*Rhinanthus minor*
Rosa cani	*Rosa canina*
Rubu frut	*Rubus fruticosus*
Rubu idae	*Rubus idaeus*
Sagi proc	*Sagina procumbens*
Sali capr	*Salix caprea* agg.
Sali repe	*Salix repens*
Sang minor	*Sanguisorba minor*
Sani ceur	*Sanicula europaea*
Sene cios	*Senecio* sp.
Sesl albi	*Sesleria albicans*
Sile vulg	*Silene vulgaris*
Sonc aspe	*Sonchus asper*
Sorb aria	*Sorbus aria*
Stac sylv	*Succisa pratensis*
Succ prat	*Stachys sylvatica*
Tripinod	*Tripleurospermum inodorum*
Tara xoff	*Taraxacum officianalis*
Thui tama	*Thuidium tamariscinum*
Thym druc	*Thymus drucei*
Tric flav	*Tri flavescens*
Tric ampe	*Trifolium campestre*
Trip rate	*Trifolium pratense*
Trir epen	*Trifolium repens*
Tuss farf	*Tussilag farfara*
Ulex euro	*Ulex europaeus*
Ulmu smaj	*Ulmus major*
Vero cham	*Veronica chamaedrys*
Vero offi	*Veronica officianalis*
Vibu opul	*Viburnum opulus*
Viol hirt	*Viola hirta*
Viol rivi	*Viola riviniana*
Viol seed	*Viola seedlings*

APPENDIX - Species Lists

1. Regraded spoil slope

Dicotyledons

Acer pseudoplatanus
Achillea millefolium
Aegopodium podagraria
Angelica sylvestris
Anthriscus sylvestris
Anthyllis vulneraria
Arenaria serpyllifolia
Bellis perennis
Betula pendula
Carduus nutans
Centaurea nigra
Centaurium erythraea
Cerastium holosteoides
Chaenorhinum minus
Chamaenerion angustifolium
Cirsium spp.
Cirsium arvense
Cirsium palustre
Cirsium vulgare
Crataegus monogyna
Dactylorhiza purpurella
Echium vulgare
Epilobium montanum
Euphorbia helioscopia
Euphrasia officianalis agg.
Fragaria vesca
Gynmadenia conopsea
Heracleum sphondylium
Hieracium spp.
Hieracium pilosella
Hypericum perforatum
Lathyrus pratensis
Leontodon hispidus
Leontodon autumnalis
Leucanthemum vulgare
Linum catharticum
Lotus corniculatus
Medicago lupulina
Plantago lanceolata
Plantago major
Polygala vulgaris
Potentilla anserina
Potentilla reptans
Primula veris
Prunella vulgaris
Ranunculus repens
Reseda lutea
Rhinanthus minor
Rosa canina
Rubus fruticosus
Sagina procumbens
Salix caprea agg.
Salix repens
Senecio spp.
Silene vulgaris
Sorbus aria agg.
Stachys officinalis
Succisia pratensis
Taraxacum officianalis agg.
Thymus drucei
Trifolium campestre
Trifolium pratense
Trifolium repens
Tripleurospermum inodorum
Tussilago farfara
Veronica chamaedrys
Veronica officianalis

Grasses / Sedges

Agropyron repens
Agrostis stolonifera
Arrhenatherum elatius
Brachypodium sylvaticum
Bromus erectus
Carex flacca
Catapodium rigidum
Dactylis glomerata
Deschampsia cespitosa
Festuca arundinacea
Festuca rubra
Holcus lanatus
Lolium perenne
Phleum pratense
Poa pratensis
Poa trivialis

Mosses

Barbula recurvirostra
Brachythecium rutabulum
Brachythecium velutinum
Bryum sp.
Calliergon cuspidatum
Campylium chrysophyllum
Campylium stellatum
Ctenidium molluscum
Eurhynchium swartzii

2. Quarry floor

Dicotyledons

Acer pseudoplatanus
Betula sp.
Campanula rotundifolia
Carlina vulgaris
Centaurea nigra
Chamaenerion angustifolium
Crataegus monogyna
Dactylorhiza fuchsii
Dactylorhiz purpurella
Epipactis atrorubens
Euphrasia officinalis agg.
Fragaria vesca
Fraxinus excelsior
Geum rivale
Gymnadenia conopsea
Helianthemum nummularium
Heracleum sphondylium
Hieracium sp.
Hieracium pilosella
Hypericum perforatum
Leontodon hispidus
Linum catharticum
Listera ovata
Lotus corniculatus
Pimpinella saxifraga
Plantago lanceolata
Polygala vulgaris
Potentilla reptans
Primula veris
Prunella vulgaris
Ranunculus repens
Rhinanthus minor
Rosa canina agg.
Rubus fruticosus agg.
Salix caprea
Sanguisorba minor
Taraxacum officinalis agg.
Thymus drucei
Trifolium repens
Tussilago farfara
Ulmus
Viola hirta
Viola riviniana
Viola seedling sp.

Grasses / sedges

Brachypodium sylvaticum
Briza media
Bromus erectus
Carex flacca
Dactylis glomerata
Festuca arundinacea
Festuca pratensis
Festuca rubra
Festuca ovina
Sesleria albicans

Mosses

Barbula recurvirostra
Brachythecium rutabulum
Calliergon cuspidatum
Campylium stellatum
Ctenidium molluscum
Eurhynchium swartzii
Fissidens taxifolius
Pseudoscleropodium purum

3. Primary grassland

Dicotyledons

Achillea millefolium
Agrimonia eupatoria
Campanula rotundifolia
Centaurea nigra
Centauria scabiosa
Cirsium palustre
Crataegus monogyna
Dactylorhiza fuchsii
Filipendula ulmaria
Fragaria vesca
Fraxinus excelsior
Galium verum
Gymnadenia conopsea
Heracleum sphondylium
Hieracium spp
Hypericum perforatum
Leontodon hispidus
Linum catharticum
Listera ovata
Lotus corniculatus
Pimpinella saxifraga
Plantago lanceolata
Polygala vulgaris
Potentilla erecta
Potentilla reptans
Primula veris
Prunella vulgaris
Pteridium aquilinum
Rosa canina
Rubus fruticosus
Sanguisorba minor
Stachys officinalis
Succisa pratensis
Thymus drucei
Trifolium pratense
Trifolium repens
Tussilago farfara
Ulex europaeus
Veronica chamaedrys
Viburnum opulus
Viola hirta
Viola riviniana
Viola seedlings spp.

Grasses / sedges

Avenula pratensis
Brachypodium sylvaticum
Briza media
Bromus erectus
Carex flacca
Danthonia decumbens
Deschampsia cespitosa
Festuca ovina
Festuca rubra
Molinia caerulea
Poa trivialis
Sesleria albicans

Mosses

Barbula recurvirostra
Brachythecium rutabulum
Brachythecium velutinum
Calliergon cuspidatum
Campylium stellatum
Ctenidium molluscum
Eurhynchium swartzii
Fissidens taxifolius
Plagiomnium undulatum
Pseudoscleropodium purum

4. Scrub cleared area

Dicotyledons

Ajuga reptans
Centauria nigra
Cirsium palustre
Cirsium vulgare
Cirsium spp seedling
Crataegus monogyna
Cruciata laevipes
Epilobium montanum
Euphrasia officinalis agg.
Filipendula ulmaria
Fragaria vesca
Fraxinus excelsior
Galium aparine
Geranium robertianum
Geum rivale
Heracleum sphondylium
Hieracium spp.
Hypericum perforatum
Lathyrus pratensis
Leontodon hispidus
Linum catharticum
Listera ovata
Lotus corniculatus
Plantago lanceolata
Potentilla reptans
Primula veris
Prunella vulgaris
Rosa canina
Rubus fruticosus
Rubus idaeus
Sanicula europaea
Sonchus asper
Stachys officinalis
Stachys sylvatica
Taraxacum officinalis agg.
Trifolium repens
Tussilago farfara
Ulmus
Veronica chamaedrys
Viburnum opulus
Viola riviniana

Grasses / sedges

Agrostis stolonifera
Arrhenatherum elatius
Avenula pubescens
Brachypodium sylvaticum
Briza media
Bromus erectus
Carex flacca
Dactylis glomerata
Deschampsia cespitosa
Festuca rubra
Sesleria albicans

Mosses

Barbula recurvirostra
Brachythecium rutabulum
Calliergon cuspidatum
Campylium stellatum
Ctenidium molluscum
Eurhynchium praelongum
Eurhynchium swartzii
Fissidens taxifolius
Pseudoscleropodium purum
Thuidium tamariscinum

Appendix - *The species and numbers of seedlings emerging in each tray. (Trays with no seedlings have been omitted).*

Transect/ Quadrat	*Anthyllis vulneraria*	*Arrhenatherum elatius*	*Carduus nutans*	*Cirsium vulgare*	*Cress sp.*	*Holcus lanatus*	*Medicago lupulina*	*Taraxacum officinale agg.*	*Thlapsi arvense*	*Trifolium pratense*	*Trifolium repens*	*Tripleurospl inodurum*	unknown dicotyledons	unknown grasses	Total
1/2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
1/7	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
1/8	-	-	-	-	-	-	-	-	-	-	-	-	5	2	7
1/9	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
1/10	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
1/11	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
1/12	-	-	-	-	-	-	-	-	-	-	-	-	2	3	5
1/13	-	-	-	-	-	-	-	-	-	-	-	2	5	3	10
1/14	-	-	-	-	-	-	-	-	1	-	-	-	2	1	4
1/15	-	-	-	-	-	-	-	-	-	-	-	-	4	-	4
1/16	-	-	-	-	-	-	-	-	-	-	-	-	2	6	8
2/1	-	-	-	-	-	-	1	-	-	-	-	-	2	18	21
2/2	-	-	-	-	2	-	-	1	-	-	1	-	31	33	68
2/3	-	-	-	-	-	3	5	-	-	1	-	-	37	37	83
2/4	-	-	-	-	-	-	-	-	-	-	-	-	13	22	35
2/5	-	-	-	-	-	-	-	-	-	-	-	-	11	10	21
2/6	-	-	-	-	-	-	-	-	-	-	-	-	13	2	15
2/7	-	-	-	-	-	-	1	-	-	-	-	-	20	7	28
2/8	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3
2/9	-	-	-	-	-	-	-	-	-	-	-	-	2	2	4
2/10	-	-	-	-	2	-	-	-	-	-	-	-	-	3	5
2/11	-	-	-	-	-	-	-	-	-	-	-	-	11	5	16
2/12	-	-	-	-	-	-	-	-	-	-	-	-	-	8	8
2/13	-	-	-	-	-	-	-	-	-	-	-	-	1	7	8
2/14	-	-	-	-	-	-	-	-	-	-	-	-	1	5	6
2/15	-	-	-	-	-	-	-	-	-	-	-	-	0	7	7
2/16	-	-	-	-	3	-	1	-	-	-	-	-	18	6	28
2/17	1	1	-	-	-	-	-	-	-	-	-	-	17	9	26
3/1	-	-	-	-	-	-	-	-	-	-	-	-	2	2	5
3/2	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
3/3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
3/4	-	-	-	-	-	-	-	-	-	-	-	-	9	2	11
3/5	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1
3/6	-	-	1	1	-	-	-	-	-	-	-	1	9	33	46
3/7	-	-	-	-	-	-	-	1	-	-	1	-	31	33	68
3/8	-	-	1	-	-	-	-	-	-	-	-	-	7	14	22
4/1	1	1	-	-	-	-	-	-	-	-	-	-	17	8	26
4/2	-	-	-	-	1	-	-	-	-	-	-	-	4	1	5
4/3	-	-	-	-	2	-	-	-	-	-	-	-	0	1	2
4/4	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Total	2	2	2	1	11	3	8	2	1	1	2	3			