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THE VEGETATION OF DISUSED RAILWAY LINES IN THE DURHAM AREA

M.A. Dockery M.Sc. Ecology 1978

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CONTENTS

Chapter 1

Introduction

The study was made along disused railway tracks in County Durham. The aims of the study were as follows:

1. to investigate whether disused tracks show succession of species

2. to assess the influence of embankment and cutting species on the track species

3. to investigate certain habitat factors and to assess their role in influencing the species composition of disused railway tracks

4. to study the morphology and performance at different track sites of two ubiquitous species viz. *Plantago lanceolata* and *Dactylis glomerata*

The disused railway track appeared to be suited to such a study since the track substrate is fairly uniform in size and type of material (as are the cutting and embankment slopes), the existence of the two exactly opposite and steep slopes would enable the influence of aspect and exposure to be determined, the country through which the lines are constructed is varied and so the influence of adjacent land use on the railway flora could be established and the date of closure of each line is known such that changes in vegetation over time could be assessed.

Uniformity of management techniques, while the lines were in use, was also practised. When carrying traffic the railway tracks were principally kept free of vegetation through the application of weedkillers by spraying and by the practice of covering the track with a loose matrix of stone as ballast. The required standard of British Rail in

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regard to the growth of vegetation along railway tracks is that spraying should be effective in keeping the width of the line ballast 98% weed free and the inter-track spaces 95% weed free. Without such checks on weed growth there was a danger of fire and wheelslip. British Rail also took measures to reduce particular species e.g. Chamaenerion angustifolium, from embankments and cuttings to reduce the fire risk.

From the dense network of lines in Britain in the early part of this century, the current traffic is carried on a severely truncated system. With the closure of many lines the opportunity was thus afforded for the investigation of plant species found growing along the tracks and slopes of the disused lines.

Chapter 2

Materials and Methods

1. Selection of Sites

The area of study was that within a thirty five mile radius of the city of Durham with the field work completed during an eight week period from early May to early July. Sites were selected where access was possible and which gave a representative sample of dates since closure of the railway lines.

Twenty eight sites were chosen and in the text these are identified with a letter code A - Z (with four sites having a double letter code viz. Ba, Bb, Na and Nb). The sites are indicated on the map (Fig. 1), the map being derived from the Ordnance Survey Quarter Inch Series (Map Sheet 9). The grid reference of each site is contained in the appendix (Table 1) and a photograph of each site is included.

The aim of selection was to select disused railway line sites which would form a homogeneous group regarding the environmental conditions of the tracks e.g. climatic conditions, gradients, size and shape of ballast material etc. The choice of the particular section of track for analysis was made with respect to a specific criterion viz. to choose sections of track exhibiting homogeneity of flora. A forty metre section of track was marked out and used for the analysis of vegetation and a number of site characteristics.

2. Methods of Sampling and Analysis

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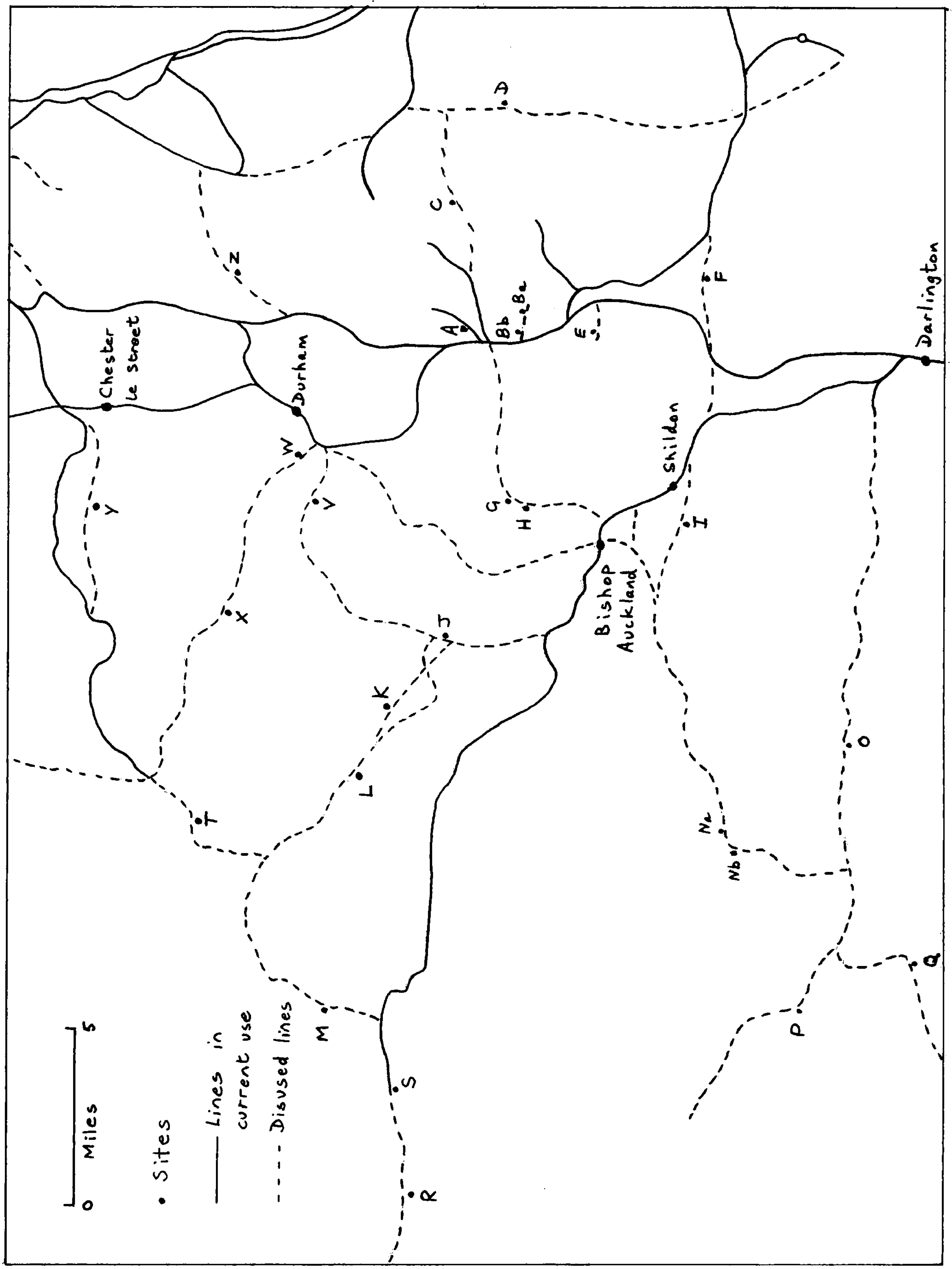
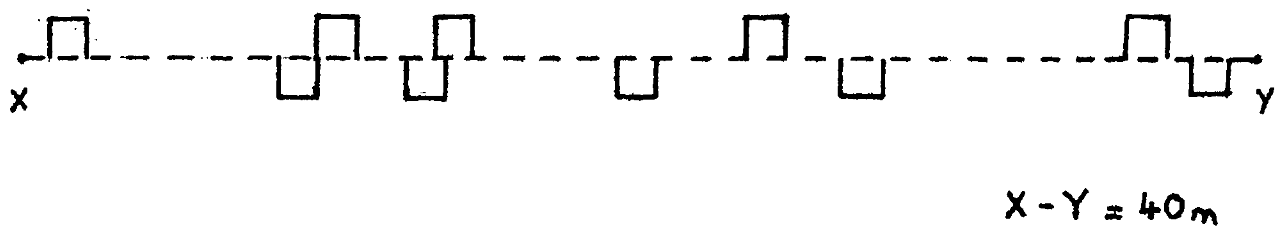
i) Vegetation

Within the forty metre section, analysis of the vegetation was undertaken using a quadrat one metre square.

Fig. 1 Map showing the location of disused railway track sites.



The placing of the quadrat was determined by reference to random number tables. At each track site ten quadrats were used, five on either side of the line passing down the centre of the track, in the manner shown below e.g. site A at Coxhoe



Quadrats ($1m^2$) were also used to sample the vegetation on the cutting or embankment slopes, with five quadrats on each of the two slopes at each site. The point for sampling was again determined by reference to random number tables, the two co-ordinates obtained thus identifying the lower left hand corner of the quadrat.

The data recorded for each quadrat included:

a) the number and identification of the species present

b) an estimate of the percentage cover of each species

and c) an estimate of the percentage of bare ground within the quadrat.

Throughout the study reference was made to Clapham, Tutin and Warburg Flora of the British Isles or Excursion Flora of the British Isles for final identification. At some sites mosses and seedlings too small to be identified were recorded within the quadrats and all species were bulked under 'moss' or 'seedling'. The data is tabulated in the Appendix Tables 2, 3, 4 and 5.

ii) Typical Species

After the first few sites had been sampled and the species lists drawn up it was decided to investigate a couple of 'typical' track species, ubiquitous species found at each site, in order to assess their pattern of distribution and performance at different sites. The species selected were *Dactylis glomerata* and *Plantago lanceolata* as they occurred at almost all sites, both on the tracks and on the cutting or embankment slopes.

The pattern of distribution of the track individuals of the 'typical' species was determined in the manner outlined by Hopkins (1954). The method relates to the distance of an individual plant from a random point, with the measure also made of the distance from the plant so identified to its nearest neighbour.

A grid was overlaid on the track and the location of the random point determined by reference to coordinates selected from random number tables. Distances were measured to the nearest centimetre. The data enables a coefficient of aggregation (A) to be calculated. The coefficient was determined by calculating the mean value of the squares of the distance of a random point to the nearest individual of the species, this being divided by the mean value of the squares of the distance from the individual chosen at random to its nearest neighbour. If the coefficient is unity the distribution of the plants accords to a random one, if the coefficient is greater than or less than unity the plants tend towards an aggregated or regular distribution respectively. The degree o divergence from a random pattern is determined by computing a value x where $x = A/(1 + A)$. For values of $n < 50$ reference is made to an abac constructed for this purpose. At each site thirty random points were selected and so the abac drawn up by Hopkins was used to determine the pattern of distribution of the two species.

At the sites certain characteristics of each typical track species were recorded. For Dactylis glomerata this included:

a) height of the flowering stems
b) angle of growth of the flowering stems
c) fresh and dry weight measurements of individuals at each site
d) the biomass of the flowering stems and non-flowering material of the plants

with data recorded for twenty individuals from both the tracks and embankment or cutting slopes.

For Plantago lanceolata the data included:

a) height of the flowering stems
b) the length of leaf
c) the angle of growth of the flowering stems
d) the fresh and dry weight measurements of individuals
e) the biomass of the flowering and non-flowering parts of the plants,

with the data recorded for twenty individuals from both the tracks and the embankment or cutting slopes.

The selection of individuals for analysis was made subjectively but without conscious bias. Heights and lengths of individual plants were made to the nearest millimetre, with heights being measured from the base of the plant to the top of the flowering stem. Three angle of growth classes were defined: $0^{o} - 30^{o}$, $31^{o} - 60^{o}$ and $61^{o} - 90^{o}$. For the weighings each individual was weighed fresh on return to the laboratory and then weighed again after forty eight hours in a drying oven maintained at 105^{o}C. The mean values of the plant characteristics measured at each site were calculated (see appendix Tables 6 and 7).

iii) Soil Characteristics

Soil samples were taken from each site to assess the influence of some soil properties upon species composition. The soil characteristics determined included pH, phosphorus content and organic content.

Soil samples were collected from the track and embankment or cutting slopes. Three samples of soil were collected from the track, each sample removing soil to a depth of 6 - 8 cm, with one sample taken at either end of the section of track and one in the centre. On the slopes three samples were again taken but at different heights up the slope. The samples were taken at the top, middle and bottom of each slope, coincident with either end and the middle of the transect line on the track. On return to the laboratory the soil was thoroughly mixed to give a more homogeneous sample of track and slope soil for analysis.

a) Determination of pH

The pH of the soil was determined by the electrometric method with readings made to one decimal place. The pH meter was checked against three buffer solutions (pH 4.0, 7.0 and 9.0) before the pH of the soil slurry was determined. The results are tabulated in the appendix (Table 8).

b) Determination of organic content

An estimate of the organic matter present in the track soils was made using the loss-on-ignition method. The soil was initially air dried for two days and then a sample was oven dried at 105^{o}C for a further two days. A 10g sample was then placed in a crucible which was put into a muffle furnace. The furnace temperature was slowly raised to 450°C and held at that temperature for four hours before being allowed to cool to 150°C. The sample was then removed and allowed to cool in a desiccator. After re-weighing the organic content of the soil was calculated thus:-

$$\text{loss-on-ignition - organic content} = \frac{\text{weight loss (g)} \times 100}{\text{oven dry weight (g)}}$$

The results are tabulated in the Appendix (Table 8).

c) Determination of phosphorus content

The phosphorus content of the soils was determined using the molybdenum blue method, with stannous chloride as the reducing agent. 2.5g of air dried soil was placed in a polythene bottle, 100 ml. of Truog's reagent added and the bottle placed on a rotary shaker for one hour. The solutions were sieved through No.44 filter paper until 50 ml. had been collected and this poured into a glass flask. 2 ml. of ammonium molybdate reagent and 2 ml. of stannous chloride reagent were added to the solution which was mixed and left for half an hour. The optical density of the solution was then determined at 700 nm on the spectrophotometer using Truog's reagent as the reference. To convert machine readings to mg phosphorus a calibration curve was plotted. The stock solution enabling this to be completed was made up (1 ml.≡0.1 mg.P) and again Truog's reagent used for reference, with the optical density of 700 nm. The phosphorus content was determined thus:-

$$P = \frac{C(\text{mg}) \times \text{solution volume (ml)} \times 10^3}{10 \times \text{aliquot (ml)} \times \text{sample wt.(g)}}$$

where C = mg P derived from the calibration curve

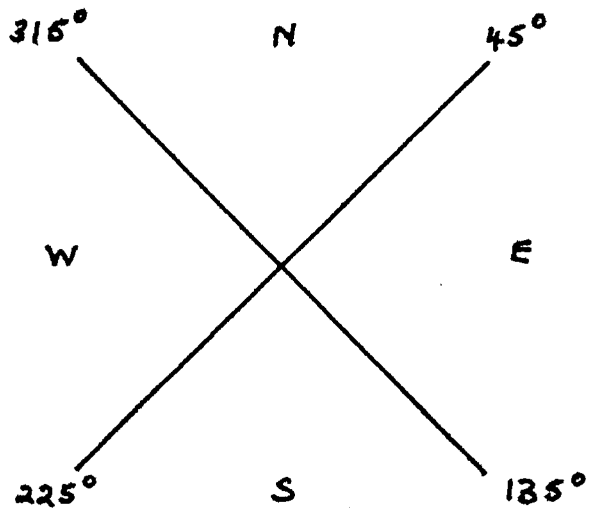
The sample weight in the above formula was dry weight. This was determined by oven drying the soils for two days at 105^{o}C with the fresh weight of soil converted to its dry weight equivalent. The phosphorus content of the soil samples are tabulated in the appendix (Table 8).

iv) Site Characteristics

Note was made of the immediate land use on either side of the railway line property in the majority of cases this was some form of agricultural activity.

Track width was also noted, the track being defined as the horizontal area between the cutting or embankment edge. The presence or absence of the track ballast was also recorded together with the gradient of the track. This was measured using an Abney level and surveying poles. Two readings were taken, one from each end of the track and the mean angle found. The Abney level was also used to determine the angle of the cutting or embankment slopes, three readings were taken and the mean determined. The height of the two slopes at each site was also noted.

The final site characteristic noted was that of aspect. The direction of alignment of the track was measured with a prismatic compass, sighting being on to the surveying poles at either end of the section of track. The data obtained enabled two and four bearing classes to be defined: these were 0 - 90^{o}, 91^{o} - 180^{o}, and 0^{o} - 45^{o}, 46^{o} - 90^{o}, 91^{o} - 135^{o} and 136^{o} - 180^{o}. With regard to the cuttings and embankments a different set of classes were identified and since aspect was the key factor in this regard it was the direction that the cutting or embankment slopes were facing that was of interest. The direction that the embankment or cutting slopes were facing was always 90^{o} different from the alignment of the track. Hence a track aligned in the south west to north east plane (recorded as bearing 45^{o}) would have cutting or embankment slopes which faced north west and south east. Since the classes for cutting or embankment slopes were north, south, east and west the definition of the class was made as outlined below, the code indicating the direction the slopes were facing.



Thus a track alignment between 46° and 135° and 225° - 315° would have cutting or embankment slopes facing north and south, if the alignment of the track was 315° - 45° and 136° - 225° the slopes would be facing east and west. The data on the site characteristics is tabulated in the appendix, Tables 9 and 10.

3. Statistical Techniques

i) Ordination

An ordination technique, as outlined by Bray and Curtis (1957), was used to enable comparisons to be made with regard to the species composition of the railway track sites. The ordination produces grouping of sites which may then be used as a basis for an assessment of the association between the pattern and particular environmental parameters.

After the species list for each site had been drawn up the coefficient of similarity was calculated between each site and all other sites using the formula below:

$$\text{coefficient of similarity} = \frac{2c \times 100\%}{a + b}$$

c = no. of species common to both sites
a and b = no. of species at any two sites A and B.

From these values interstand distances were calculated by subtracting the coefficient of similarity from 100 the theoretical maximum, with the data tabulated in the appendix (Table 11). The matrix of interstand coefficients was used to select two reference stands i.e. those stands with the greatest interstand distance between them viz. Q and S. Sites A and M were disregarded in this analysis as they were atypical, A being a site that is still used once a week to carry quarried stone and M being a moorland site at an altitude of 1400 feet. By reference to Q and S, the x axis coordinates of each of the other stands were determined by geometric construction. The reference stands for the y axis were chosen by selecting locations which were close together on the x axis but still had a high separation regarding interstand distance viz. sites C and I. These stands were used for y axis construction with all sites being thus given y coordinates. With the x and y coordinates found for each site the ordination was constructed.

ii) <u>Other statistical techniques</u>

The statistical techniques available in the S.P.S.S. computer package were used for the calculation of correlation coefficients, regression analysis and central tendency data. Apart from graphical methods the other statistical techniques used were the Chi-Square Test and the Fisher Exact Probability Test. The Chi-Square test statistic was used to determine whether cell frequencies in a contingency table were independent. The χ^2 value was calculated from the formula below:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

where O = observed frequencies
E = expected frequencies

with the degrees of freedom given by (r - 1)(c - 1) where r = no. of rows and c = no. of columns in the contingency table. In many cases the data was dichotomized on the basis of the median value of the variable under consideration. The median value was chosen since this enabled two classes to be identified on an objective basis i.e. those values greater than or equal to the median value, and those values less than the median.

The other statistical test used was the Fisher Exact Probability Test. Since it is recommended (Siegel 1956) that the Chi-Square Test be used in a 2 x 2 contingency table only when expected frequencies are $\geqslant$ 5, the Fisher Test was used when this was not the case, and where the data from the samples falls into one of two mutually exclusive classes. The test determines whether the two classes differ in the proportion with which they fall into one of two classifications. The probability of observing such a particular set of frequencies in a contingency table is given by the hypergeometric distribution.

Consider the contingency table below with the frequencies of occurrence in the mutually exclusive groups and classes given by the letters A, B, C and D.

	Group 1	Group 2	Total
Class 1	A	B	A + B
Class 2	C	D	C + D
Total	A + C	B + D	N

The probability p of the set of frequencies occurring is given by the formula below:

$$p = \frac{(A + B)!\ (C + D)!\ (A + C)!\ (B + D)!}{N!\ A!\ B!\ C!\ D!}$$

Again the median value of the data was used to establish the two classes on an objective basis.

Chapter 3

The Examination of Railway Track Vegetation

A Use of an ordination technique to compare track sites

As was outlined in Chapter 2 the ordination technique devised by Bray and Curtis (1957) was used to compare sites with respect to their species composition, so that the grouping of sites may then be examined in relation to the environmental variables studied. After the coordinates of the sites had been calculated the data were graphed and the ordination did appear to give a good separation of the sites (Fig.2).

An important indication that the ordination has been useful and can be used to indicate similarity of sites through species composition is that the site locations along the x axis and the y axis should be un-correlated. If this is so, then the y axis does add meaning to the separation of sites outlined by the x axis. The correlation coefficient between the x and y axis was found to be r = 0.0103 which for the twenty eight sites is not significant and hence the x and y axes give stand locations which are not associated.

Although sites A and M were not used for the selection of reference stands as they have been shown to be atypical (Chapter 2, Pg.9) they have been included in the graphical representation of the ordination.

The x axis is based on the interstand distance between sites Q and S, these being the most dissimilar sites regarding species composition. Site S had a track soil with a pH value of 8.8 (the highest value found at any site) with Q recording a pH of 7.3. Site S is isolated in its position on the ordination and the likely reason for this is to be found in the uniqueness of the site. This site was a disused railway line within the Weardale works of the Associated Portland Cement Manufacturers at Eastgate. It is therefore likely that the separation of S from all

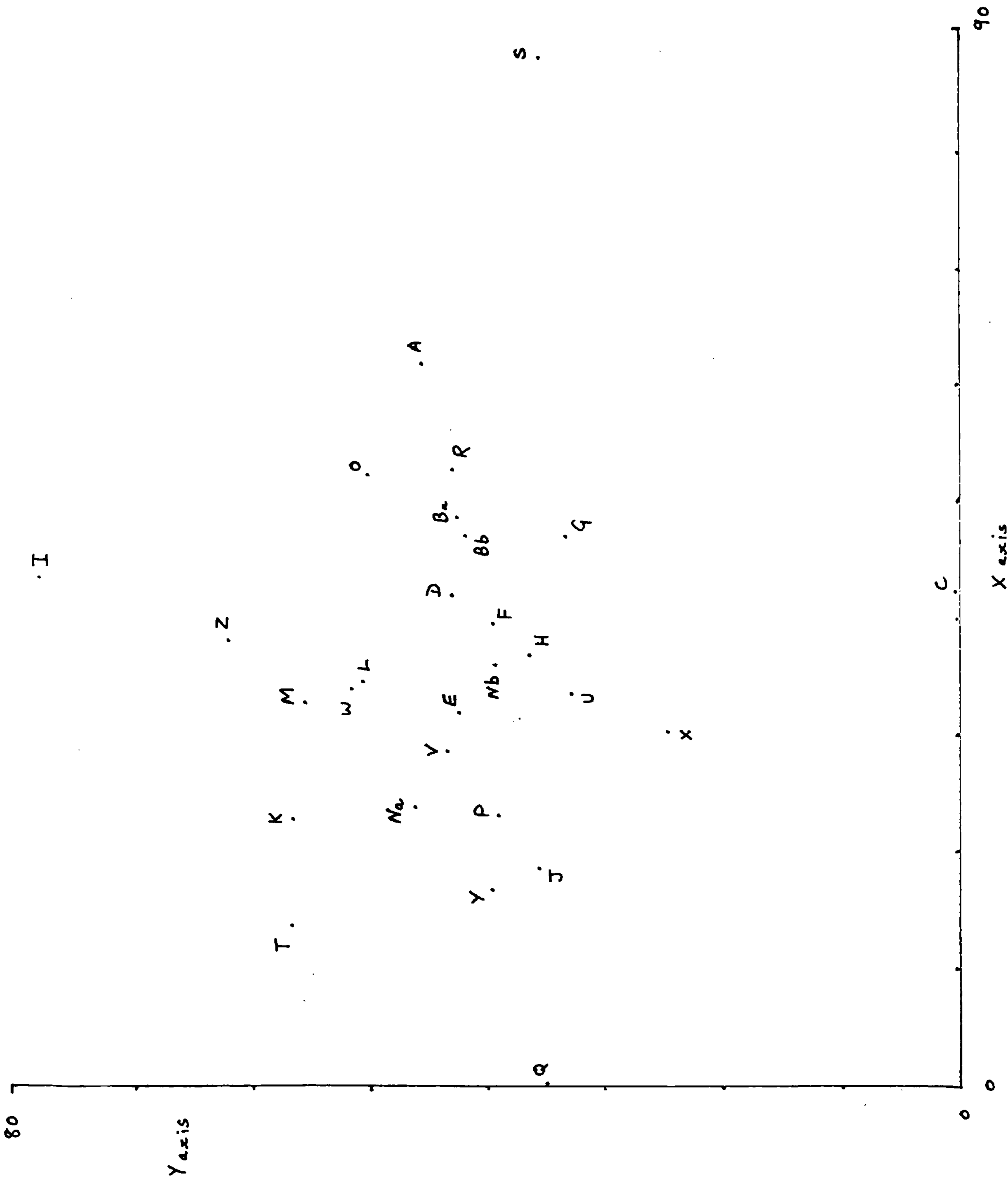


Fig. 2 Ordination of the disused railway track sites.

other sites is due to the presence of limestone dust as fallout from the industrial processes being carried on at the site, this accounting for the high pH value. Further the continuous fallout of limestone dust is likely to have an inhibitory effect on plants by its physical presence e.g. reducing photosynthetic efficiency. The section of track sampled was less than one hundred and fifty metres from the main processing building. Brandt and Rhoades (1973) have noted that pH levels on sites receiving heavy dustfalls from nearby limestone quarries and processing plants had greater values than a control site which received little or no dust. This difference proved to be significant when Brandt and Rhoades sampled soil from the A_1 and A_2 horizons, (0 - 10cm) with samples from the B_1 horizon ($>$ 10cm) approaching normal pH values for limestone derived soils. The high pH value at S thus is explained by dustfalls from the Weardale works, as the soil sampled on the track in this study was also in the A_1 and A_2 horizons being in the 0 - 8 cm range.

It is likely that limestone dust may also have been influential in the soils and the pH recorded at sites Ba (pH = 8.3), Bb (pH = 8.3), and A (pH = 8.5). Sites Ba and Bb were near to the Thrislington limestone quarry at Cornforth. Limestone dust falling from rail wagons as well as industrial fallout could also have increased the pH value of the soil taken from site A. The line is used once a week to transport quarried limestone from the quarry at Coxhoe and spillage along the line, as well as dust, could occur.

Site S also still had the rails and sleepers down and was an open site whereas site Q was a closed habitat and was without rails or sleepers. Site Q was grazed until two years ago after which it was left to re-generate without direct human or animal disturbance, whereas site S had suffered no disturbance over the years since closure. Both sites, however, were on Carboniferous Limestone and thus had similar geology.

The y axis was constructed using reference stands C and I, these being close together on the x axis but with a high separation regarding interstand distance. Site I was at Brusselton where the line was closed one hundred and twenty years ago. The line was one which included a rope hauled section over an incline plane and was replaced by an alternative route in 1858. The percentage cover within the sampled quadrats was 42% with disturbance and the presence of stone sleepers (just visible in the photographs) accounting for this.

Site C was a much more open habitat than site I and an important factor explaining the difference in vegetation at the sites is that C is on the Magnesian Limestone whereas I is on the Coal Measures. The difference in geology is likely to be very influential in determining species composition, especially in the early years of colonisation of the disused track.

With the ordination plotted, analysis was then undertaken to investigate any association that may exist between the two axes and a number of variables.

Correlation coefficients were obtained between the x and y axes and a number of non-environmental variables viz. the number of years since the track closed, the number of species of the track and the percentage cover of the track. The only variable significantly associated with either axis was the number of species which was correlated with the x axis (r = 0.4627 ***). (Throughout this study a significant level of 0.05, 0.01 and 0.001 is indicated by *, ** and *** respectively: N.S. represents non-significant). The trend of the correlatio n was an increase in the number of species towards the higher values of the x axis (Fig.3).

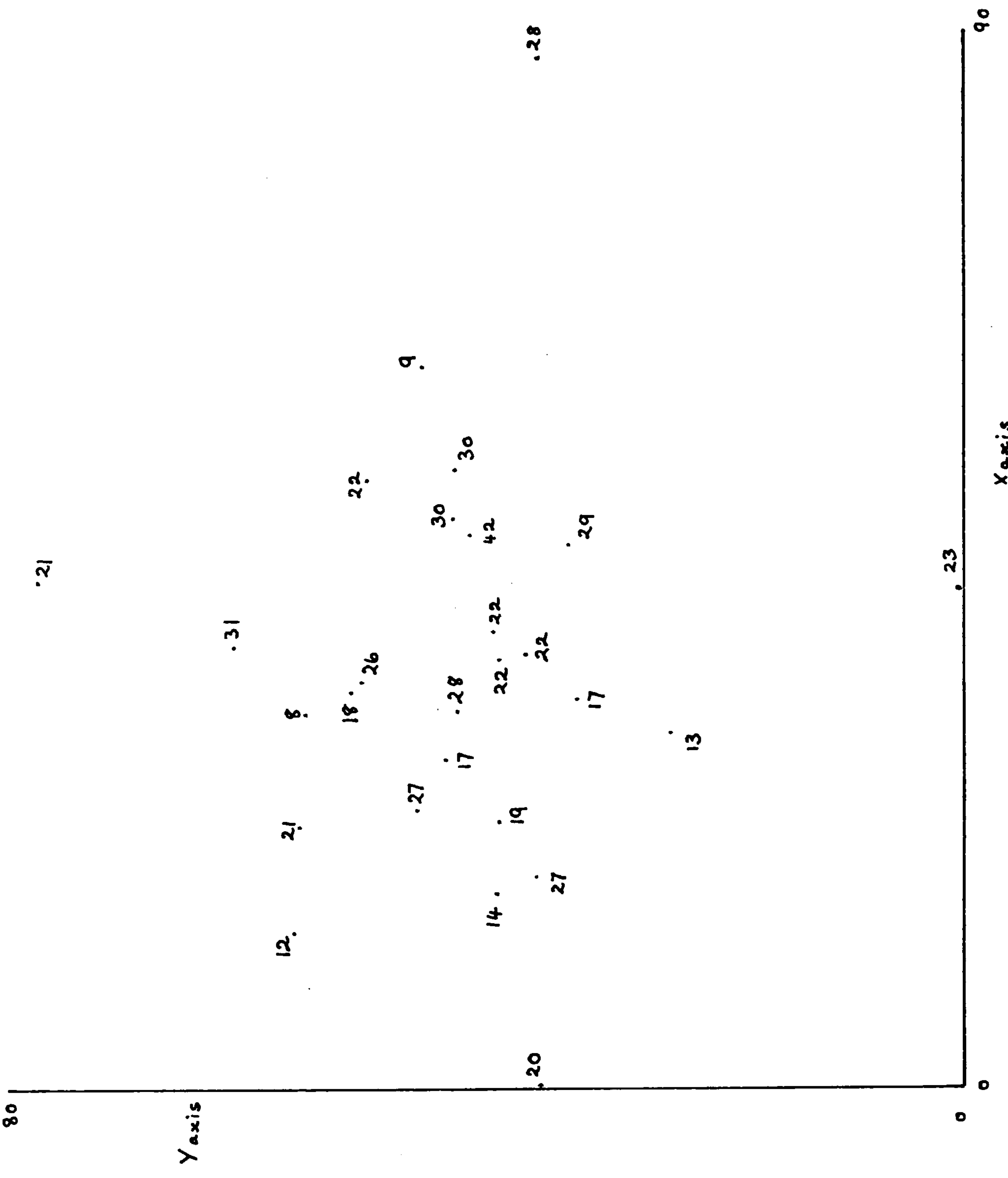


Fig. 3 Ordination showing number of species per site

The number of species found at a site will not only be a function of time since closure of the line but will also be a function of the degree of disturbance experienced along the track after it ceased to be operational, the nature of the seed bank in the track soil and the seed influx each year, the amount of stress associated with the site (stress being the external constraints which limit the dry matter production of all or part of the vegetation e.g. nutrient deficiency) and also habitat characteristics including the nature of the substrate since base rich soils e.g. those derived from limestone, tend to be more species rich sites. Since the years since closure and the percentage cover were not associated with the ordination axes this would suggest that the grouping of sites produced was not a response to time but to one or more environmental variables. Attention was then given to the environmental variables studied.

The parameters under study were pH, phosphorus and organic content of the soils, the bearing of the line and the gradient of the track. Of these variables only pH was found to be significantly correlated with the axes, being associated with both the x axis ($r = 0.5539$***) and the y axis ($r = 0.3510$ *). The trend of the correlation was for an increase in pH towards the upper end of the x axis and a decrease in pH towards the upper end of the y axis.

The pH values obtained for the track soils were superimposed upon the ordination (Fig. 4). The ordination thus separates the sites and their species composition according to pH and to a lesser extent the number of species at the sites, which will in itself be partly dependent upon pH. At high pH levels, however, stress will increase and the number of species is likely to decline as fewer species will have the capacity to tolerate increasingly alkaline conditions.

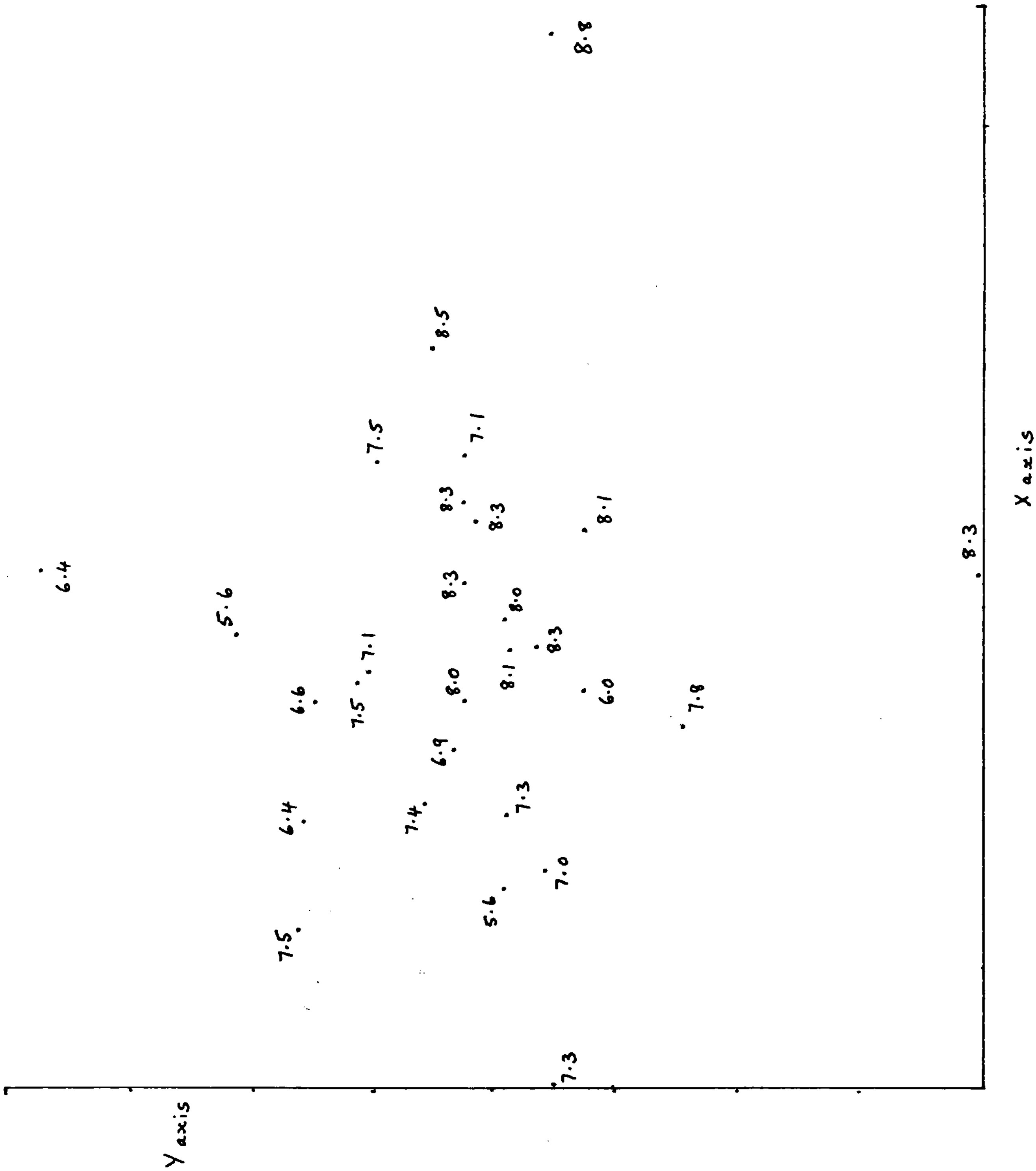


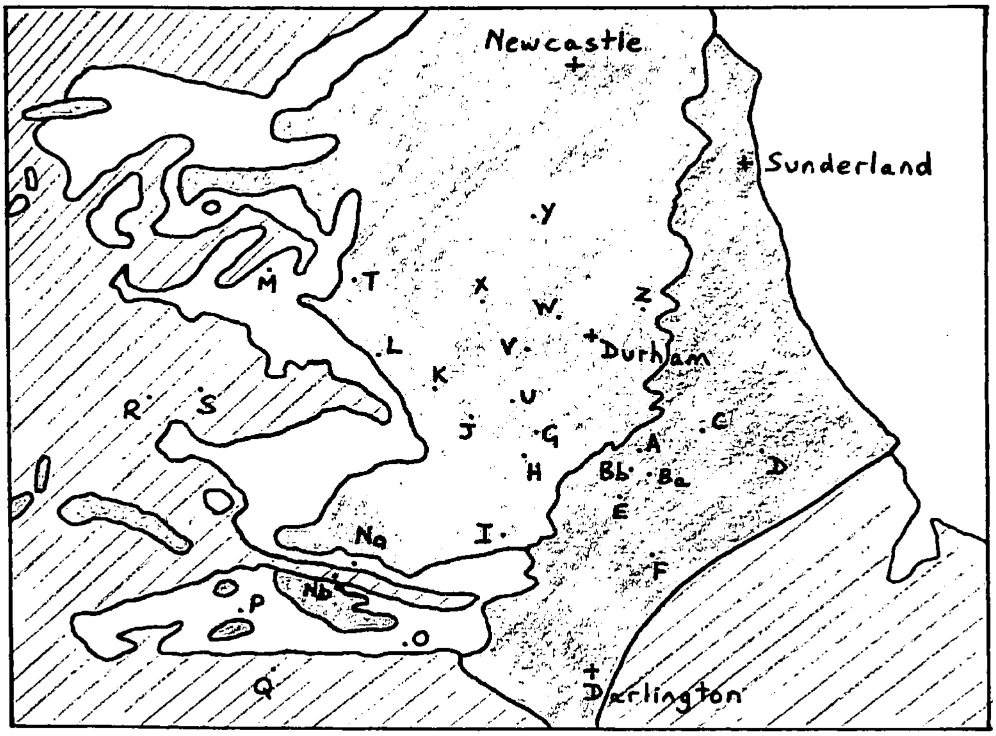
Fig. 4 Ordination showing pH of sites

The ordination thus produces an arrangement of track sites which reflects a response by the vegetation to the pH of the track substrate, which will itself be strongly influenced by the geology of the area. This influence can be seen when the geology of the Durham area is considered. The area sampled had a relatively simple solid geology, though there were complications as a result of drift materials. However, since the drift material was not usually used to provide the track substrate the underlying solid geology will be the important factor. The geology map reveals four basic rock types: Magnesian Limestone, Carboniferous Limestone, Coal Measures and Millstone Grit. The solid geology map and the location of the sites is illustrated in Fig.5.

The geological characteristics enable two classes to be identified viz. disused track sites on limestone and those not on limestone, this information is also superimposed on the ordination in Fig. 6. From the data it can be appreciated that the ordination technique classifies sites according to the underlying geological conditions. The policy of the railway companies was to use locally available material for track substrate and thus reduce to a minimum the transport costs for movement of track ballast. As a result the ballast was obtained from immediately available local resources e.g. from the spoil of quarries or mines and from nearby cuttings. In this regard sites G and H appear anomalous since they were sites on the Coal Measures yet both had track soils with pH values over 8.0 viz. 8.1 and 8.3 respectively. It is probable that instead of using mining spoil for ballast, waste from limestone quarries was used, perhaps from the nearby quarries in the Cornforth area.

The ordination thus reveals the importance of the nature of the track substrate material in explaining the vegetation along disused tracks. The vegetational similarity of sites will be strongly influenced by the geological characteristics

Fig. 5 Solid Geology of the Durham area.



KEY

- • Sites
- Coal Measures
- Millstone Grit
- Magnesian Limestone
- Carboniferous Limestone

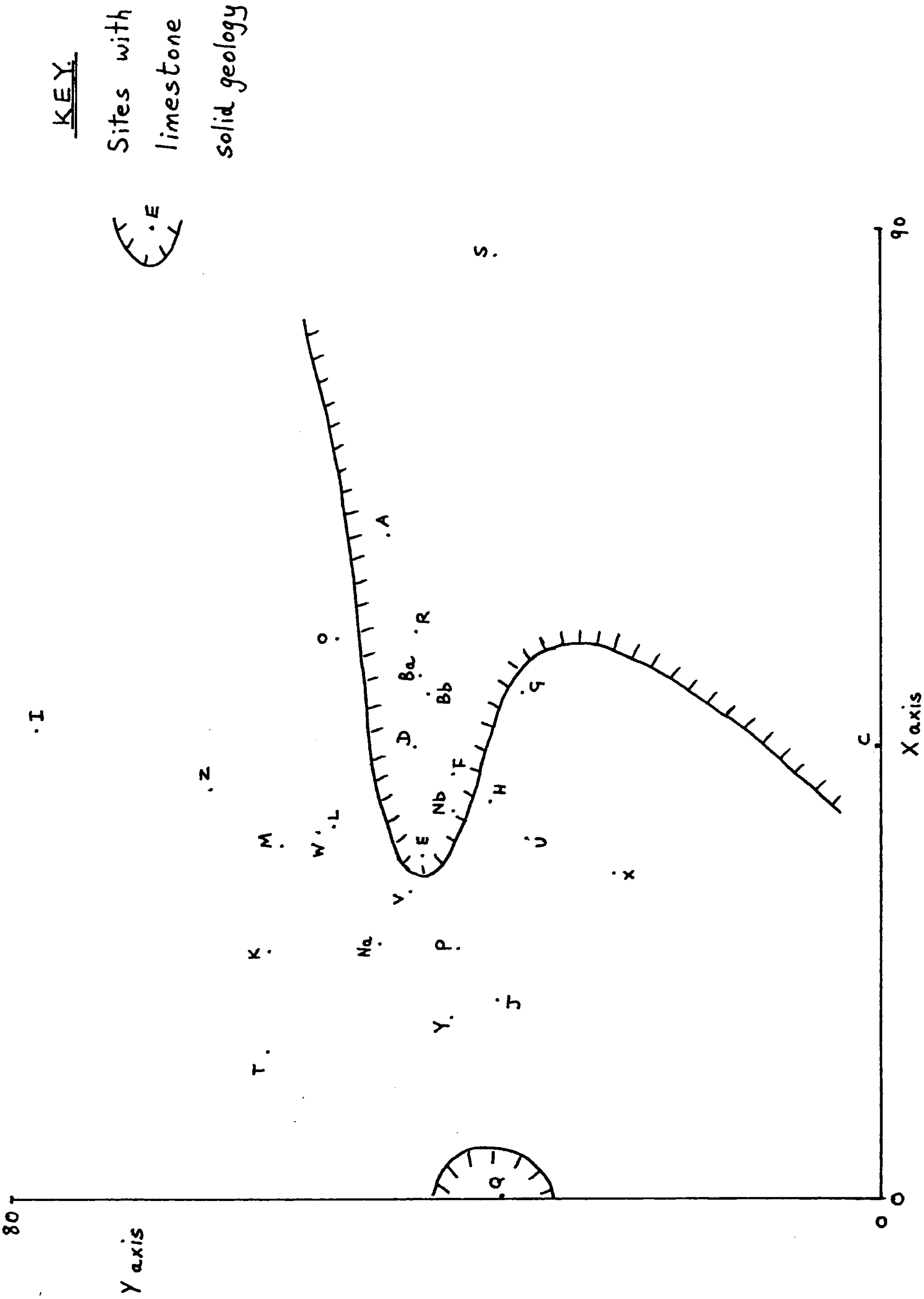


Fig. 6 Ordination showing the sites with limestone or non-limestone solid geology.

of the track substrate and thus by the pH of the track soils. The usefulness of the ordination technique in this study is thus reduced as the other environmental variables studied show no correlation with the grouping of sites. This indicates that the sites themselves do not form a homogeneous group since two different areas have been sampled viz. tracks on limestone and those not on limestone. It would clearly have been better to have sampled disused railway track sites on either the limestone areas or on the coal measures as the influence of the ballast material is so profound. If sampling had been restricted to limestone or Coal Measure areas greater homogeneity of sites would have been achieved.

With the influence of geology upon the species composition and similarity of the tracks having been established, attention was then given to other factors viz. pH, phosphorus content and organic content of the track soils, which will also influence the distribution of plants.

B Soil Factors, Vegetation and Track Age

i) The pH of Track Soils

The pH of the track soils was noted above as being significantly correlated with the x and y axes of the ordination. The pH of the track soils was also found to be correlated with the time since closure of the track (r = - 0.5106 **), the organic content of the soils (r = - 0.3752 *) and the percentage cover of the tracks (r = - 0.4379 **), see Figs. 7, 8 and 9.

On closure the disused railway tracks are xeric, stressed sites with little or no soil. Over time the characteristics of the track soils will alter. The decline in pH over time in environments which are rather

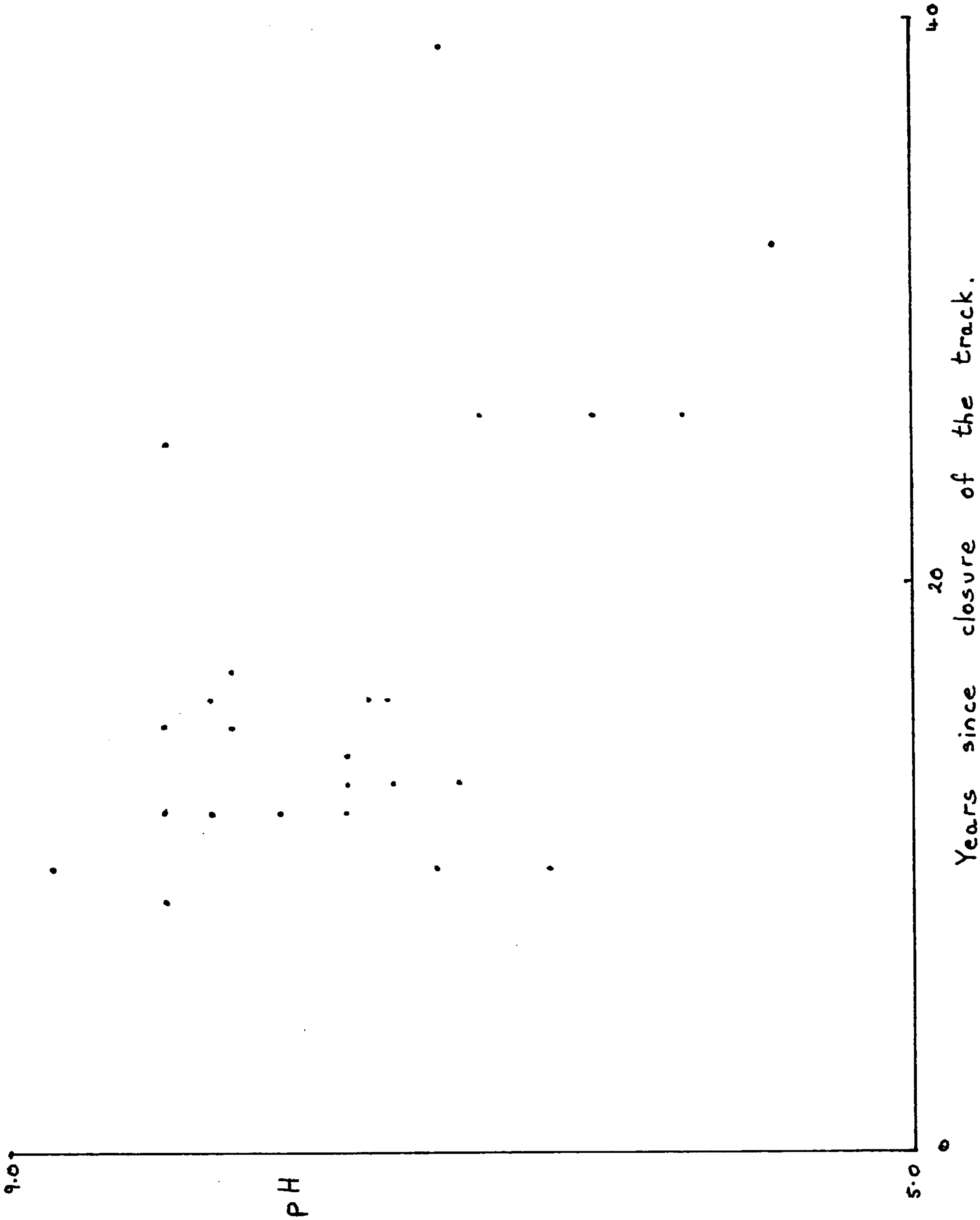


Fig. 7 Relationship between pH of the tracks and the years since the tracks closed.

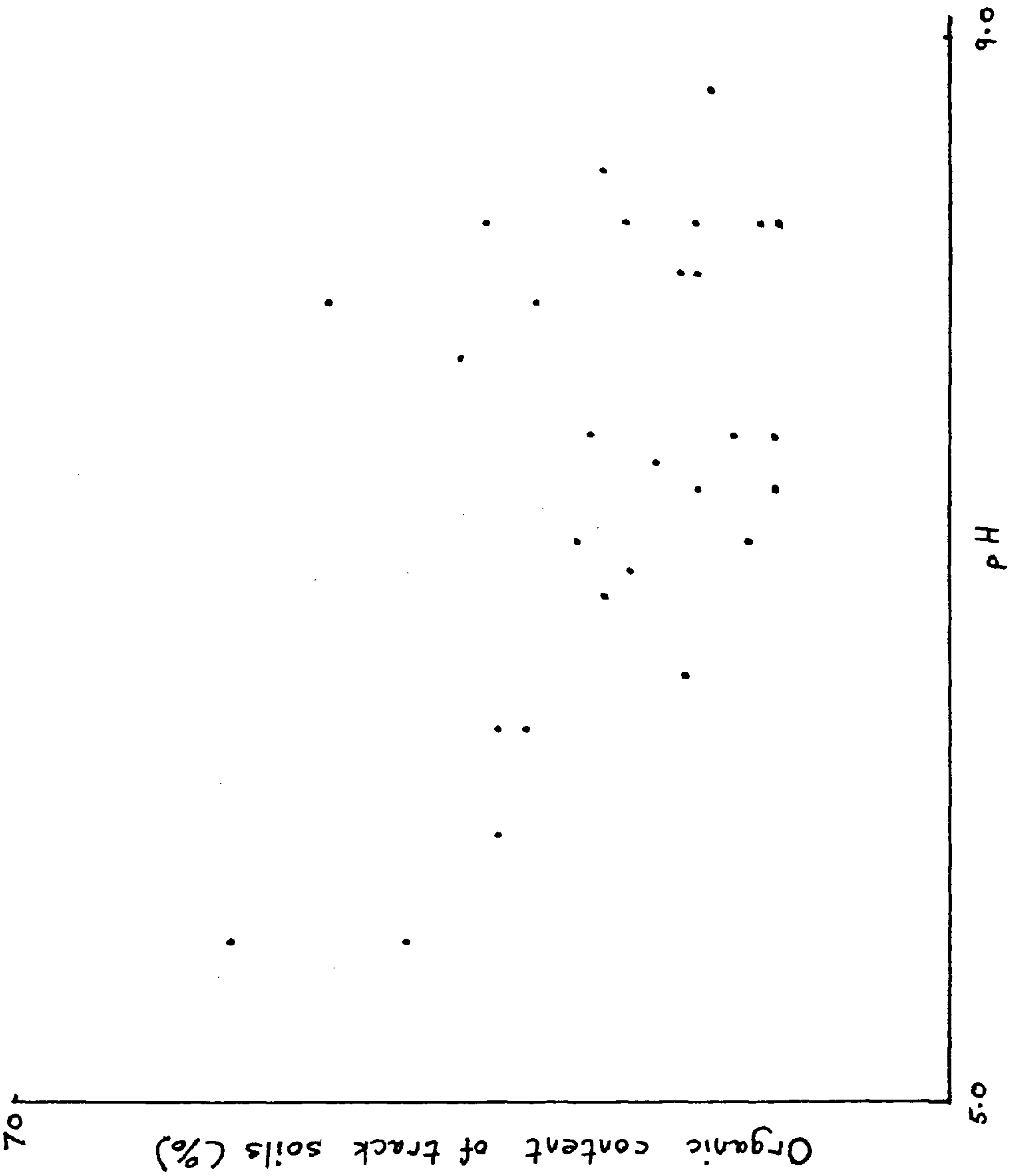


Fig. 8 Relationship between the pH of track soils and the organic content of the track soils.

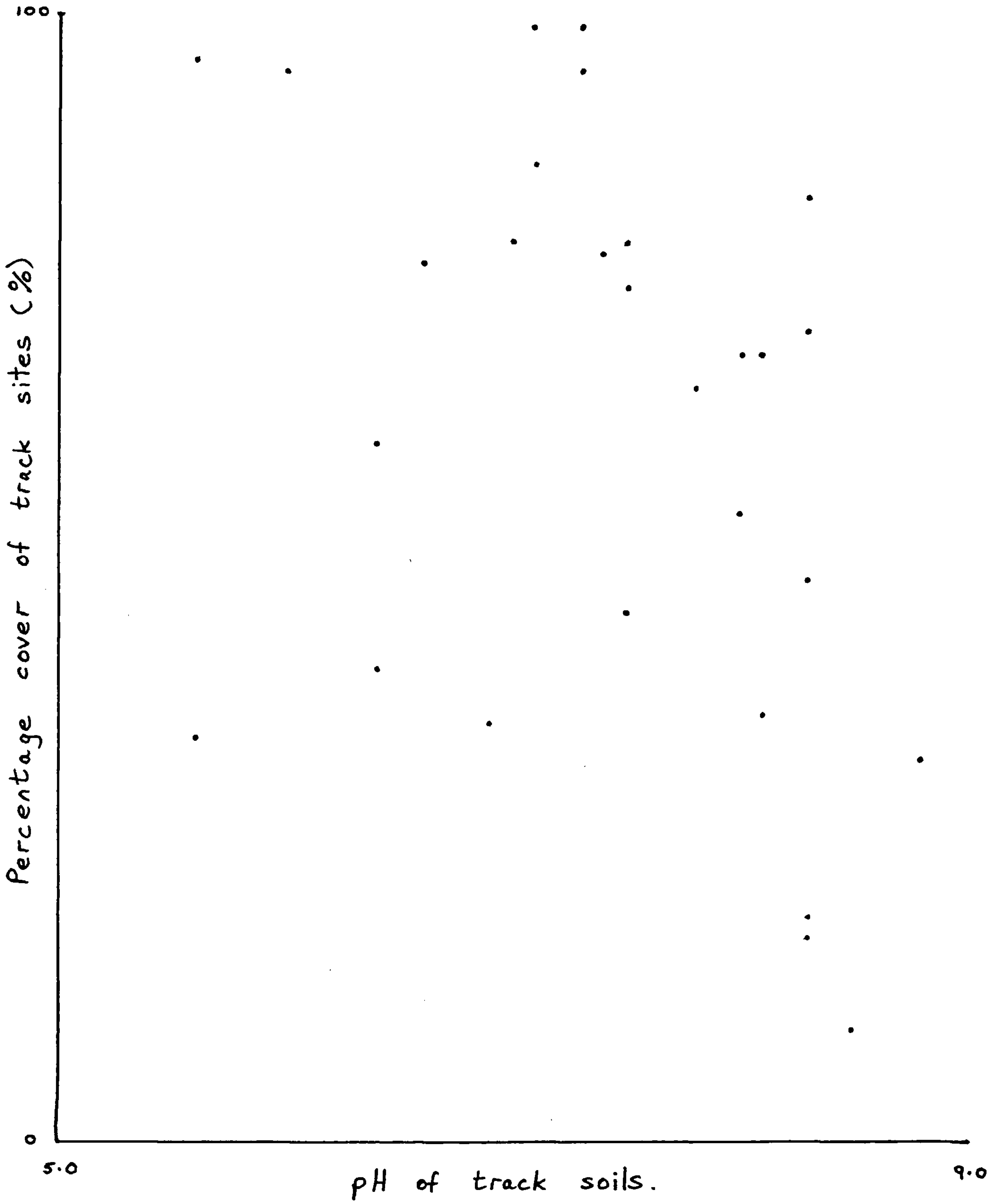


Fig. 9. Relationship between pH of track soils and the percentage cover of the tracks.

similar to disused tracks, in that they are also xeric, stressed and have little soil, has been noted by other workers e.g. Olson (1958) working on the system of sand dunes at the southern end of Lake Michigan and Lawrence (1958) working on glacial moraines in Glacier Bay, Alaska also noted this decline, with the rate of change being dependent on the type of vegetation. The disused track soils show a similar decline over time. The decline in pH will result from carbonates being leached from the soil, leaching being a fairly rapid process on such a substrate.

The other two variables correlated with pH viz. organic content of the soils and the percentage cover of the track, will also be related to time. As colonisation proceeds, vegetation cover increases and the soils become more organic and less mineral as the colonising vegetation decomposes and the humus content of the soil increases.

ii) The PhosphorusContent of Track Soils.

Phosphorus is a major element required by plants and though plant species differ in their requirements each species has a specific ability to exploit the nutrient supply and does so in a manner which will be different from other species.

The range of values shown by the track soils in respect of their phosphorus content reveals that some tracks have a very low content. The fact that legumes are not inhibited by this and are found at a number of the disused track sites suggests that the nitrogen content of the soils is also low, though this was not investigated in this study. Disused railway tracks thus are environments which are generally low in nutrient supply. Soil cover is thin and hence any minerals in the soil as a result of weathering and leaching of the ballast are easily lost due to the nature of the track substrate. Other sources of phosphorus would increase the content of the soils as a result of weathering - these would include accidental inputs when supplied to nearby agricultural activities e.g. barley, and through organisms by means of excretion, death and decay.

The phosphorus content of track soils was also found to be significantly correlated with the number of track species at the sites. This relationship is negative (r = - 0.3214 *) indicating that at higher levels fewer track species were found. It is likely that the relationship between the number of species and levels of phosphorus is a function of competitive exclusion, with competitive species being able to take advantage of the higher levels of nutrient available in soils of relatively higher phosphorus content.

A significant correlation was found between the phosphorus content of track soils and <u>Festuca rubra</u> (r = 0.3499*) and <u>Ranunculus repens</u> (r = 0.3192*). From published data (Grime and Hunt 1975, Grime 1974) the Competitive Indices of both species have a fairly high index (5.0 and 4.0 respectively) and also a fairly high R_{max} value (1.18 and 1.39 respectively) which indicates that they are both able to take advantage of increased phosphorus supply in the disused railway track soils.

iii) <u>The Organic Content of the Track Soils</u>

The organic content of the track soils was correlated with pH and this has already been noted. The increase in organic matter was also significantly correlated with the time since closure of the line (r = 0.3585*), a relationship which was to be expected.

When the line was in use the track ballast would act as a reservoir and trap dust, dirt and soil particles. The effect of a fast moving train would be to shake the track and pack the soil grains. The rate of accumulation may well be fairly slow as during the period when the line was in use the track would undergo maintenance with occasional fresh injections of ballast to give adequate support for the rails and their load. On closure of the line the organic content would increase since wind blown material would continue to accumulate but also vegetation would colonise the track. With the decomposition of these plants the organic content would increase.

The increase in organic content would also influence other soil characteristics e.g. the water retaining capacity of the soils. This would give advantage to species which could benefit from the more mesic conditions e.g. competitive grasses like *Arrhenatherum elatius*. Species already in situ would not necessarily be ousted if they could adapt to the changing conditions e.g. *Dactylis glomerata* which was an effective competitor with *Arrhenatherum elatius* on embankment or cutting slopes where soil moisture levels are likely to be higher.

iv) Changes in Soil Characteristics and Time Since Closure of the Tracks.

Both pH and organic content of the soils were correlated with the time since closure of the tracks, the former declining and the latter increasing with time since closure. These changes would be expected as the nature of the ballast would initially influence strongly the pH of the thin soil layer, which would have a low organic content.

Chapter 4

The Influence of the Embankment and Cutting Species on the Track Species at Disused Sites.

A Similarity of Vegetation Between Tracks and Slopes

The coefficient of similarity was used to determine the similarity of species between the disused tracks and the embankment or cutting slopes. Coefficients were calculated for the track and slopes and also for the two slopes. The data was obtained for twenty seven sites (site Nb at Copley was a viaduct and thus had no slopes), see Appendix Table 12.

Initially analysis sought to determine if the embankment or cutting slopes were more similar (with respect to species composition) to each other than they were to the track. The hypothesis under test was that there was no difference in similarity between the two slope and between the track and the slopes. The contingency table is outlined below:

	Track & Slopes	Both Slopes	Total Number of sites
The number of sites where either the track and slopes or both slopes were more similar.	8	18	26

$\chi^2 = 3.85$ * (df=1)

(Only twenty six sites occur in the table as at one site P, the coefficients were identical)

A significant difference was thus found to exist. The two embankment or cutting slopes are thus more similar than are the slopes and track.

The slopes and track were also compared as to the number of species and percentage cover found at each site. When the number of species occurring on the tracks and on the slopes at each site was studied no significant difference was found between the two environments.

A highly significant difference, however, was found between the tracks and the slopes when the percentage cover was studied (for the slopes the mean percentage cover of the two slopes was used). The contingency table is illustrated below.

		Tracks	Embankment or Cutting Slopes	Total
Percentage Cover	≥Median	7	21	28
	<Median	20	6	26
Total		27	27	54

(Median percentage cover = 84.0% : the median was derived by ranking the percenta-ge cover at all sites and then selecting the central value).

The hypothesis under test was that there was no difference between the tracks and the slopes with respect to percentage cover. The χ^2 value was 14.538 *** (df=1).

This significant difference would be expected since when the arresting factor (disturbance through the annual application of weedkiller) was removed from the track when it ceased to be operational, succession would proceed from an unvegetated substrate. The slopes, however, (though they had suffered disturbance through cutting and burning) would subsequently develop from an already vegetated state when the line was closed.

Data was collected relating the total cover of particular species (those species with>0.5% of the total cover at all sites) and the number of sites at which they were found. The data is represented graphically Figs. 10 and 11.

For the track sites the dominance of Festuca rubra is clear with a second group of plants having both extensive cover and also were found at most sites viz. Lotus corniculatus, Cynosurus cristatus, Trifolium repens, Dactylis glomerata, Plantago lanceolata, and Poa annua. The remaining species show a fairly constant cover per site.

A different pattern of points is shown in the embankment plot. A fairly uniform increase in cover per site is shown by the six species with greatest cover viz. Urtica dioica, Arrhenatherum elatius, Chamaenerion angustifolium, Rubus fruticosus, Dactylis glomerata and Festuca rubra. It might be expected that Arrhenatherum elatius, Chamaenerion angustifolium and Urtica dioica (with competitive indices of 6.0, 7.5 and 6.5 respectively) would have occurred at more sites as they are large and very competitive species. They often occur in monocultural stands in wastelands, field boundaries etc. but they did not exhibit this tendency to any degree at any of the sampled sites. In contrast to these, other species e.g. Plantago lanceolata, Poa annua, have less competitive growth forms (with competitive indices of 2.0 and 1.0 respectively) yet occur at most sites. This would suggest that the railway embankment and cutting slopes are also stressed environments of low nutrient supply. Though soil depth, organic content and water retention capacity were not measured in this study it is likely that they were greater, in each respect, than the tracks, and that competitive growth forms e.g. Urtica dioca, Chamaenerion angustifolium and Arrhenatherum elatius had been able to make use of these improvements in the soil. Although these competitive species may be found on the embankment and cutting slopes it is likely to be some time before they increase their

Fig. 10. Cover of most frequently occurring track species.

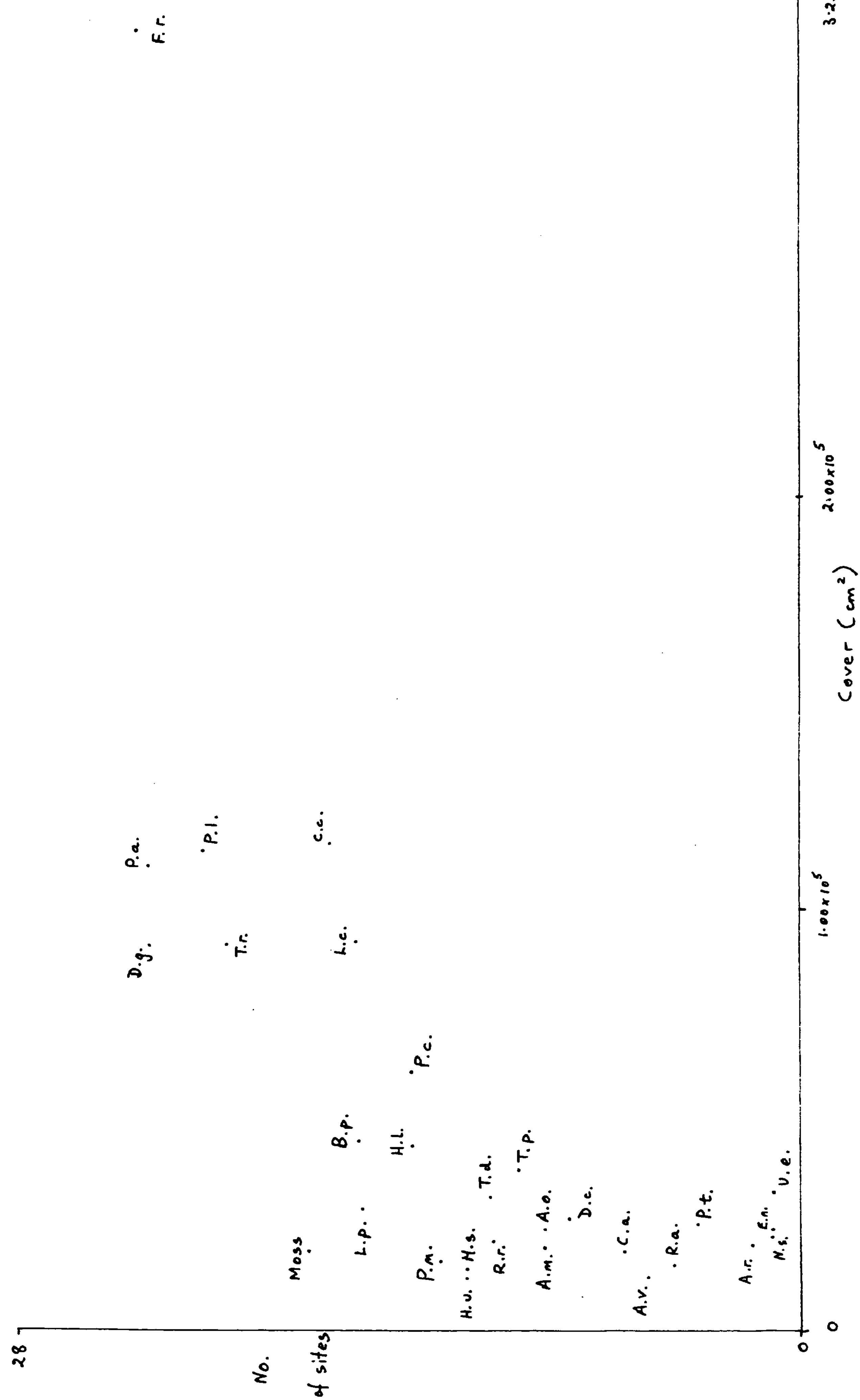
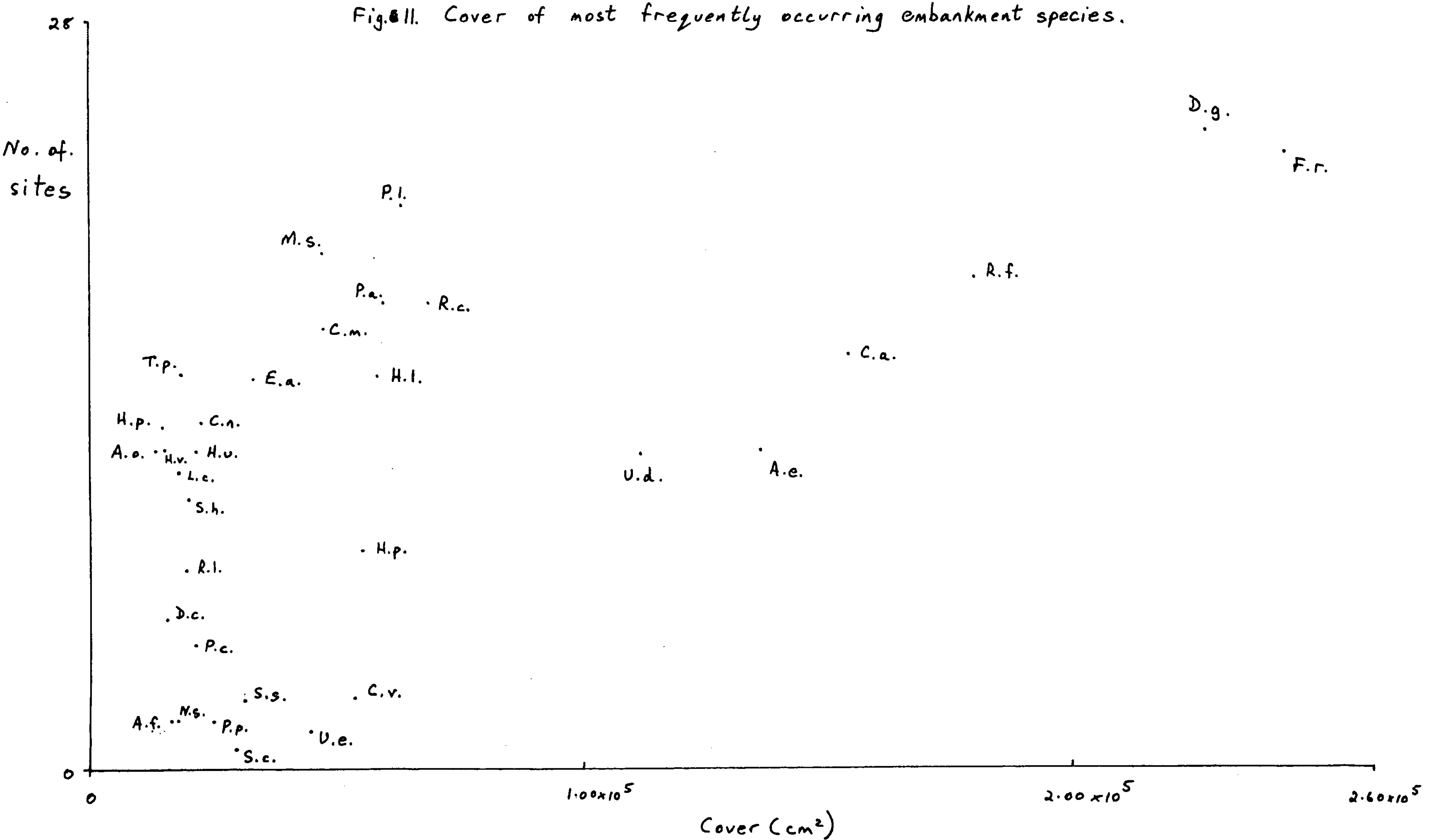


Fig. 11. Cover of most frequently occurring embankment species.



track cover substantially i.e. not until the stress of the track environment is reduced.

Investigation was also made as to whether the aspect of the slopes was influential in explaining the similarity of vegetation i.e. if the east/west alignment of the slopes were as similar as north/south alignment. Expectation may be that north/south slopes may be less similar since they experience different micro-climatic conditions (Suominen 1969, Niemi 1969). Analysis was undertaken by reference to the median value of the similarity coefficients for the slopes. The hypothesis under test was that there was no difference in the similarity of vegetation and the aspect of the slopes. The data is tabulated below:

Slope Aspect	East/West Alignment	North/South Alignment	Total
≥ Median	8	6	14
< Median	3	10	13
	11	16	27

(Median similarity coefficient = 60.9)

$\chi^2 = 3.251$ df=1 N.S.

The null hypothesis is thus accepted and the difference that existed regarding the similarity of the vegetation was not related to the aspect of the slopes.

B. Soil Characteristics of the Embankment and Cutting Slopes in Relation to the Tracks.

The pH and phosphorus content of the soils on the embankment and cutting slopes was determined at each site. In each case the hypothesis of no difference in the pH or phosphorus content of the track and slope soil was tested. The data was dichotomized on the basis of the median. In this analysis the individual values obtained for each slope were used. The data is tabulated below:

	Tracks	Embankment or Cutting Slopes	Total
$\geq$ Median	19	23	42
$<$ Median	8	31	39
Total	27	54	81

(Median pH = 7.2)

χ^2 = 5.563 * df = 1

A significant difference was thus found to exist in the pH values of the tracks and the slopes, with track sites revealing higher pH values. This is to be expected since although the tracks and slopes had in most cases a substrate derived from similar geology, as succession proceeds and vegetation cover increases the soil becomes more organic, less mineral and (on a substrate of initially high pH) the pH of the soil declines.

	Tracks	Embankment or Cutting Slopes	Total
$\geq$ Median	15	26	41
$<$ Median	12	28	40
Total	27	54	81

(Median phosphorus content = 0.027 mg/g dry wt.)

χ^2 = 0.393 df = 1 N.S.

No significant difference was found to exist between the tracks and the slopes with regard to the phosphorus content of the soils. In this respect the slopes and tracks revealed homogeneity.

However, a significant correlation (r = 0.398 ***) was found between phosphorus levels and the type of terrain i.e. if the track was on level ground, on an embankment or within a cutting, the correlation indicated that phosphorus levels were higher at level ground sites. Although no soil samples were taken from the land adjacent to the disused tracks, it may be that the increased levels of phosphorus at these level sites was influenced by agricultural practices on the adjacent land through the application of fertilisers.

Thus differences in similarity of vegetation between the tracks and the slopes are thus seen to be influenced by the pH of the soils in the two different environments. Differences also exist in the percentage cover of tracks and the embankment and cutting slopes. Further differences between the slopes and the tracks are likely to be influential also viz. time and disturbance, though this was not measured in this study.

The emb-ankment and cutting slopes will have had a greater period of time since initial colonisation for the vegetation to develop, in spite of disturbance, and reveal a greater cover and number of shrub and tree species e.g. Rosa spp., Crataegus monogyna etc., Also more highly competitive species were found on embankments and cuttings with a greater cover and this would again reflect greater successional development, as well as differences in the soil characteristics. It was noticeable that many typical ruderal species e.g. Senecio jacobaea, Senecio squalidus, were only found on tracks which is indicative of an earlier successional stage.

The embankment and cutting slopes will not have

? vulgaris ?

received such regular disturbance. When in use the tracks were sprayed annually with weedkiller to limit vegetation. The slopes were cut or burnt to prevent the re-generation of woody species which would constitute a fire hazard, particularly in the days of steam engine. Such disturbance, however, was not a regular annual event. On closure of the lines it is likely that the tracks would have suffered more disturbance from trampling than the slopes. The tracks thus show a higher number of species which can accommodate such disturbance e.g. Plantago major.

Chapter 5

Examination of Typical Species

The two track species chosen for more detailed analysis were Plantago lanceolata and Dactylis glomerata. Analysis was confined to fourteen sites because of limited time available.

A Pattern of Distribution

The method of analysis of the pattern of distribution of both species was outlined in Chapter 2. The method allows for a measure of the deviation of the pattern from a random distribution and the results are tabulated in the Appendix (see Table 13).

The data shows that both Plantago and Dactylis are generally associated with aggregated distributions on the disused railway tracks, with only one site (Nb) where this does not apply to either of the species.

For Plantago lanceolata the pattern of distribution accords with the observations made by Sagar and Harper (1964) and is a function of the plant reproducing vegetatively.

For Dactylis glomerata an aggregated distribution would be expected since the sites were not grazed and had suffered only light trampling. Beddows (1959) notes that in the absence of grazing animals plants of Dactylis grow to form tussocks. All track species investigated in this study were found to form tussocks. The pattern of distribution found viz. an aggregated one, is explained by Dactylis producing relatively large seeds which thus stay close to the parent plant, hence the observed clustering.

B Performance of the Species

i) Plantago lanceolata

The basic data relating to *Plantago lanceolata* is summarised in the Appendix (Table 7).

a) Plant Characteristics

Analysis was undertaken to establish if a significant difference existed between the individuals taken from either of the two embankment or cutting slopes with regard to height, weight and weight loss on drying. The relevant data is tabulated below with the data dichotomized on the basis of the median. The hypothesis under test was that no difference existed between the individuals from the slopes. The Chi-Square statistic and the Fisher Exact Probability Test were used to test the hypothesis.

Tables overleaf.....

Scape height

(Median = 39.1 cm)

	West/ South	East/ North	Total
≥ Median	7	5	12
< Median	6	6	12
Total	13	11	24

χ^2 = 0.168 df= 1 N.S.

Dry Weight of Leaf

(Median = 0.08 g)

	West/ South	East/ North	Total
≥ Median	9	6	15
< Median	4	5	9
	13	11	24

p = 0.505 N.S.

Leaf Length
(Median = 19.8 cm)

	West/ South	East/ North	Total
≥ Median	6	6	12
< Median	7	5	12
Total	13	11	24

χ^2 = 0.168 df = 1 N.S

Dry/Fresh Weight of Scape
(Median = 0.295)

	West/ South	East/ North	Total
≥ Median	6	6	12
< Median	7	5	12
	13	11	24

χ^2 = 0.168 df = 1 N.S

Dry Weight of Scape
(Median = 0.24g)

	West/ South	East/ North	Total
≥ Median	8	6	14
< Median	5	5	10
Total	13	11	24

χ^2 = 0.122 df = 1 N.S

Dry/Fresh Weight of Leaf
(Median = 0.190)

	West/ South	East/ North	Total
≥ Median	8	4	12
< Median	5	7	12
	13	11	24

χ^2 = 1.510 df = 1 N.S

No significant differences were found and thus the individuals of *Plantago lanceolata* included in the samples were homogeneous with respect to the qualities measured.

Investigation was then undertaken to establish if significant differences existed between the slope and track individuals with respect to the plant characteristics studied. The data is tabulated below and again the data was dichotomized on the basis of the median.

Scape Height
(Median = 28.5 cm)

	Tracks	Slopes	Total
≥ Median	2	11	13
< Median	11	2	13
Total	13	13	26

$\chi^2 = 12.461$ df = 1 ***

Leaf Length
(Median = 12.05 cm)

	Tracks	Slopes	Total
≥ Median	4	9	13
< Median	9	4	13
	13	13	26

$\chi^2 = 3.846$ df = 1 *

Dry Weight of Scape

(Median = 0.165 g)

	Tracks	Slopes	Total
≥ Median	2	11	13
< Median	11	2	13
Total	13	13	26

$\chi^2 = 12.461$ df = 1 ***

Dry Weight of Leaf

(Median 0.063g)

	Tracks	Slopes	Total
≥ Median	4	9	13
< Median	9	4	13
	13	13	26

$\chi^2 = 3.846$ df = 1 *

Dry/Fresh Weight of Scape
(Median = 0.309)

	Tracks	Slopes	Total
≥ Median	8	5	13
< Median	8	5	13
Total	16	10	26

$\chi^2 = 1.385$ df = 1 N.S

Dry/Fresh Weight of Leaf
(Median = 0.201)

	Tracks	Slopes	Total
≥ Median	8	5	13
< Median	8	5	13
	16	10	26

$\chi^2 = 1.385$ df = 1 N.S

Angle of Growth of Scape
(Median = 8.0 stems)

	Tracks	Slopes	Total
≥ Median	9	3	12
< Median	4	8	12
Total	13	11	24

χ^2 = 4.196 df = 1 *

For this characteristic attention focused on the number of Plantago stems on the track or slopes which were found in angle class one viz. with an angle of growth from $0^o - 30^o$.

In this analysis only eleven sites had Plantago growing on both slopes.

At the other two sites it was found on only one of the slopes and these two sites were thus excluded from this analysis.

Significant differences between the two environments were noted for the height of the scapes, the length of leaf, the dry weight of the scape, the dry weight of the leaf and the node of growth of the leaf.

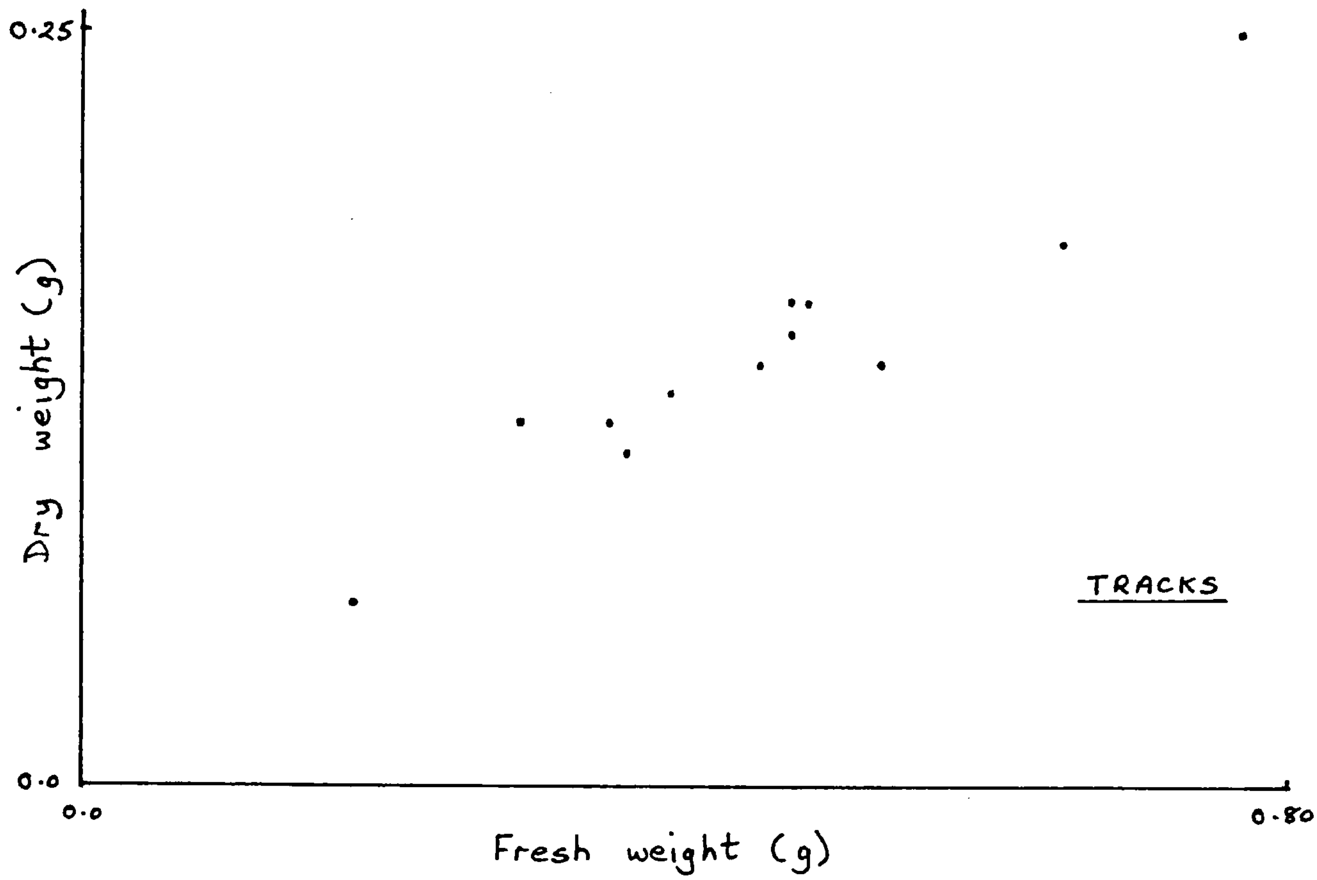
Thus individuals of Plantago lanceolata found growing on the embankment or cutting slopes were taller, heavier and had leaves that were not appressed. This suggests that there are significant phenotypic differences between track and slope individuals which is likely to reflect differences in soil depth, the water retention capacity of the soils and the degree of disturbance to which the two environments are subject. Nowhere was trampling severe on the slopes and the slopes have a more mesic substrate and both factors would be important in explaining the variation in the plant characteristics that were noted.

Differences in loss of weight of both scape and leaf on being dried were not found to be significant and the two populations of Plantago thus exhibited similar weight loss. This would suggest that the track individuals are more likely to suffer from water stress than the slope individuals since drainage would be more rapid on the track

(also surrounding vegetation)

substrate which will also have a thinner soil. The greater stress experienced by the track individuals would also be influential in determining their size and weight which has been found to be significantly less than slope individuals.

The data relating dry and fresh weights of the mean of the individuals sampled at each site was graphed and is illustrated below (Figs. 12 and 13).



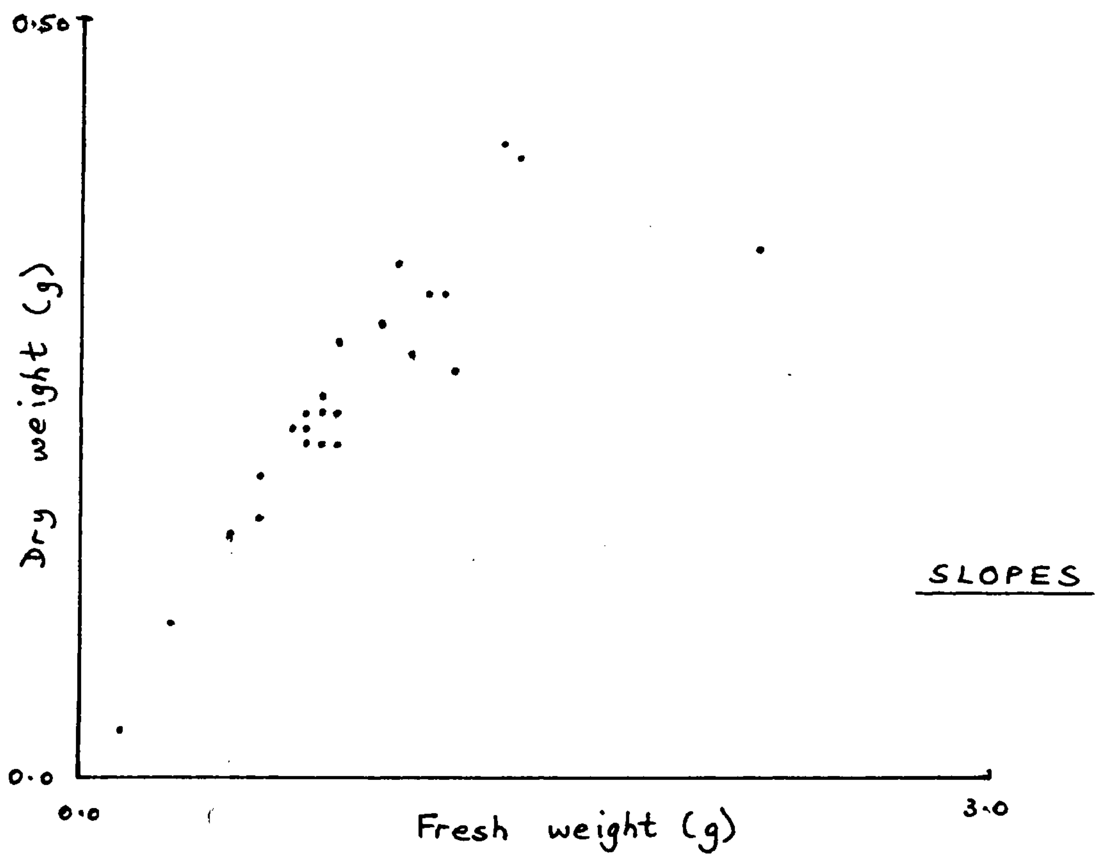
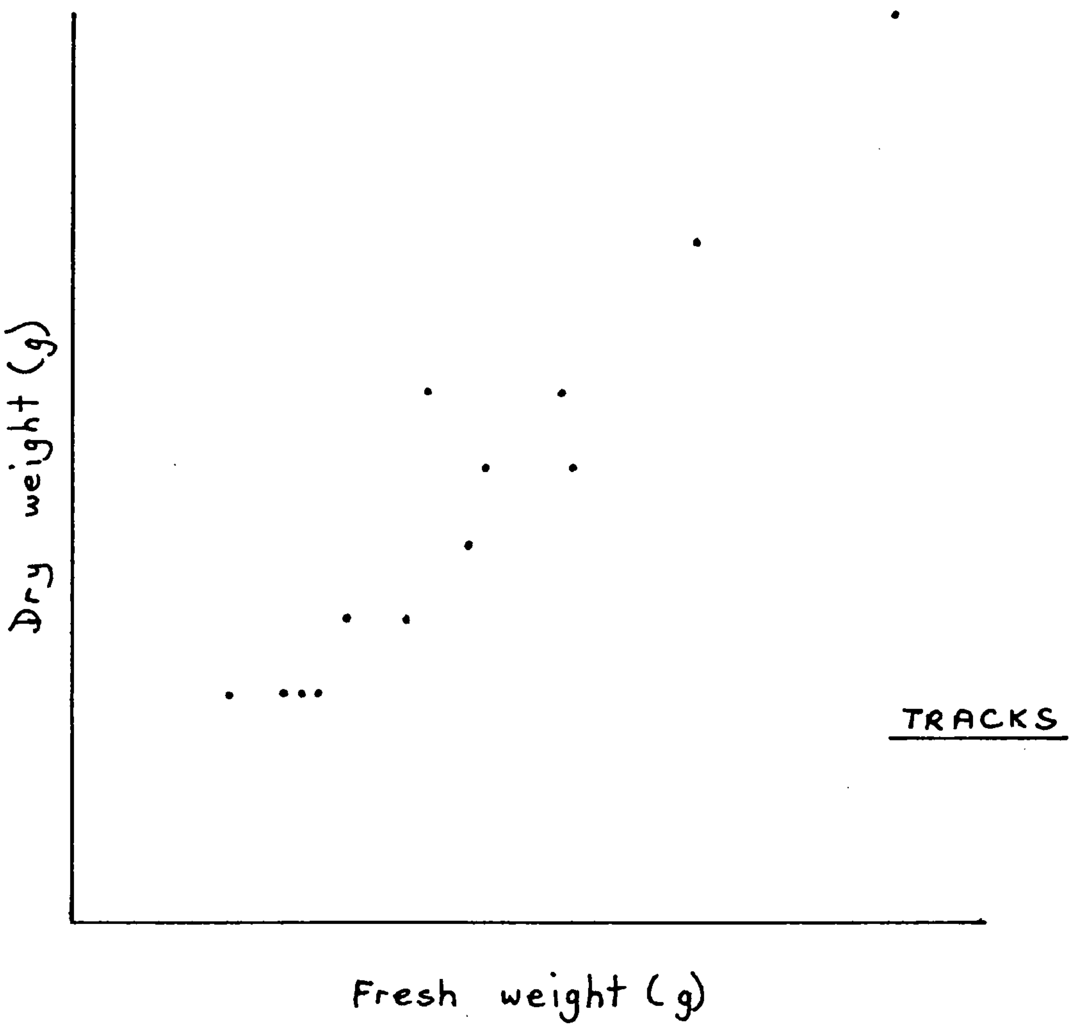


Fig. 12 Relationship between fresh and dry weight of Plantago lanceolata scapes on the tracks and slopes at the disused railway line sites.



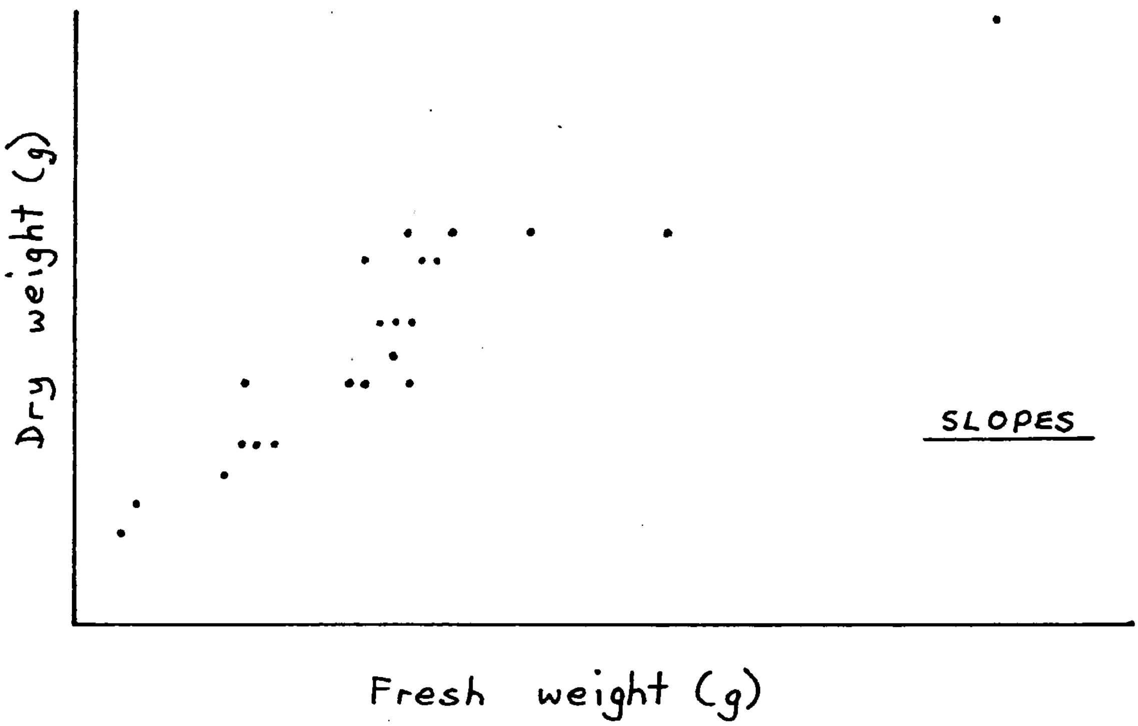


Fig. 13. Relationship between fresh and dry weight of *Plantago lanceolata* leaves on the tracks and slopes at the disused line sites.

Note was also made of the number of scapes per plant and the number of leaves per plant for track and slope sites. The data reveals that the tracks have a greater number of scapes and leaves per plant. There was, however, insufficient data to assess if these differences were significant and represent different strategies adopted by the individuals in the two environments in response to the severity of the stress, disturbance or competition with other species. Though track individuals are smaller and lighter than slope individuals, by producing a greater number of scapes and leaves reproductive success may be assured. On the embankments Plantago individuals are in greater competition with more competitive species e.g. Arrhenatherum elatius, Chamaenerion angustifolium, and taller and hence fewer, scapes and leaves would be produced.

b) Soil Characteristics

Study was also made of the influence of pH, organic content and the phosphorus content of the track soils on the performance of Plantago lancerolata viz. on the height and weight of the scapes and leaves. The data is tabulated below. The Fisher Exact Probability Test was used to test the hypothesis of independence.

Scape height	pH		Total
	$\geq$Mdn	<Mdn	
$\geq$Mdn	4	3	7
<Mdn	4	2	6
Total	8	5	13

Mdn_{pH} = 7.3
Mdn_{height} = 26.2 cm

$p = 0.408$

Leaf Length	pH ≥ Mdn	pH < Mdn	Total
≥ Mdn	4	3	7
< Mdn	4	2	6
Total	8	5	13

Mdn_{pH} = 7.3

Mdn_{length} = 10.5 cm

p = 0.408

Weight of scape	pH ≥ Mdn	pH < Mdn	Total
≥ Mdn	5	2	7
< Mdn	3	3	6
Total	8	5	13

Mdn_{pH} = 7.3

Mdn_{weight} = 0.14g

p = 0.163

Leaf Weight	pH ≥ Mdn	pH < Mdn	Total
≥ Mdn	5	2	7
< Mdn	3	3	6
Total	8	5	13

Mdn_{pH} = 7.3

Mdn_{weight} = 0.05g

p = 0.163

Scape height	Organic content ≥ Mdn	Organic content < Mdn	Total
≥ Mdn	4	3	7
< Mdn	3	3	6
Total	7	6	13

Mdn_{org} = 24%

Mdn_{height} = 26.2 cm

p = 0.408

Leaf length	Organic content ≥ Mdn	Organic content < Mdn	Total
≥ Mdn	4	3	7
< Mdn	3	3	6
Total	7	6	13

$Mdn_{organic}$ = 24%

Mdn_{length} = 10.5cm

p = 0.408

Weight of scape	Organic content		Total
	≥ Mdn	< Mdn	
≥ Mdn	4	3	7
< Mdn	3	3	6
Total	7	6	13

$Mdn_{organic} = 24\%$

$Mdn_{weight} = 0.14g$

$p = 0.408$

Weight of leaf	Organic content		Total
	≥ Mdn	< Mdn	
≥ Mdn	4	3	7
< Mdn	3	3	6
Total	7	6	13

$Mdn_{organic} = 24\%$

$Mdn_{weight} = 0.05g$

$p = 0.408$

Scape length	Phosphorus content		Total
	≥ Mdn	< Mdn	
≥ Mdn	4	3	7
< Mdn	3	3	6
Total	7	6	13

$Mdn_{phos} = 0.031$ mg/g

$Mdn_{length} = 26.2$ cm

$p = 0.408$

Leaf length	Phosphorus content		Total
	≥ Mdn	< Mdn	
≥ Mdn	4	3	7
< Mdn	3	3	6
Total	7	6	13

$Mdn_{phos} = 0.031$ mg/g

$Mdn_{length} = 10.5$ cm

$p = 0.408$

Weight of Scape	Phosphorus content		Total
	≥ Mdn	< Mdn	
≥ Mdn	4	3	7
< Mdn	3	3	6
Total	7	6	13

$Mdn_{phos} = 0.031$ mg/g

$Mdn_{weight} = 0.14g$

$p = 0.408$

Weight of leaf	Phosphorus content ≥ Mdn	< Mdn	Total
≥ Mdn	4	3	7
< Mdn	3	3	6
Total	7	6	13

Mdn_{phos} = 0.031 mg/g

Mdn_{weight} = 0.05g

$p = 0.408$

The probability levels all indicate that there was no significant difference in the performance of Plantago for the plant characteristics noted. Its presence and degree of cover indicate that Plantago lanceolata seems to be well suited to the disused railway track environment and is able to tolerate and successfully colonise substrates showing a range of pH (8.3 - 5.6), organic content (54 - 13%)and phosphorus content (0.008 - 0.177 mg/g dry weight).

ii) Dactylis glomerata

The basic data relating to Dactylis glomerata is summarised in the Appendix (Table 6).

a) Plant Characteritics

Analysis was undertaken to establish if the individuals sampled on either of the two cutting or embankment slopes were significantly different. The data is tabulated below with the information again dichotomized on the basis of the median.

Length of flowering stem

	West/ South	East/ North	Total
≥ Mdn	7	5	12
< Mdn	5	7	12
Total	12	12	24

(Mdn = 78.3 cm)

$\chi^2 = 0.667$ df = 1 N.S

Dry weight of Flowering Stem

	W/S	E/N	Total
> Mdn	7	5	12
< Mdn	5	7	12
Total	12	12	24

(Mdn = 1.25 g)

$\chi^2 = 0.667$ df = 1 N.s

Dry/Fresh Weight of Flowering Stem

	W/S	E/N	Total
> Mdn	8	4	12
< Mdn	4	8	12
Total	12	12	24

(Mdn = 0.292)

$\chi^2 = 2.667$ df = 1 N.S

None of the observed differences proved to be significant and thus the Dactylis individuals sampled on the slopes did appear to come from the same population. Thus aspect does not significantly influence the characteristics of Dactylis glomerata that were observed in this study.

Analysis was then undertaken to assess if the homogeneity that existed between the embankment or cutting slopes also existed between the slopes and the tracks. The data is tabulated below:

Length of Flowering Stem

	Tracks	Slopes	Total
> Mdn	0	12	12
< Mdn	12	0	12
Total	12	12	24

$\chi^2 = 24.00$ df = 1 ***

(Mdn = 61.6 cm)

Dryweight of Flowering Stem

	Tracks	Slopes	Total
> Mdn	1	11	12
< Mdn	11	1	12
Total	12	12	24

(Mdn = 0.83g)

$\chi^2 = 16.667$ df = 1 ***

Dry/Fresh weight of Flowering Stem

	Tracks	Slopes	Total
≥Mdn	11	1	12
< Mdn	1	11	12
Total	12	12	24

(Mdn = 0.318)

χ^2 = 16.667 df = 1 ***

Mode of Growth of Flowering Stem

	Tracks	Slopes	Total
≥Mdn	2	10	12
< Mdn	10	2	12
Total	12	12	24

Mdn = 16.5 stems in angle class one

χ^2 = 10.667 df = 1 **

For each of the characteristics measured viz. length of flowering stem, the dry weight of the stem, the dry/fresh weight loss and the angle of growth of the flowering stem, significant differences were found. The embankment individuals were taller and heavier, lost a greater amount of water when dried and had flowering stems with a vertical mode of growth, rather than being appressed like the track individuals. These differences would suggest that there is phenotypic variation between the track and slope individuals which is likely to indicate differences in substrate characteristics and disturbance through grazing or, more likely, trampling. Greater soil depth and water retention would be likely to be found on the slopes and these would be influential factors in explaining why individuals on the embankment were taller and heavier and, because the slopes were not trampled or grazed, had a vertical mode of growth. The greater soil depth and retentivity would also explain why water loss by the embankment individuals was greater since the slope is a less stressed environment. Track individuals, being on a substrate that would drain more rapidly than slopes and would experience higher temperatures, are in an environment with higher stress with greater water losses through drainage and evaporation. Ashenden et al (1975) noted that the major factors limiting the growth of Dactylis glomerata on sand dunes are the water holding capacity of the soil and the soil resistance to surface evaporation. Also humus additions to the soil would significantly increase the water holding capacity of the soil. Since humus levels on tracks will be less than on the embankments the water retention capacity of track soils must be lower. Hence survival would require an ability to tolerate lower moisture levels and hence losses on drying will be lower. The data relating to dry and fresh weights on both tracks and embankments was graphed and is illustrated in Fig.14.

Note was also made of the number of flowering stems of Dactylis glomerata per tussock on the tracks and slopes. Fewer flowering stems were found on the tracks and it may be that the more xeric nature of the substrate and the greater trampling pressure would be influential in this regard.

b) Soil Characteristics

An investigation was also made into the influence of certain track soil characteristics and their influence on the performance of Dactylis track individuals viz. the height and weight of the flowering stems. The soil characteristics under study were pH, organic content and phosphorus content and the relevant data is tabulated overleaf. The data was dichotomized on the basis of the median and the Fisher Exact Probability Test was used to test the hypothesis of independence in each case.

Relevant tables follow......

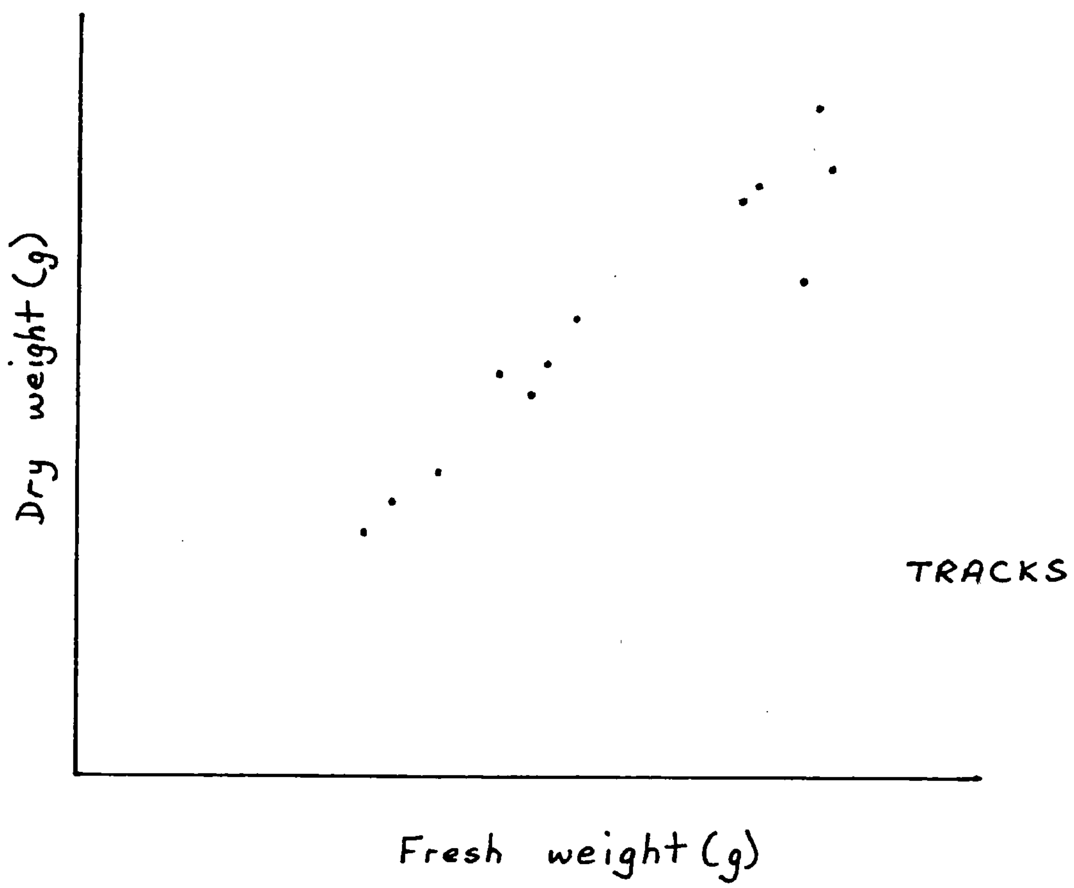


Fig. 14 Relationship between fresh and dry weight of Dactylis glomerata stems on the tracks and slopes at the disused line sites.

Height of Stem	pH ≥ Mdn	< Mdn	Total
≥ Mdn	3	3	6
< Mdn	3	3	6
Total	6	6	12

Mdn_{pH} = 7.35

Mdn_{height} = 46.65 cm

p = 0.433 N.S

Weight of Stem	pH ≥ Mdn	< Mdn	Total
≥ Mdn	3	3	6
< Mdn	3	3	6
Total	6	6	12

Mdn_{pH} = 7.35

Mdn_{weight} = 0.535g

p = 0.433 N.S

Height of stem	Organic content ≥ Mdn	< Mdn	Total
≥ Mdn	3	3	6
< Mdn	3	3	6
Total	6	6	12

$Mdn_{organic}$ = 25.0%

Mdn_{height} = 46.65 cm

p = 0.433 N.S

Weight of Stem	Organic content ≥ Mdn	< Mdn	Total
≥ Mdn	2	4	6
< Mdn	4	2	6
Total	6	6	12

$Mdn_{organic}$ = 25.0%

Mdn_{weight} = 0.535g

p = 0.244 N.S

Height of Stem	Phosphorus content ≥ Mdn	< Mdn	Total
≥ Mdn	2	4	6
< Mdn	4	2	6
Total	6	6	12

$Mdn_{phos.}$ = 0.026mg/g dry wt.

Mdn_{height} = 46.65 cm.

p = 0.244 N.S

Weight of Stem	Phosphorus Content		
	$\geq$ Mdn	$<$ Mdn	Total
$\geq$ Mdn	4	2	6
$<$ Mdn	2	4	6
Total	6	6	12

Mdn_{phos} = 0.026 mg/g

Mdn_{weight} = 0.535g

$p = 0.244$ N.S

No significant differences were found in the performance of individuals of *Dactylis glomerata* and the track soil characteristics measured. *Dactylis glomerata* thus seems well suited to the range of pH (8.3 - 5.6), organic content (13 - 54%) and phosphorus content (0.008 - 0.225 mg/g dry wt) found in the soils of the disused railway tracks that were studied.

Chapter 6

Succession Along Disused Railway Lines

The disused railway track was also studied with a view to examining changes in succession that would occur along the lines. This was attempted since the environments appeared to be relatively homogeneous with similar general characteristics and because the date since closure of the track and hence the time for successional development, was known (Cook and Hoole 1975, Whittle 1971 and personal communication with the Estate Surveyor and Manager of the North Eastern Region of British Rail.

In view of the limited time available it was decided to examine two aspects of succession viz. the variation in the number of species and the percentage cover of the tracks. In both cases expectation would be that the number of species and the percentage cover would increase over time since closure of the track. When correlation coefficients were determined for time since closure and the number of species and the percentage cover, they proved not to be significant (for the number of species $r = 0.1210$ and for the percentage cover $r = 0.2363$).

Thus the disused railway track environment appears to be a rather unsuitable environment within which to examine successional changes. The basic reason for this lies in the heterogeneity of tracks studied. Note has already been made of the wide range of pH, phosphorus content and organic content found at the sites. There was also variation in other respects, though no direct measurements were made in this study. The degree of disturbance to which the tracks had been subject varied.

Some had been subject to occasional trampling whilst other sites e.g. site S, had been completely undisturbed. At one site, site M, sheep had direct access and at site O two sheep were observed grazing on the line having gained access through a broken fence. Other aspects of disturbance might not be constant viz. the frequency and efficacy of the application of weedkiller on the track to restrict plant growth. Further, the presence of the track ballast is also likely to be influential in determining the success of colonising species. The nature of the ballast is such that the substrate would experience rapid drainage, large thermal fluctuations, have a thin soil and would generally be a low nutrient environment. Hence, for plants to become successfully established they would need to be able to adapt to the physico-chemical characteristics of the track.

Also the time period under study (the tracks, with one exception, having an age since closure of less than forty years) is such that successional developments could not be fully observed. Thus for a glacial moraine in Alaska, which has a rather similar substrate being a loose matrix of stones and having a thin soil with a high mineral content, Lawrence (1958) notes that succession would take a period of about two hundred and fifty years. Further, shrub and tree species were seldom found on the tracks, the exception being site L and with $>$ 30% of the total track cover being represented by Ulex europaeus. In fact the other sites with the greatest cover of tree species were sites A and S where the rails and sleepers were still in position. A characteristic of both sites was that these tree species were always found in the lee of the rails and may have escaped grazing pressure there.

Thus by virtue of their heterogeneity the disused railway tracks are environments which appear rather unsuitable for an examination of succession. There are a number of unknown variables operating which produce a very complex environment e.g. the history of each section of track is different, as are the building materials, the residual effects of weedkiller are not known, the influence of introduced species was not studied, the effect of firing the embankments is not adequately described etc., Since the starting points of the tracks are so different this heterogeneity blurs any change one might wish to ascribe to succession.

Chapter 7

Discussion

The ordination method employed in this study followed that outlined by Bray and Curtis (1957), with the exception that the interstand distances were calculated from (100 - C) rather than (C_{max} - C) after Bannister (1968) had shown that (100 - C) gives an ordination that is no less efficient. Though Austin and Orloci (1966) had shown that the interstand distance outlined by the Bray and Curtis method was not a Euclidean distance the method devised by Bray and Curtis was adhered to in this study, though there will inevitably be some loss in the efficiency of the ordination as a result. The purpose of the ordination was to describe the "spatial" arrangement of the disused railway track sites. Ecological data could then be superimposed such that the observed vegetation could be related to habitat factors.

The pattern of the sites described in the ordination was found to be correlated with the pH of the track and the number of species found on the tracks, the latter being some function of the former. The pH of the track soil will be directly influenced by the nature of the substrate and the geology of the area. It is shown that the ordination produces an arrangement of sites which reflects the basic geology of the study area of County Durham, and specifically if sites were or were not on limestone. The influence of pH on vegetational composition can be seen if reference is made to site S on the ordination. Through the unique characteristics of the site S is clearly different from other sites, even other sites on limestone. It is likely that the cause of the high pH value is limestone dust as fallout from the adjacent cement works. It would be possible in the field to monitor the fallout (Brandt and Rhoades 1973) and thus assess the impact of the dust, both physically and its influence on track pH. The fact that none of the other habitat factors or the time since closure of the lines were correlated with the ordination suggests that in the early years of succession (of the twenty-eight sites, twenty had dates since closure of less than twenty years) the vegetation composition of disused railway tracks shows a prime response to pH.

One of the major reasons for the selection of the disused railway track environment as an area of study was that it would be relatively uniform but this did not prove to be so, with wide variations in soil characteristics (pH, phosphorus content and organic content) and general characteristics (aspect, geology, the type, height and angle of slopes etc.,) As a result of this heterogeneity the usefulness of the ordination is reduced since the vegetational composition at the sites could not be linked more closely to habitat factors. Some reduction in heterogeneity could have been achieved by selecting sites on similar geology. Also, at each site a greater number of sections of track should have been sampled since the length sampled in this study would represent only a very small fraction of the total length of track of a particular age. A greater number of sampled sections along a specific length of track may have revealed that variation within sites along the line could have been as great, or greater, as that between tracks in different areas of Durham which would suggest that the number of quadrats would need to be increased. Messenger (1968) notes that there are often startling variations in the vegetation along even short stretches of apparently uniform embankments, which emphasises the importance of sample size.

pH values of soil samples taken on both tracks and embankments reveated a range (4.9 - 8.8) greater than that found by Niemi (5.6 - 8.8) (1969) on Finnish lines, though the tracks he studied were still in use. Field experiments could be undertaken to assess if plants that were successful at a site, measured by their percentage cover or vigour of growth, would respond in a similar manner in soils of different pH. Thus transplant experiments could be initiated or lime added to acid or neutral track soils to assess plant response to changing conditions, with plant performance monitored. pH was also related to time since closure of the track, similar trends being noted elsewhere, albeit the substrates were not exactly the same Lawrence (1958) and Olson (1958). pH was also related to the organic content of the track soils. The organic content of the disused track soils was also found to be positively correlated with time since closure of the line. Though other studies did not reveal such a relationship on track soils, this relationship has been found in other environments e.g. grassland communities (Wells et al 1976). The phosphorus content of the track soils were generally low showing that they are stressed environments. Although no measures of nitrogen content of the soils were taken it is likely that the levels are also low, suggested by the legume cover at many sites. The low nutrient status of disused track soils probably accounts for the low cover of highly competitive species like *Arrhenatherum elatius*, *Chamaenerion angustifolium* and *Urtica dioica*. Rorison (1968) showed how the levels of phosphorus in soil was influential in the development and growth of *Urtica dioica*, growth increasingly rapidly with increasing phosphorus levels.

Analysis of the track and the embankment or cutting slopes showed that the vegetation on the slopes were more similar than between the tracks and the slopes. Though there was no significant difference in the number of species on the tracks and embankment or cutting slopes there were significant differences in the percentage cover, with percentages higher on the slopes. Further, highly competitive species viz. Arrhenatherum elatius, Chamaenerion angustifolium and Urtica dioica were only found to any significant degree on the slopes, which indicates that the embankments and cuttings are less stressed environments than the tracks. The absence of Arrhenatherum elatius from the tracks could be due to grazing (Wells et al 1976) with Festuca rubra becoming the dominant grass on tracks. Experiments simulating grazing (Mahmoud and Grime 1976) have shown that Arrhenatherum elatius though dominant in the absence of clipping loses its dominance if clipped because it is not tolerant of disturbance. There was some evidence of grazing on the disused tracks though trampling was probably a disturbance factor of greater significance.

In this study, aspect was not found to be significant in explaining vegetational differences. This is in direct contrast to Suominen (1969) who found differences in vegetation between the different exposures of the slopes due to differences in thermal and moisture conditions. No micro-climatic measures were made in this study and it may be that the frequency of disturbance may be influential in determining the similarity of vegetation on the slopes at the sampled sites. In Britain the vegetation on the slopes may have been maintained in a more stable ecological balance by burning and cutting which perhaps takes place more frequently than in Finland. It is likely that this may be so since Niemi (1969) records some plant cover on Finnish tracks which still carry traffic but observation on currently used British tracks reveals little, if any, vegetation on the track bed suggesting more frequent use of herbicides. Suominen (1969) also notes differences in vegetation which exist between the upper and lower sections of embankment or cutting slopes. This was not studied here as the number of quadrat placings on each slope was insufficient, in view of the limited time available, to enable this analysis to be undertaken. No significant differences were found between the phosphorus content of the track and embankment or cutting soils though there were significant differences in soil pH, which are largely a response to time.

When two typical track species were studied, the pattern of distribution of *Plantago lanceolata* and *Dactylis glomerata* was found to be an aggregated one for both species which accords to the pattern found by Sagar and Harper (1964) and Beddows (1959). For both species track individuals were smaller and lighter and this is likely to result from the track being a more nutrient poor environment, having a thinner soil and being a less mesic environment. It is likely that on closure of the line drought is an important ecological factor limiting species to those with roots deep enough to reach moister soil at lower levels. As organic matter builds up over time the water retention capacity of the upper soil levels increases and drought ceases to be such a significant factor. There will thus be a shift in the relative importance of the ecological factors operating on the lines which results in changes in species, such that at any moment in time species exist which are able to achieve a state of equilibrium with the current and immediately previous ecological factors.

Thus in the initial stages of succession only species that can accommodate the stress of the tracks will be found, the stresses being the low nutrient status and the low moisture status of the substrate. Many typical ruderals and legumes were found to confirm this. Factors controlling the course of succession include seed availability, the nutrient status and moisture conditions of the substrate when the seeds are dispersed and the subsequent management of the succession (Wells et at 1976). No data was collected on seed dispersal or the nature of the seed bank of tracks,the latter being attempted but the results were insufficient to enable any conclusions to be made. However, incidental data on management, by direct observation, showed that trampling and to a lesser extent grazing, were features of disturbance found to be operating along many of the tracks. It has been shown that nutrient levels of track soils are low and that tracks are xeric sites (Suominen 1969) which explains why the tracks under study revealed that the rate of succession is slow since there was only minimal cover of competitive species, characteristic of later stages in succession (Grime 1976). Greater cover of competitive and tree species were found on the embankments though the differences in time for development of vegetation are obvious. Of the data collected on aspects of succession in this study viz. percentage cover and the number of species, neither proved to be significantly correlated with time. Auclair and Goff (1966) note that the mesic nature of the site is a determining factor in relating succession to the number of species found. Thus on a mesic site they studied, the number of species increased, peaked and then declined, whilst at a xeric site the diversity gradually increased over time. It may be that for disused tracks the low nutrient status of the soil blurs this relationship.

This study, however, shows that it is difficult to study successional change on disused railway tracks in view of their heterogeneity. Not only do the nature and characteristics of the substrate vary so greatly but the meso and micro-climatic features are also variable (Niemi 1969). Further the number of alien species is well documented (Niemi 1969) and the influence of the draught caused by passing trains when the track was in use may be important, particularly for species not uniformly distributed along the line (Niemi 1969). The embankment and cutting slopes would also be susceptible to the introduction of species from similar sources, though the influence of the adjacent land use appears to be of importance (Suominen 1969). In Finland this may well be the case but in the United Kingdom, where intensive agriculture is more dominant, the nature of the adjacent land use is probably less important as a source of railway species. Currently work is being undertaken by the Institute of Terrestrial Ecology into the flora of embankment and cutting slopes along currently used lines in the U.K. and the results of this study may enable this influence to be assessed. Whatever the source of introduction, however, the success of a species in establishing itself will depend upon the habitat.

ACKNOWLEDGEMENTS

I would like to express my thanks to the Estate Manager of the North East region of British Rail Property Board for supplying data relating to dates of closure of the lines and to the Traffic Manager of British Rail, Durham for permission to visit the site at Coxhoe (site A).

Thanks are also due to landowners who gave permission to visit disused tracks on their properties.

TABLE 1 Site locations, opening dates and years since closure of disused railway tracks (grid references for metric 1 : 50,000 unless otherwise stated).

Site			Opening date of line.	Years of operation.	Years since closure of line.
Code	Location	O.S.Grid Ref. & Map Sheet.			
A	Coxhoe	309349 Sheet 93	1834	144	Still in use
Ba	Thrislington	315328 Sheet 93	Unknown	–	25
Bb	Thrislington	310329 Sheet 93	Unknown	–	25
C	Trimdon	354349 Sheet 93	1839	124	15
D	Hurworth	411340 Sheet 93	1878	91	9
E	Chilton	308298 Sheet 93	1836	125	17
F	Stillington	333243 Sheet 93	1833	130	15
G	Byers Green	227326 Sheet 93	1837	129	12
H	Byers Green	228331 Sheet 93	1837	12	
I	Brusselton	213256 Sheet 84 1" series	1825	33	120
J	Roddymoor	161369 Sheet 93	1842	123	13
K	Sunniside	134386 Sheet 84 1" series	1845	107	26
L	Wolsingham N.Moor	099406 Sheet 84 1" series	1845	94	39
M	Crawleyside	997435 Sheet 87	1834	134	10
Na	Copley	080232 Sheet 84 1" series	1863	99	16
Nb	Copley Viaduct	070225 Sheet 84 1" series	1863	99	16
O	Little Newsham	124180 Sheet 84 1" series	1856	109	13
P	Cotherstone	996200 Sheet 84 1" series	1868	97	13
Q	Boldron	022148 Sheet 84, 1" series	1861	101	16
R	Westgate	905378 Sheet 84 1" series	1895	73	10
S	Eastgate	951385 Sheet 84 1" series	1895	73	10

TABLE 1 (continued

Site			Opening date of line.	Years of Operation.	Years since closure of line.
Code	Location	O.S.Grid Ref. & Map Sheet.			
T	Healey-field	078477 Sheet 88	1834	130	14
U	Brance-peth	217377 Sheet 93	1856	96	26
V	Ushaw Moor	208428 Sheet 88	1858	94	26
W	Bearpark	249427 Sheet 88	1862	104	12
X	Lanchester	185459 Sheet 88	1862	104	12
Y	Grange Villa	230524 Sheet 88	1834	112	32
Z	Pittington	331460 Sheet 88	1836	124	18

TABLE 2 Number of Plant Species and Total Percentage Cover at Each Track Site.

Track Site	Number of Species	Total Cover (%)
A	9	10
Ba	30	72
Bb	42	84
C	23	20
D	21	18
E	28	70
F	22	56
G	29	70
H	22	50
I	21	42
J	27	80
K	21	62
L	26	99
M	8	78
Na	27	79
Nb	22	38
O	22	80
P	19	95
Q	20	99
R	30	87
S	28	34
T	12	76
U	17	95
V	17	37
W	18	47
X	13	67
Y	14	36
Z	31	96

TABLE 4 Number of Plant Species and Total Percentage Cover on Each Slope at Each Site.

Site	Number of Species				Total Cover %			
A	s	10	n	24	s	56	n	85
Ba	s	25	n	30	s	99	n	85
Bb	s	13	n	11	s	98	n	99
C	s	27	n	25	s	78	n	92
D	w	24	e	15	w	77	e	86
E	s	26	n	22	s	83	n	100
F	s	28	n	18	s	97	n	100
G	w	22	e	18	w	70	e	100
H	w	18	e	21	w	97	e	90
I	s	14	n	12	s	98	n	81
J	w	23	e	20	w	87	e	97
K	s	17	n	10	s	85	n	52
L	w	22	e	19	w	100	e	100
M	w	9	e	11	w	93	e	59
Na	s	23	n	23	s	70	n	97
Nb								
O	s	19	n	19	s	100	n	100
P	w	20	e	19	w	93	e	82
Q	w	32	e	12	w	84	e	100
R	s	16	n	11	s	96	n	82
S	s	17	n	16	s	42	n	98
T	s	12	n	15	s	95	n	100
U	w	25	e	25	w	94	e	100
V	s	19	n	25	s	70	n	92
W	w	24	e	24	w	81	e	100
X	s	25	n	16	s	99	n	100
Y	s	17	n	15	s	87	n	98
Z	w	19	e	13	w	96	e	100

(N,S,E,W - directions the two slopes were facing)

TABLE 8 Site values of pH, phosphorus and organic content for track soils and embankment or cutting soils.

Site	pH			Phosphorus content			Organic content of the Track Soils. %
	Track	Embankment or cutting & aspect		Track	Embankment or cutting & aspect		
A	8.5	8.0 S	8.2N	.005	.013N	.014S	26
Ba	8.3	8.3N	8.4S	.014	.009S	.012N	13
Bb	8.3	8.4N	8.3S	.004	.026S	.011N	14
C	8.3	8.1S	8.3N	.020	.049S	.047N	35
D	8.3	8.3E	8.0W	.018	.004W	.008E	24
E	8.0	7.6N	7.6S	.021	.004S	.021N	47
F	8.0	7.8N	7.8S	.008	.013S	.022N	31
G	8.1	8.1E	7.6W	.030	.024W	.041E	19
H	8.3	6.9E	7.1W	.064	.036W	.027E	19
I	6.4	6.9N	5.6S	.018	.039S	.028N	31
J	7.0	6.2E	7.5W	.011	.029W	.034E	24
K	6.4	5.6N	5.4S	.003	.021S	.008N	34
L	7.1	6.1E	5.7W	.014	.009W	.091E	28
M	6.6	6.9E	6.5W	.259	.008W	.006E	20
Na	7.4	6.4N	7.0S	.075	.016S	.022N	22
Nb	8.1	-	-	.005	-	-	20
O	7.5	6.7N	6.2S	.016	.041S	.007N	27
P	7.3	6.3E	6.5W	.124	.026W	.025E	19
Q	7.3	7.9W	7.0E	.031	.023E	.016W	13
R	7.1	6.7N	7.4S	.126	.036S	.044N	15
S	8.8	8.8N	8.6S	.297	.044S	.018N	18
T	7.5	7.0N	6.2S	.163	.053S	.023N	13
U	6.0	6.0E	6.2W	.228	.046W	.087E	34
V	6.9	6.7W	6.0E	.177	.029S	.064N	26
W	7.5	5.5E	6.0W	.058	.037W	.026E	16
X	7.8	7.2N	7.5S	.424	.267S	.204N	37
Y	5.6	4.9N	5.2S	.225	.076S	.028N	54
Z	5.6	5.9W	6.1E	.142	.260E	.191W	41

TABLE 9 Track characteristics and adjacent land use at each site.

Site	Track width (m)	Alignment of the track (^{o})	Gradient of the track (^{o})	Adjacent Land Use
A	4.1	50	0^{o} 50'	Barley, Pasture
Ba	3.8	55	0^{o} 55'	Scrub, Scrub
Bb	3.6	90	1^{o} 30'	Barley, Barley
C	7.8	85	1^{o} 25'	Scrub, Pasture
D	9.1	15	0^{o} 15'	Reservoir, Reservoir
E	3.3	95	1^{o} 35'	Barley, Pasture
F	6.4	120	2^{o} 00'	Pasture, Wheat
G	3.9	5	0^{o} 5'	Pasture, Pasture
H	4.5	5	0^{o} 5'	Pasture, Barley
I	3.1	115	1^{o} 55'	Road, Pasture
J	7.2	145	2^{o} 25'	Pasture, Road
K	4.1	100	1^{o} 40'	Pasture, Road
L	4.2	170	2^{o} 50'	Pasture, Pasture
M	3.8	145	2^{o} 25'	Rough grazing, Rough grazing
Na	7.9	80	1^{o} 20'	Pasture, Pasture
Nb	7.3	175	2^{o} 55'	Viaduct
O	3.8	105	1^{o} 45'	Pasture, Pasture
P	4.1	155	2^{o} 35'	Pasture, Pasture
Q	7.4	40	0^{o} 40'	Road, Pasture
R	3.8	90	1^{o} 30'	R. Wear, Scrub
S	4.0	65	1^{o} 5'	Cement Works, Wasteland
T	4.9	105	1^{o} 45'	Pasture, Road
U	7.8	5	0^{o} 5'	Barley, Barley
V	3.2	75	1^{o} 15'	Road, Pasture
W	9.6	140	2^{o} 20'	Pasture, Barley
X	9.4	125	2^{o} 5'	Barley, Pasture
Y	3.6	105	1^{o} 45'	Pasture, Pasture
Z	8.7	45	45'	Barley, Pasture

TABLE 10 Slope characteristics at each site

Site	Slope type E Embankment C Cutting L Level	Slope Characteristics					
		Aspect	Length (m)	Angle(^{o})	Aspect	Length(m)	Angle(^{o})
A	E	S	14.50	38	N	13.60	39
Ba	E	S	6.60	31	N	9.50	15
Bb	C	S	2.10	31	N	2.70	29
C	L	S	–	–	N	–	–
D	E	W	15.20	32	E	17.50	33
E	E	S	12.50	35	N	15.30	25
F	C	S	12.60	30	N	12.20	31
G	E	W	21.50	31	E	22.10	30
H	C	W	10.30	35	E	10.00	34
I	E	S	7.30	23	N	4.60	30
J	C	W	5.30	19	E	5.90	21
K	C	S	11.20	29	N	6.80	21
L	L	W	–	–	E	–	–
M	E	W	5.70	31	E	9.90	33
Na	C	S	5.80	28	N	7.80	29
Nb		Viaduct					
O	C	S	6.40	27	N	18.70	21
P	C	W	2.80	23	E	2.20	19
Q	C	S	6.80	25	N	8.70	22
R	E	S	6.50	18	N	5.10	12
S	L	S	–	–	N	–	–
T	E	S	7.60	19	N	10.20	31
U	C	W	18.50	17	E	12.90	25
V	C	S	10.70	33	N	9.60	31
W	L	W	–	–	E	–	–
X	L	S	–	–	N	–	–
Y	E	S	4.50	21	N	3.40	22
Z	L	W	–	–	E	–	–

Table ●11 Matrix of similarity coefficients and interstand distances for track sites.

	A	Ba	Bb	C	D	E	F	G	H	I	J	K	L	M	Na	Nb	O	P	Q	R	S	T	U	V	W	X	Y	Z
A		15.4	15.7	12.5	6.7	5.4	19.4	26.3	12.9	13.3	5.6	0.0	5.7	0.0	0.0	0.0	19.4	0.0	0.0	15.4	16.2	0.0	7.7	7.7	14.8	0.0	0.0	10.0
Ba	84.6		38.9	34.0	31.4	41.4	38.5	47.5	38.5	39.2	24.6	39.2	35.7	10.5	45.6	26.9	38.5	28.6	28.0	36.7	34.5	33.3	34.0	38.3	41.7	23.3	40.9	36.1
Bb	84.3	61.1		36.9	38.1	42.9	40.6	47.9	46.9	41.3	40.6	34.9	38.2	8.0	46.4	43.8	43.8	42.6	35.5	47.2	40.0	29.6	44.1	33.9	43.3	21.8	32.1	60.3
C	87.5	66.0	63.1		31.8	39.2	40.0	42.3	44.4	22.7	32.0	40.9	24.5	0.0	32.0	31.1	31.1	28.6	37.2	34.0	35.3	17.1	35.0	35.0	29.3	38.9	37.8	18.5
D	93.3	68.6	61.9	68.2		49.0	41.9	48.0	55.8	38.1	50.0	28.6	42.6	13.8	37.5	46.5	37.2	45.0	43.9	43.1	40.8	30.3	36.8	42.1	41.0	23.5	40.0	46.2
E	94.6	58.6	57.1	60.8	51.0		48.0	59.6	52.0	44.9	61.8	65.3	63.0	11.1	58.2	48.0	64.0	51.1	58.3	55.2	39.3	55.0	48.9	48.9	26.1	23.3	57.1	54.2
F	80.6	61.5	59.4	60.0	58.1	52.0		58.8	59.1	41.9	40.8	41.9	45.8	13.3	49.0	45.5	59.1	32.6	47.6	42.3	40.0	47.1	51.3	46.2	55.0	28.6	50.0	34.0
G	73.7	52.5	52.1	57.7	52.0	40.4	41.2		74.5	36.0	50.0	48.0	50.9	10.8	50.0	39.2	58.8	41.7	44.9	57.6	49.1	39.0	47.8	43.5	51.1	23.8	41.9	53.3
H	87.1	61.5	53.1	55.6	44.2	48.0	40.9	25.5		41.9	53.1	51.2	54.2	13.3	57.1	36.4	60.5	48.8	57.1	53.8	44.0	47.1	56.4	56.4	60.0	28.6	50.0	49.1
I	86.7	60.8	58.7	77.3	61.9	55.1	58.1	64.0	58.1		29.2	38.1	38.3	13.8	41.7	32.6	46.5	30.0	34.1	39.2	32.7	36.4	29.2	42.1	46.2	23.5	40.0	46.2
J	94.4	75.4	59.4	68.0	50.0	38.2	59.2	50.0	46.9	70.8		33.3	56.6	11.4	55.6	49.0	53.1	52.2	72.3	56.1	36.4	51.3	68.2	50.0	53.3	30.0	48.8	55.2
K	100.0	60.8	65.1	59.1	71.4	34.7	58.1	52.0	48.8	61.9	66.7		59.6	13.8	58.3	37.2	60.5	55.0	63.4	58.8	28.6	60.6	52.6	57.9	51.3	29.4	68.6	46.1
L	94.3	64.3	61.8	75.5	57.4	37.0	54.2	48.1	45.8	61.7	43.4	40.4		11.8	49.1	29.2	62.5	48.9	52.2	50.0	37.0	47.4	46.5	46.5	45.5	20.5	50.0	56.1
M	100.0	89.5	92.0	100.0	86.2	88.9	86.7	89.2	86.7	86.2	88.6	86.2	88.2		11.4	6.7	13.3	14.8	14.3	15.8	5.6	20.0	16.0	16.0	15.4	9.5	18.2	15.4
Na	100.0	54.4	53.6	68.0	62.5	41.8	51.0	50.0	42.9	58.3	44.4	41.7	50.9	88.6		53.1	57.1	56.5	68.1	59.6	32.7	51.3	54.5	45.5	48.9	20.0	43.9	58.6
Nb	100.0	73.1	56.2	68.9	53.5	52.0	54.5	60.8	63.6	67.4	51.0	62.8	70.8	93.3	46.9		36.4	43.9	42.9	38.5	32.0	35.3	41.0	35.9	40.0	34.3	38.9	41.5
O	80.6	61.5	56.2	68.9	62.8	36.0	40.9	41.2	39.5	53.5	46.9	39.5	37.5	86.7	42.9	63.6		43.9	26.2	53.8	36.0	47.1	46.2	41.0	50.0	28.6	44.4	24.5
P	100.0	71.4	57.4	71.4	55.0	48.9	67.4	58.3	51.2	70.0	47.8	45.6	51.1	85.2	43.5	56.1	56.1		66.7	53.1	29.8	58.1	50.0	44.4	54.1	18.8	48.5	48.0
Q	100.0	72.0	64.5	62.8	56.1	41.7	52.4	55.1	42.9	65.9	27.7	30.6	47.8	85.7	31.9	57.1	73.8	33.3		30.0	12.5	56.3	59.5	48.6	57.9	30.3	58.8	43.1
R	84.6	63.3	52.8	66.0	56.9	44.8	57.7	42.4	41.2	60.8	43.9	41.2	50.0	84.2	40.4	61.5	46.2	46.9	70.0		41.4	38.1	53.3	51.1	50.0	23.3	45.5	55.7
S	83.8	65.5	60.0	64.7	59.2	60.7	60.0	50.9	56.0	67.3	73.6	71.4	63.0	96.4	67.3	68.0	64.0	70.2	87.5	58.6		15.0	40.0	26.7	30.4	14.6	19.0	33.9
T	100.0	66.7	70.4	82.9	69.7	45.0	52.9	61.0	52.9	63.6	48.7	39.4	52.6	80.0	48.7	64.7	52.9	41.9	43.7	61.9	85.0		48.3	55.2	66.7	32.0	53.3	23.3
U	92.3	66.0	55.9	65.0	63.2	51.1	48.7	52.2	43.6	70.8	31.8	47.4	53.5	84.0	45.5	59.0	53.8	50.0	40.5	44.7	60.0	51.7		58.8	51.4	33.3	51.6	45.8
V	92.3	61.7	66.1	65.0	57.9	51.1	53.8	56.5	43.6	57.9	50.0	42.1	53.5	84.0	54.5	64.1	59.0	55.6	51.4	48.9	73.3	44.8	41.2		51.4	46.7	64.5	29.2
W	85.2	58.3	56.7	70.7	59.0	73.9	45.0	48.9	40.0	53.8	46.7	48.7	54.5	84.6	51.1	60.0	50.0	45.9	42.1	50.0	59.6	33.3	48.6	48.6		32.3	50.0	40.8
X	100.0	76.7	78.2	61.1	76.5	76.7	71.4	66.2	71.4	76.5	70.0	70.6	79.5	90.5	80.0	65.7	71.4	81.2	69.7	76.7	85.4	68.0	66.7	53.3	67.7		37.0	22.7
Y	100.0	59.1	67.9	62.2	60.0	42.9	50.0	58.1	50.0	60.0	51.2	31.4	50.0	81.8	56.1	61.1	55.6	51.5	41.2	54.5	81.0	46.7	48.4	35.5	50.0	63.0		31.1
Z	90.0	63.9	39.7	81.5	53.8	45.8	66.0	46.7	50.9	53.8	44.8	53.9	43.9	84.6	41.4	58.5	75.5	52.0	56.9	44.3	66.1	76.7	54.2	70.8	59.2	77.3	68.9	

Similarity coefficients in the upper right hand part of the matrix.

TABLE 12 Similarity coefficients for the tracks and slopes at each site.

Site	Track and slopes (both).	Track and one slope.	Track and other slope.	Both Slopes.
A	40.0	36.4 N	63.2 S	52.9
Ba	60.6	54.5 S	60.0 N	69.1
Bb	43.3	29.1 S	41.5 N	50.0
C	49.1	44.0 S	50.0 N	69.2
D	56.0	53.3 W	38.9 E	51.3
E	63.4	59.3 S	60.0 N	54.2
F	37.7	36.0 S	35.0 N	60.9
G	60.7	62.7 W	38.3 E	65.0
H	54.2	62.0 W	51.2 E	71.8
I	70.3	57.1 S	54.5 N	76.9
J	52.6	52.0 W	42.6 E	60.5
K	54.5	47.4 S	38.7 N	37.0
L	76.9	70.8 W	75.6 E	73.2
M	84.2	94.1 W	84.2 E	90.0
Na	55.2	56.0 S	48.0 N	65.2
Nb	NO EMBANKMENTS - SITE ON A VIADUCT			
O	40.0	34.1 S	34.1 N	52.6
P	66.7	76.9 W	57.8 E	66.7
Q	46.4	25.0 E	50.0 W	36.4
R	40.0	43.5 S	39.0 N	51.9
S	52.8	53.3 S	45.5 N	48.5
T	12.5	16.7 S	7.4 N	51.9
U	37.5	42.9 W	38.1 E	76.0
V	32.0	33.3 S	23.8 N	50.0
W	36.7	38.1 W	38.1 E	70.8
X	47.8	52.6 S	20.7 N	39.0
Y	52.9	38.7 S	41.4 N	75.0
Z	81.5	76.0 W	54.5 E	62.5

TABLE 13 Table of significance of the deviation of the distribution of species away from a random distribution.

Site	Plantago lanceolata		Dactylis glomerata	
	x value	Significance level	x value	Significance level
D	.6093	*	.5049	N.S.
E	.6658	**	.7548	***
F	.6887	**	.8448	***
J	.9087	***	.9146	***
L	.9320	***	.7211	***
Na	.5227	N.S.	.5904	N.S.
Nb	.4066	N.S.		
O	.7980	***		
P	.6404	*		
Q	.8100	***	.8305	***
R	.7799	***	.6046	***
T			.8360	***
U	.7545	***	.6591	**
V	.6004	*	.8225	***
W	.7813	***	.6058	*
Y	.8603	***	.8416	***
Z	.6656	**	.7182	***

TABLE 14 Species found on the disused railway tracks

Achillea millefolium	e
Aegopodium podagraria	
Agropyron repens	e
Agrostis stolonifera	e
Agrostis tenuis	e
Alopecurus pratensis	e
Anthoxanthum oderatum	e
Anthriscus sylvestris	e
Anthyllis vulneraria	e
Arrhenatherum elatius	e
Bellis perennis	e
Betonica officinalis	
Betula pendula	e
Brassica rapa	
Bromus sterilis	e
Capsella bursa pastoris	e
Carduus tenuiflorus	
Carex flacca	e
Carex ovalis	
Centaurea nigra	e
Centaurea scabiosa	e
Cerastium glomeratum	e
Cerastium vulgatum	e
Chaerophyllum temulentum	
Chamaemelum nobile	
Chamaenerion angustifolium	e
Chrysanthemum leucanthemum	e
Chrysanthemum vulgare	e
Cirsium arvense	e
Cirsium vulgare	e
Crataegus monogyna	e
Crepis biennis	e
Cynosurus cristatus	e
Dactylis glomerata	e
Deschampsia Caespitosa	e
Deschampsia flexuosa	e

TABLE 14 (Continued)

Empetrum nigrum	e
Equisetum arvense	e
Euphorbia heliscopia	
Festuca ovina	e
Festuca pratensis	e
Festuca rubra	e
Frageria vesca	e
Galium aparine	e
Galium oderatum	
Galium saxatile	e
Geranium pratense	e
Helictotrichon pratense	e
Helictotrichon pubescens	e
Hieracium pilosella	e
Hieracium umbellatum	e
Hieracium vulgatum	e
Holcus lanatus	e
Hypericum humifusum	
Hypochaeris radicata	e
Juncus articulatus	
Juncus conglomeratus	e
Knautia arvensis	e
Lamium album	e
Larix decidua	
Lathyrus montanus	e
Lathyrus pratensis	e
Leontodon hispidus	e
Leontodon taraxacoides	e
Linum catharticum	e
Lolium perenne	e
Lotus corniculatus	e
Luzula campestris	e
Malva sylvestris	e
Myosotis arvenis	e
Nardus stricta	e
Pimpinella saxifraga	e
Pinus sylvestris	
Plantago lanceolata	e

TABLE 14 (Continued)

Plantago major	e
Plantago media	e
Poa angustifolia	e
Poa annua	e
Poa compressa	e
Poa pratensis	e
Poa trivialis	e
Polygonum aviculare	e
Potentilla reptans	e
Poterium sanguisorba	e
Primula veris	e
Primula vulgaris	
Prunella vulgaris	
Prunus padus	e
Ranunculus auricomus	e
Ranunculus repens	e
Reseda lutea	e
Rhinanthus minor	e
Rosa arvensis	e
Rosa canina	e
Rosa villosa	e
Rubus fruticosus	e
Rumex acetosa	e
Rumex acetosella	e
Rumex crispus	e
Rumex obtusifolius	e
Scabiosa collumbaria	
Sedum acre	
Senecio jacobaea	
Senecio squalidus	
Senecio vulgaris	e
Sesleria caerulea	e
Silene vulgaris	e
Sinapis arvensis	
Sonchus asper	e
Stellaria holostea	e

TABLE 14 (Continued)

Taraxacum officinale	e
Thymus drucei	e
Trifolium dubium	e
Trifolium pratense	e
Trifolium repens	e
Trifolium scabrum	e
Tussilago farfara	e
Ulex europaeus	e
Urtica dioica	e
Veronica chamaedrys	
Veronica persica	
Vicia cracca	
Vicia sepium	
Viola riviniana	

e : also found on embankment or cutting slopes

TABLE 15 Additional species found on embankment and cutting slopes.

Acer pseudoplatanus
Alnus glutinosa
Arabis hirsuta
Avena fatua
Betula pubescens
Calluna vulgaris
Calystegia sepium
Carex remota
Conopodium majus
Convolvulus arvensis
Digitalis purperea
Euphrasia officinalis
Galium laevipes
Geum rivale
Heracleum sphondylium
Lathyrus sylvestris
Lolium multiflorum
Petasites hybridus
Phleum pratense
Potentilla erecta
Pteridium aquilinum
Quercus robus
Rubus idaeus
Sanguisorba officinale
Sarothamnus scoparius
Sonchus oleraceous
Symphytum officinale
Teucrium scorodonia
Torilis japonica
Vaccinium myrtillus
Vicia sativa
Viola oderata

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PHOTOGRAPHS OF DISUSED RAILWAY TRACK SITES

Site A

Site Ba

Site Bb

Site C

Site D

Site E

Site F

Site G

Site H

Site I

Site J

Site K

Site L

Site M

Site Na

Site Nb

Site O

Site P

Site Q

Site R

Site S

Site T

Site U

Site V

Site W

Site X

Site Y

Site Z