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The flora and vegetation of walls in County Durham

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THE FLORA AND VEGETATION OF WALLS
IN COUNTY DURHAM

by

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A dissertation submitted as part of the requirements for the degree of Master of Science by advanced course in Ecology at the University of Durham.

Contents

Summary

A survey of the flora of walls along an east to west transect across Co.Durham was undertaken Presence and abundance of lichens, bryophytes, pteridophytes, gymnosperms and angiosperms were assessed. A selection of descriptive variables were taken for each sample. The biological data was analysed using multivariate community analysis programs. The analysis revealed the major importance of wall substrate, atmospheric pollution and water to the development of different wall communities. Other factors such as aspect, shade and method of wall construction were shown to be important for individual walls. The species found and their characteristics are discussed as are the types of community and the importance of individual factors to those communities.

Introduction

This project set out to look at the flora and vegetation of walls in County Durham. My own interest in this subject came from, (i) reading Darlington's recent book "Ecology of Walls' (1981), and (ii) my budding interest in lichens, these organisms forming an important part of the flora of many walls. By conducting a survey of wall vegetation in the County it was possible to work with both of these subjects.

What is a wall?

The Concise Oxford English Dictionary defines a wall as a "continuous and usually vertical and solid structure of stones, bricks, concrete, timeber etc., narrow in proportion to length and height, serving to enclose (partly) or protect or divide off town, house, room, field etc." This is a wide ranging definition but walls do come in many forms. However walls of 'timber' were not considered, and walls dividing rooms in houses do not, usually, have a flora. Walls in this survey included dividing walls of fields and of building plots (i.e. garden walls), structural walls of bridges and buildings and retaining walls holding back banks of soil.

Previous work on walls

Walls have long been an area neglected by biologists, (Segal, 1969) with only a few studies being made of particular walls. More work has been done on Continental Europe than in Britain, probably because of its greater heritage of old walls, the Roman ruins of Italy being an example. This work consists mainly of floral lists of sites that stood out because of their plant coverage. In Italy lists were made as early as the beginning of the nineteenth century (Sebastiani 1815), from the Flavian amphitheatre in Rome and later lists include those of Deakin (1855), Mazzanti(1875, 1876, 1877), Damanti (1903), De Rosa (1905), Beguinot (1911, 1912, 1915) and Gabelli (1915).

In France Chatin (1861), Kirschleger (1862), Lepage (1861), Vallot (1884, 1887), Richard (1888) and Gagnepain (1897) have published floral lists. Lists from other countries include those of Barnewitz (1898), Jourdan (1867, 1872), Meijer (1943), Van Koningsdaal et al (1956), Guittart (1957), C.J.N. (1959), Beylsmit and Maten (1965) and De Wever (1942). Tuxen (1937) and Oberdorfer (1957) have attempted some ecological work, but based only on a few releves.

In Britain three papers are known (Rishbeth 1948, Woodell and Rossiter 1959 and Kent 1961). In these papers some attention is paid to ecological factors such as shade, aspect, inclination, materials and moisture.

More recently Segal (1969) has conducted an extensive examination of wall ecology. His 'Ecological notes on wall vegetation' is the principal work in the field to date. It is the result of an examination of over 1,200 releves from walls all over Europe. Many aspects of wall ecology are considered and a community analysis carried out on the data. However the scope is limited as shown by Segal's conditions for a wall to be included;- 'built of stones or bricks, jointed with not too hard a type of mortar, of fairly considerable age, and situated in an environment in which no prolonged period of drought prevails'. This hardly sets precise limits but for example, clearly excludes the drystone walls of much of upland Britain. As with most of the studies on walls it appears that many frequently encountered types of wall are ignored.

Segal also appears to have been the only worker to have included lichens in his survey, although these are not considered in detail in his 'Ecological notes on wall vegetation'. In my study no attempt was made to concentrate on those walls with a particularly good higher plant flora, drystone walls were included, and lichens were recorded. Indeed on may drystone walls lichens are the only organisms apart from algae. Figure 1

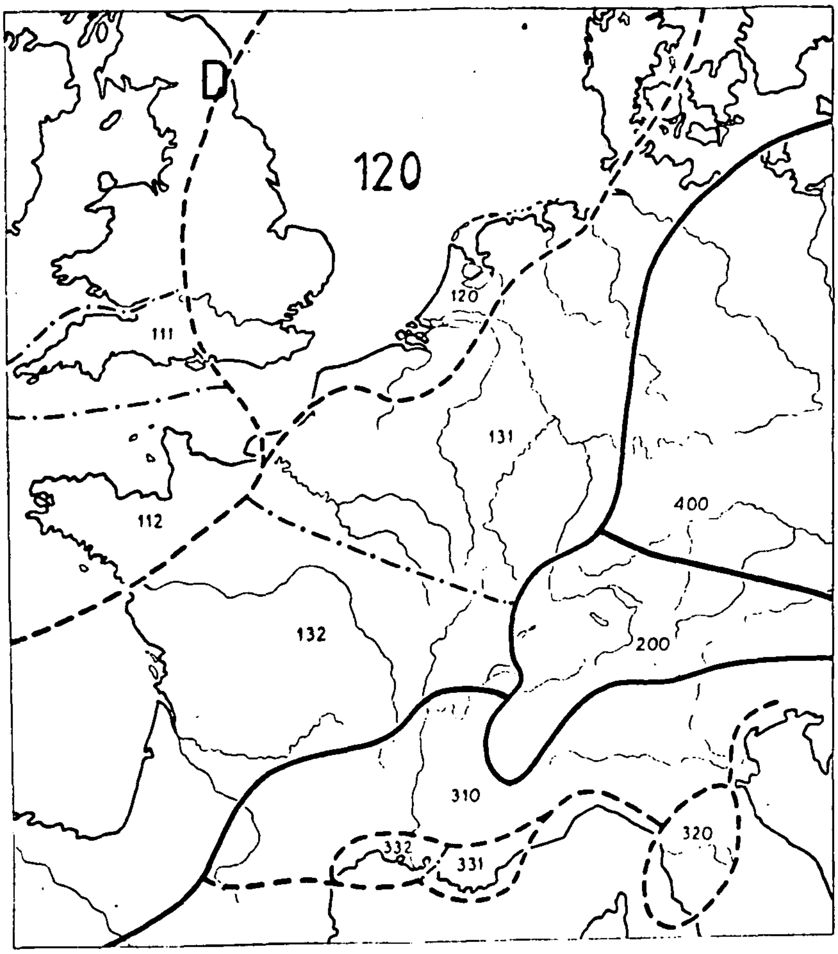


FIGURE I

Segal's (1969) survey areas
D = Durham

shows Segal's working areas with Durham lying on the edge of zone 120. Thus it appears that this area would not have received much attention from him. In his study, Segal only considers wall sides, i.e. vertical surfaces. However in this study wall tops are included it being considered that these are an equally important component of the wall ecosystem.

Darlington (1981) has written a more popularised account of wall ecology, based extensively on Segal's work, but with original observations and experiments included. This book represents an interesting introduction to the subject and points out many areas of wall ecology which would be worthwhile investigating. Darlington does not discuss drystone walls though, and most attention is focused on higher plants, ferns and mosses on the botanical side. Schmitt (1950) has also written a brief popular account of wall biology, in German.

Walls as sites for rarities

The extent to which walls are sites of national importance for rarities is not known, but several examples can be found. For many species the specific name suggests that walls are a major site of occurrence. Examples are Lecanora muralis, Tortula muralis, Asplenium ruta-muraria, Hieracium murinum and Hordeum murinum. Lecanora muralis used to be a fairly rare lichen in its original habitat of bird perching (nutriment enriched) sites in upland areas, but lowland walls, and asbestos and concrete roofs have now been extensively colonised by this species. Because of this, and its tolerance of air pllution, it is now a common species.

Two examples known to me of walls as sites for rarities are firstly, in Sussex where a railway tunnel wall provides the habitat for that county's largest colony of the liverwort Cenocephalum conicum (P.Syms pers.comm.), and secondly in Bristol where the introduced spider (reputedly Britain's largest) Segestria florentina (Bristowe 1958), lives in crevices in walls around the docks. In some areas, for example East Anglia, walls provide the only exposed rock surface available to saxicolous species of lichens, bryophytes etc. for many miles. An examination of the lichen flora of Berkshire, Buckinghamshire and Oxfordshire (Bowen 1980) shows that no less than nine species of lichen described therein as rare are found on walls in the area (Bacidia muscorum, Bacidia trachona, Caloplaca velana, Collemaa cristatum, Rhizocarpon distinctum, Staurothele rugulosa, Thelidium incavatum, Toninia coeruleonigicans and T.lobulata).

Walters (1969) looking at the records of the rare Cambridgeshire ferns Asplenium adiantum-nigrum and Cystopteris fragilis finds that the major sites for these spcies are; church walls for A.adiantum-nigrum, and a railway platform wall for C.fragilis.

Thus we can see that walls do provide sites for many rarities, and further investigation is merited.

The Survey

The aim of the project was to floristically survey at least 60 to 80 walls in an East to West transect across County Durham, and to subject the data to a modern phytosociological analysis. It was hoped that the project would demonstrate the importance of factors such as aspect, component materials, pollution and shade, to the wall flora, and would give an insight into the major types of communities found on Durham walls.

Due to limitations of time, and the essentially exploratory nature of the project, it was necessary to limit the extent of the data collected to some subset of the total available data for each wall. Thus it was considered that measures of the permeability and pH of wall materials for example, were not necessary in this survey, and the data collected were limited to those required to provide an adequate floristic and general characterisation of the walls, upon which a preliminary analysis would be based. Such a survey represented a feasible workload in the available time, but would provide data with a considerable potential for analysis, and upon which hypotheses might be generated, providing pointers to further work in this field in the future.

Nomenclature

Names of the higher plants, excluding ferns, follow Clapham et al (1982).

Names of the ferns follow Jermy (1978).

Names of the mosses follow Smith (1978).

Names of the lichens follow Hawksworth et al,(1980).

Names of the liverworts follow Watson (1968).

Methods

The area selected for the survey consists of an east-west transect across the County from the coast (including a little of Teesmouth), to the County border. The transect was 10km wide, the Northern limit being 5-434, and the Southern limit 5-334. This transect included Durham City and the North of Hartlepool in the east, and Weardale in the west. The roads associated with Weardale provided a suitable access to that area.

Within the transect, walls were selected more or less randomly, although easy access from a road was a necessary condition for selection, meaning that all walls were within a few metres of roads. The top and the two sides (where appropriate) of each wall were considered separately, preliminary observations indicating that this was necessary, clear differences being seen. From each of these a 50 x100 cm quadrat was taken, subjectively placed in a representative area, or where this was not possible a quadrat of the same area with differing dimensions. A minimum area of quadrat for each group of species; lichens, mosses etc., was not calculated. The 50 x 100cm quadrat was considered sufficient for these, and a size which would be quickly assessed. A larger quadrat would have been necessary to include most ferns and higher plants. Instead all species that were present within 5 metres of the quadrat were recorded as "also present". The base of the wall was not included, as the base-ground junction of a wall often has a different flora, and Segal (1969) considers this a separate zone.

For each quadrat the species present were recorded, with their Domin scale cover-abundance assessed. The following non-biological data were also recorded:

(1) East to west grid reference.
(2) Height.
(3) Width of the top.
(4) Width of the base.
(5) Altitude.
(6) Moisture (a subjective 1 to 4 scale).
(7) Shade (a subjective 0 to 10 scale).
(8) Type of surrounding area.
(9) Whether the sample was the top or side of the wall.
(10) Materials the wall was made of.
(11) The type of wall; freestanding, structural or retaining.
(12) The diameter of the largest *Rhizocarpon geographicum* colony, if this species was present on the wall.
(13) The diameter of the largest *Parmelia saxatilis* colony, if this species was present on the wall.

Inclination and colour were measured also, but this data was not subsequently used. Inclination tended to be a meaningless figure due to the irregularities of wall structure. Colour was usually a result of the species present, rather than the wall materials.

The sizes of the two species of lichens were recorded as possible indications of the age of a wall. Rhizocarpon geographicum has been extensively used as an indicator of the age of rock structures (Webber and Andrews 1973), and Parmelia saxatilis forms colonies which may also be useful in this respect.

Species unidentifiable in the field were sampled and identified later in the laboratory. This consisted mainly of lichen work with some mosses also. Duncan (1970) and Dobson (1979) were used as idenification manuals for the lichens. The stains paraphenylenediamine, potassium hydroxide and calcium hypochlorite were used as described in Dobson (1979). Where necessary microscope preparations of spores were made. Mosses were identified using Smith (1978) and Watson (1968).

Data Analysis

The completed dataset is of a multivariate nature with many variables recorded for each quadrat taken. Traditional uni or bivariate analysis methods such as regression, cannot therefore be used and a different group of methods have arisen to cope with such data. Two broad approaches are available for multivariate community analysis. Firstly ordination, a process of producing a simplified low dimensional picture of multidimensional data, and secondly classification, the process of assigning samples and species to groups.

It is useful to carry out both these methods of analysis on the data since they are complementary in allowing comparison of the results of each, and in giving separate information. The classification produces defined groups, while the ordination shows more clearly the relationships of individuals and groups to each other.

Separate analyses were carried out on the biological data, (the species and species abundances recorded for each quadrat), and on the non-biological data (the measurement and observations describing each wall). By doing this it was possible to compare the two sets of results, for example to check whether a particular group of walls corresponds to a particular community of species.

A classification of the species data was made using the program TWINSPAN (Two-Way INdicator SPecies ANalysis), (Hill 1979), a hierachical polythetic divisive method. It has proven previously to be a most robust and effective method of community analysis and has many possible applications with multivariate data (Gauch 1982). The tabular rearrangement of the data by TWINSPAN is probably the best rearrangement by a computer program available (Gauch 1982). It has the advantage that similar groups of species and samples are placed close to each other in the rearrangement, making data interpretation easier.

An ordination of the species data was made using the program DECORANA (DEtrended COrrespondence ANAlysis), (Hill and Gauch 1980). Detrended correspondence analysis is an improved eigenvector ordination technique based upon reciprocal averaging, intended to correct the main faults of that method (Hill 1979, Hill and Gauch 1980). It firstly corrects the arch distortion of the second and higher derived axes, with respect to the first axis, and secondly corrects the compression of the first axis ends, compared to the middle of that axis (Hill and Gauch 1980, Gauch 1982). It also has proven a robust and effective technique with community analysis projects (Gauch 1982).

For the non-biological data set the analyses used were based upon the Gower dissimilarity matrix, which is able to use the mixed data types collected (Gower 1966). The ordination technique used was that of principal coordinates analysis (Gower 1966). The computer program PCOORD adapted by H.J.B.Birks from Blackith and Reyment (1971) was used. The classification technique used was that of minimum variance cluster analysis (Adam et al 1975). The program was NEWCLUS written by H.J.B.Birks and B.Huntley.

Results and discussion

For each group of organisms a complete list of species found during this study is given, followed by comments upon that list.

The lichens

Table I Complete species list of lichens found during the survey

+ *Acarospara fuscata*
A.smaragdula
Aspicilia calcarea
A.cinera
A.contorta
Bacidia muscorum
+ *Buellia aethalea*
Caloplaca citrina
C.ferruginea
C.heppiana
C.saxicola
Candelariella auella
+ *C.vitellina*
Catillaria chalybeia
C.lenticularis
Cladonia chlorophaea
C.ciliata v.tenuis
+ *C.coniocraea*
C.macilenta
C.squamosa
Clathroporina calcarea
Lecidella scabra
L.stigmatea
Collema tenax
Fusidea cyathoides
Haematomma ventosum
Huilia albocaerulescens
+ *H.macrocarpa*
H.tumida
Hypocenomyce scalaris
Hypogymnia physodes
H.tubulosa
Lecania erysibe
+ *Lecanora atra*
L.campestris
+ *L.conizeoides*
+ *L.dispersa*
+ *L.intricata*
+ *L.muralis*
+ *L.polytropa*
L.rupicola
Lecidea monticola
L.osrothea
Rhizocarpon concentricum

R.geographicum
R.obscuratum
+ *Lepraria incana*
Ochrolecia parella
Parmelia glabratula subsp.*fuliginosa*
+ *P.saxatilis*
+ *P.sulcata*
Peltigera praetextata
Pertusaria coccodes
P.corallina
P.dealbescens
+ *Physica adscendens*
+ *P.caesia*
P.tenella
+ *Placynthium nigum*
Polysporina simplex
+ *Protoblastinia rupestris*
Pseudoevernia furfurcea
+ *Psilolechia lucida*
Rinodina gennarii
R.umbilicatum
Scoliciosporum umbrisnum
Stereocaulon vesuvianum
Tremolecia atrata
Trapelia coarctata
+ *Verrucaria baldensis*
V.coerulea
V.glaucina
V.muralis
+ *V.nigrescens*
Xanthoria aureola
X.candelaria
X.parietina

+ indicates this species was also recorded by Raistrick and Gilbert (1963).

Three unidentified species were also found.

Lichens are the most ubiquitous group of wall species, because of their ability to withstand drought. Most saxiolous species can survive extreme dessication, only needing short periods of wetness in which growth occurs. Sacicolous lichens can be considered the best adapted 'eukoryote' group to the extreme conditions which most walls present. This is shown by the fact that lichens were the group with the largest numbers of species found during this survey. On most walls lichens are the primary colonisers (Segal 1969), and as in the case of many drystone walls in this survey they often are the only organisms, apart from algae, present on a wall.

The species in Figure I cover a range from suphur dioxide pollution tolerant lichens (Scoliciosporum umbrinum, Caloplaca citrina, Candelariella aurella,C.vitellina, Cladonia coniocaea, C.macilenta, Lecanora dispersa, L.muralis, L.conizeoides, Lepraria incana, Placynthium nigrum. Xanthoria parietina) to pollution intolerant lichens (Fusidea cyathoides, Lecidea osrothea, Peltigera praetextata,Rhizocarpon umbilicatum and Tremolecia atrata). The most tolerant of pollution are Lecarora conizeoides, L.dispersa and Lepraria incana. These three species are often the only lichens present in some inner city 'lichen deserts' (Gilbert 1971). These pollution tolerances were reflected in the distributions of the species within the transect area,pollution tolerant species being found mainly in the industrial east, and pollution intolerant species in the cleaner air of the west of the transect.

The species found also cover a range of favoured substrates. Lichens favouring acidic substrates are Rhizocarpon sp., Lecanora intricata, L. polytropa, Lecidea osothea, L.macrocarpa and Parmelia saxatilis. Characteristic calciocoles are Verrucaria sp. Aspilicia calcarea, A.contorta and Clathroporina calcarea. In contrast Scoliciosporum umbrinum and Caloplaca citrina are found on a variety of substrates, both acidic and calcareous.

Most of the species in Table I are reasonably common. Only Verrucaria coerulea can be described as uncommon. Hypocenomyce scalaris is generally a corticolous species, but is rarely found in a saxicolous habitat (Duncan 1970). However this species was recorded growing on rock during this survey. Acarospora fuscata is said to be tolerant of dust thrown up by vehicles onto roadside walls (Gilbert 1980), and was found to be common in this situation in Durham.

Previous workers have largely ignored lichens on walls. The only list with which Table 1 can be compared is that complied by Raistrick and Gilbert(1963), from Malham Tarn House in Yorkshire. Twenty-two of the species on their list were found during this survey (see Table I). These represent a group of very common lichens, and it is possible to speculate that these may be a basic group of lichens that in the North of England are common wall species.

The mosses

Table II Complete species list of mosses found

O!+	Amblystegium serpens
!+	Barbula convoluta
+	B.fallax
!+	B.rigidula
	B.trifaria
O	B.unguiculata
!	B.vinealis
O!+	Bryum argenteum
O!	B. caespiticium
!+	B.capillare
O.+	Ceratodon purpureus
	Dicranella heteromalla
	Dicranum scoparium
+	Ditrichum flexicaule
	Fissidens cristatus
O.+	Grimmia pulvinata
	G.torquata
O!+	G.trichophylla
	Homalothecium lutescens
+	H.sericeum
O!	Hypnum cupressiforme
	Neckera complanata
!	Orthotrichum anomalum
	Pohlia carnea
	P.elongata
	Ptychomitrium polyphyllum
+	Rhacomitrium fasiculare
	R.heterostichum
!+	Schistidium apocarpa
O!+	Tortula muralis
	T.subulata
	Trichostomum brachydontium
	T.crispulum
	Weissia controversa

O indicates this species was recorded by Woodell and Rossiter (1959).

! indicates this species was recorded by Rishbeth (1948)

\+ indicates this species was recorded by Raistrick and Gilbert (1963)

The mosses show several similarities to the lichens. For example their occurrence is affected by sulphur dioxide pollution and by substrate. Also the ability to withstand drought is an important factor for wall growth.

Mosses from Table II which are known to show pollution tolerance are Ceratodon purpureus, Bryum argenteum, Tortula muralis and Hypnum cupressiforme (Gilbert 1968). In this survey Tortula muralis and Hypnum cupressiforme clearly showed this tolerance, being the most frequent mosses in the most polluted area east of Durham City. Ceratodon purpureus and Bryum argenteum were not recorded frequently enough to come to any conclusions in this respect. Gilbert (1968) has shown that the moss Grimmia pulvinata avoids highly sulphur dioxide polluted areas, and gaps in its distribution can be used to map such areas. In this survey the moss was not found in the more highly polluted areas east of Durham City.

Distinct calcicoles amongst the species are Orthotrichum anomalum, Trichostomum crispulum and Homalothecium lutescens. Those showing a preference for acid substrates are Dicranella heteromalla, Ceratodon purpureus, Rhacomitrium heterostichum and R.fasiculare. Many of the species are more catholic in their choice of substrates, for example Tortula muralis, Bryum agenteum and Hypnum cupressiforme. However Gilbert (1968) has shown that pollution can affect their range of substrate, the species becoming more calcicole as pollution increases. In this survey the preferences of most of these species were clearly seen, particularly of the limestone preferring species such as Trichostomum brachydontium and Orthotrichum anomalum. The effects that substrate can have on mosses were most clearly shown in the survey by the differing floras of a sandstone wall top, and a limestone block placed on top of it. While no mosses were recorded from the sandstone wall top, the limestone block was abundantly covered with Grimmia pulvinata, Schistidium apocarpa and Tortula muralis.

Table II shows the abundance of small acrocarpous mosses on walls compared to pleurocarpous mosses. The only pleurocarpous mosses of regular occurrence were Hypnum cupressiforme and Homalothecium sericeum which were often dominant on a wall. The abundance of the acrocarpous mosses may be explained by the water relations of the species. The compact cushion forms are better adapted for water conservation, presenting a lesser surface area than the pleuvcarpous species. They are thus better adapted to the often dry conditions of walls. Table II shows that genera such as Grimmia and Barbula which also undergo twisting together of the leaves when dry to conserve water, are well represented. It is clear that the availability of water is a major ecological factor for most wall species.

The species list contains no rarities. Most of the mosses are common and many have been found on walls before. Watson (1968) describes many such mosses and the previous wall surveys of Rishbeth (1948) and Woodell and Rossiter (1959) have also recorded many, (see Table II). It appears that species such as Amblystegium serpens, Bryum argenteum, Ceratodon purpureus, Grimmia pulvinata and Tortula muralis are frequent and widespread colonisers of this habitat in England. Of the species not previously described, many are common on walls anyway according to Watson (1968) and others are probably of casual occurrence, such as Weissia controversa, Homalothecium lutescens, Pohlia carnea and Neckera complanata. A wide variety of ecological conditions can be encountered on a wall, for example on a turf capped wall, with a covering of grass, grassland mosses could easily occur. Dicranum scoparium for example was found growing in this way.

Bryum argenteum was not recorded as frequently as other workers suggest it may occur (Segal 1969, Watson 1968) and this is because it is mostly a species which occurs at the junction of a wall with the ground. Such areas were not included in this survey.

The liverworts

Lunularia cruciata and *Conocephalum conicum* are the most typical wall liverworts. (Woodell and Rossiter 1959, Watson 1968, Phillips 1981). Watson (1968) lists other species associated with walls but their frequency of occurrence is not known.

The only liverwort recorded in this survey was *Solenostoma triste*, as far as I know not previously recorded from a wall. It was found inhabitating the centre of a moss cushion, brought back to the laboratory for identification. It is possible that other liverworts may be found growing in this manner but they cannot be considered a part of wall ecology.

The ferns

Table III Complete species list of ferns found

*O! *Asplenium ruta-muraria*
*O! *A.trichomanes*
Cystopteris fragilis
Dryopteris oreades
*! *Polypodium vulgare*

* indicates this species was recorded by Kent (1961)
O indicates this species was recorded by Woodell and Rossiter (1959)
! indicates this species was recorded by Rishbeth (1948)

From the list it can be seen that only *Dryopteris oreades* and *Cystopteris fragilis* have not been previously recorded from walls during wall flora surveys, and I suggest that this is mainly due to their distributions not coinciding with areas investigated up to now. Other ferns not recorded in this survey but found on walls are *Phyllitis scolopendrium*, *Ceterach officianarum*, *Dryopteris felix-mas*, *Asplenium adiantum-nigrum* and *Pteridium aquilinum* (Darlington 1981, Segal 1969, Rishbeth 1948, Kent 1961, Woodell and Rossiter 1959).

The species in Table III are a selection of ferns often associated with walls. Phillips (1980) describes all of these species as occurring regularly on walls.

Asplenium ruta-muraria and *A.trichomanes* are common wall ferns. They are resistant to dessication, and were found in the survey growing in dryer sites than the other species. They are both somewhat calcicole and were found in cracks in mortar, a typical habitat.

Cystopteis fragilis, *Dryopteris oreades* and *Polypodium vulgare* were found growing on retaining walls, much damper than freestanding walls. *Polypodium vulgare* was also found on the top of a deeply shaded wall. Dessication is reduced and walls stay wet after rain for longer periods when they are shaded (Rishbeth 1948). Thus the importance of moisture to wall ecology is again shown. The particular drought tolerance of *Polypodium vulgare* is discussed by Potts and Penfound (1948).

Dryopterisoreades does in fact grow on drystone walls and may be more drought resistant than *Polypodium vulgare* and *Cystopteris fragilis* (Phillips 1980).

Three of the species, *Asplenium ruta-muraria*, *Dryopteris oreades* and *Cystopteris fragilis* were found growing at the lead ontaminated ex-smelting site at Rookhope, Co.Durham. Some degree of lead tolerance may be a factor in their growth there.

Compared with groups such as lichens, mosses and angiosperms, the ferns were not frequently found. However in some areas walls may represent a significant proportion of the sites on which they occur.

The gymnosperms

No gymnosperms were found during this survey although *Taxus baccata* is a well known wall dwelling species on occasions (Darlington 1981).

The angiosperms

Table IV Complete species list of angiosperms found

*O!	Agropyron repens
*O!	Agrostis stolonifera
O!	Arrhenatherum elatius
O	Bromus mollis
*O!	Dactylis glomerata
	Festuca tenuifoilia
*O!	F.rubra
* !	Holcus lanatus
O	H.mollis
*O!	Poa annua
*O!	P.pratensis
*	P.trivialis
*O!	Acer pseudoplatanus
!	Coryllus avellana
*O!	Sambucus nigra
*O!	Sorbus aucuparia
* !	Ulmus sp.
*O!	Achillea millefolium
	Anthriscus sylvestris
O!	Bellis perennis
	Cardamine flexuosa
	Cerastium fontanum
*O!	Chamerion angustifolium
*O!	Cirsium sp.
*O!	Convolvulus arvensis
* !	Crepis sp.
*O	Cymbalaria muralis
*O!	Epilobium montanum
!	Erophila verna
	Euphrasia officianalis agg.
*O!	Galium aparine
O!	Geranium robertianum
*O!	Geum urbanum
*O!	Hedera helix
*O!	Hieracium sp.
*O!	Lamium purpureum
*O	Lapsana communis
	Matthiola incana
*O!	Plantago lanceolata
*O!	Rubus fruticosus
*O!	Rumex acetosa
*O!	Sedum acre
*O!	Senecio jacobaea
*O!	S.vulgaris
*O!	Stellaria media
*O!	Taraxacum officianale
	Thymus praecox
O	Trifolium repens
O!	Tussilago farfara
*O!	Urtica dioica
!	Viola sp.

* indicates this species was recorded by Kent (1961)

O indicates this species was recorded by Woodell and Rossiter (1959)

: indicates this species was recorded by Rishbeth (1948).

Angiosperms can be affected by atmospheric pollution, similarly to the mosses and lichens, and are particularly affected by soot and smoke. For example Fitter (1945) and Kent (1961) discuss the severe effects in London, the most badly affected area in England (Open University 1975). I can however find no evidence of any effect in the survey area, and Woodell and Rossiter (1959) concluded that atmospheric pollution had little or no effect on the higher plants in Durham City. Since the 1959 Clean Air Act greater attempts have successfully been made to make cities less polluted in this manner and so it is unlikely that the situation has worsened.

The majority of the species in table IV do not show preferences for a narrow range of pH conditions. This I think may highlight one of the characteristics of a successful wall plant. Such a plant must be adaptable, able to cope with difficult conditions, able to produce enough seed to increase its likelihood of colonising the wall. In fact it would seem that the majority of wall plants tend to be opportunist plants. They tend towards the r strategy of MacArthur and Wilson (1967) or using Grimes (1979) system more of the S (stress tolerant) and R (ruderal) strategies, rather than the C (competitive) strategy. This can be seen more clearly by looking at the normal habitats of wall plants, shown in Table V.

Table V The normal habitats of wall plants

Habitat	Number of species found in this habitat	Percentage total number of species on walls
Walls	8	15.7
Waysides	18	35.3
Hedges	15	29.4
Grassland	25	49.0

Table V cont'd

Habitat	Number of species found in this habitat	Percentage total number of species on walls
Woods (shady places)	18	35.3
Cultivated ground	14	27.5
Garden plants	2	3.9
Heaths/moors	5	9.8
Rocky/stoney places	13	25.5
Wasteground	24	47.1

data from Clapham et al (1981), Hubbard (1968) and personal observations.

A high proportion, nearly half, of the species are also found on wasteground, and many are weeds of cultivated ground. These are typical MacArthur and Wilson r-strategy habitats. These are typical habitats for r-strategist species, whose attributes will often enhance their ability to colonise walls. Woodell and Rossiter (1959) touch upon this idea, when they suggest that plants of wasteground and cultivated ground are better suited to colonise walls than other plants. Thus it seems that a wall is a habitat favouring r strategy plants. It is an unstable environment in terms of its water supply, and also in terms of its long term future, being subject to decay, rebuilding and replacement etc.

Plants of waysides are well represented (see Table V). This may well be because most of the sampled walls were on waysides and so colonisation would not be inhibited by distance from a seed source. Hedge plants are also frequent probably because of the large component of wayside plants which grow in hedges and the use of walls like hedges as field boundaries. Plants of rocky and stoney places are of frequent occurrence, possibly because such places resemble walls in their ecological problems, little soil, a tendency to drought conditions etc.

Garden plants do occur on garden walls, the best example being "Stocks", *Matthiola incara* in this survey. It is interesting to note the poor representation of moorland plants on walls, especially in view of the fact that substantial parts of the survey area are moorland. Typical moorland plants would seem to be poorly adapted for wall growth. The damp climate of typical moorland may mean that moorland plants can not usually cope with the dry conditions of most walls.

Other habitats well represented amongst the wall plants are grasslands, and woods and shady places. Many of the species of these habitats tend more towards a K-strategy but opportunistically exploit walls which traverse their normal habitats; species of woods and shady places in particular being found primarily on walls in such situations.

The woody species were all small seedlings found under large parent trees. It is unlikely however that they would ever develop to maturity, although some good examples of mature *Taxus baccata* are known (Darlington 1981). Finally some of the species, 15.7%, have walls given as a normal habitat. These are *Poa pratensis*, *Crepis sp.*, *Cymbalaria muralis*, *Epilobium montanum*, *Erophila verna*, *Hedera helix*, *Lapsana communis* and *Sedum acre*.

Table IV does not contain any uncommon plants. It does show the comparison with other known British wall surveys. From this it appears that a large number of the species are typical of walls in all the study areas. No less than 54.9% of the plants are recorded from the three other wall surveys as well, 17.6% from only two, 13.7% from only one, and only 13.7% have not been previously recorded. Thus within this species list there appears to be a large group of plants which are commonly found on walls all over England.

Methods of dispersal of wall species

Lichens, bryophytes and pteridophytes are all propagated by spores which are wind blown. Some lichens also have light vegetative popagules called soredia and isidia (Duncan 1970). Only with the angiosperms do other mechanisms than wind dispersal assume major importance.

This group shows greater variation although wind dispersal is still important. The major modes of dispersal of the species recorded in this, and other surveys are given in Table VI.

It is most common to have no special method of dispersal. These species are mainly small annuals and the gasses. Some such as Urtica dioica and Rumex acetosa rely mainly on producing large quantities of seed increasing the chances of accidental spread, for example on the foot of an animal. Woodell and Rossiter (1959) list a large number of species for which dispersal by birds is known, and this list includes many of these species.

Wind dispersal is obviously important and is reflected in the number of composites which are found on walls (see Table IV). They are probably the best represented family on English walls.

Animal dispersal is also important for many species. Plants with berries constitute a regular proportion, and plants such as Geum urbanum and Gallium aparine with hooked seeds are not uncommon. Animals, including man are probably often also responsible for the dispersal to walls of plants with no special dispersal adaptations. Segal (1969) points out the importance of ants to the dispersal of Cymbalaria muralis and Lamium purpureum, having observed ants carrying the seeds of these species. Ants are also known to disperse seeds of Veronica spp. and Ulex spp. (Brian 1977) and further investigation may reveal other species for which ant dispersal may be important.

It is interesting to see how the figures from other sites are very similar. This would tend to indicate that this is a typical situation throughout England. The only discrepancy is with the number of wind dispersed species on Cambridge walls. This is probably due to Rishbeth (1948) including very light seeds as well as those with 'wings' or plumes in the wind dispersed category.

Table VI Dispersal mechanisms of the angiosperms

	Present survey		Comparable data for % no. of species from:		
Mechanism	No. of species	% no. of species	London	Cambridge	Durham
Wind	15	29.4	19.1	50.0	20.2
Edibile fruits	5	9.8	13.2	13.0	12.5
Adhesive seeds	2	3.9	1.5	3.0	2.4
Others	3	5.9	0	0	1.8
No special mechanism	26	51.0	66.2	34.0	63.1

Other data taken from Kent (1961)

The commonest wall species

A list of the 20 species which occurred most frequently in the survey is given in Table VII.

Table VII The 20 commonest wall species

Species	Number of records (from 243 samples)	Percentage number of records
Algae	162	66.7
Lecidea tumida	116	47.7
Lecanora dispera	93	38.8
Parmelia saxatilis	88	36.2
Lecanora intricata	84	34.6
Lecanora atra	83	34.2
Acarospora fuscata	79	32.5
Candelariella vitellina	77	31.7
Protoblastinia rupestris	76	31.3
Lecanora polytropa	64	26.3
Rhizocarpon geographicum	53	21.8
Lecanora rupicola	52	21.4
Tortula muralis	47	19.3
Lecanora conizeoides	45	18.5
Rhizocarpon obscuratum	44	18.1
Scoliciosporum umbrinum	44	18.1
Xanthoria parietina	44	18.1
Candelariella aurella	43	17.7
Hypnum cupressiforme	43	17.7
Grimmia pulvinata	42	17.3

As can be seen the majority of the species are lichens. There are no angiosperms or pteridophytes in the 'top twenty' and only 3 mosses.

The commonest angiosperm was Taraxacum officianale with only 20 records. Thus when considering the previous discussion of the species this table helps put the comments in perspective. It confirms the relative abundance of lichens compared to all other groups.

Algae was a collective term and from observations probably referred to several different species, including one 'blue-green' alga.

The table also points out that most of species recorded were in fact quite uncommon. In fact 93 or 61.2% of the species were recorded less than 5 times and 51 of the species or 33.6% were recorded only once. This is not unexpected as Kent's (1961) figures show that 67.2% of his plants were recorded less than 5 times (500 sample sites), and no less than 40.7% only once. This is a typical situation in community ecology and was first pointed out by Fisher et al (1943). In most communities there are very few abundant species and very many rare species.

The walls

There are three basic types of walls, freestanding, retaining and structural (part of a building or construction). All these categories were included in this survey, but freestanding walls are by far the most common. Retaining walls were present in enough quantity to see that they tended to be moister and so supported a more diverse flora often with more higher plants than freestanding walls. Woodell and Rossiter (1959) did not find this in their work, which is surprising, Rishbeth (1948) only comments that retaining walls should have a better flora, without producing any evidence and Kent (1961) fails to discuss the subject. This survey shows clearly the richer flora of retaining walls. The average retaining wall had 7 species of bryophytes, pteridophytes or angiosperms, while the other categories averaged only 1.9 species per sample.

The variations and different factors affecting structural walls are great, and as so few were sampled it is difficult to draw any conclusions about them. The complexities are shown by Segal's (1969) example of church walls in the Netherlands. Here there is a vast floral difference between Protestant and Roman Catholic churches of the same age. This is because in Protestant churches the services are less frequent and so the periods of heating in the church are less. The walls tend to cool rapidly and take up water vapour and this causes damage to masonry and mortar, greater than that of Roman Catholic churches. The greater decay allows plants to colonise far better and thus Protestant church walls have a more diverse flora.

The materials a wall is made of are obviously important. In towns and villages walls of brick and concrete are common, but in more rural areas the freestanding walls tend to be made of the available local stone. Thus the wall materials are associated with the local geology. The geology of Durham is discussed by Eastwood (1946). Across the transect area there are 3 main rock systems. Firstly east of Durham City there is the magnesian limestone, secondly the millstone grits and coal measures around Durham City, and thirdly the lower carboniferous limestone in the west of the transect. All of these rock types were seen incorporated into walls. The effects of substrate on the flora have already been partially discussed and will be dealt with further later on. Mortar when present is important and can act as a refuge for calcicoles on an acidic rock wall.

The surrounding area of a wall will affect the flora of that wall, determining the local available seed sources. A wide variety of surrounding areas were included, from mooreland to lowland grassland, arable fields and pastoral fields, and town and village areas. Age of the wall is also important but difficult to measure or assess. The lichen colony sizes measured were not helpful in this respect. Decay of materials and the build up of soil or litter are all long term features of a wall. Segal (1969) suggests that the best walls are 100 to 500 years old.

Because of the nature of the transect the walls also cover a range of altitude from 0 to just over 2,000 feet and go from the clean air of the west to the more polluted air of the east (Gilbert 1968).

Species name abbreviations

In the following sections the names of species may be abbreviated in the diagrams. Table VII below gives a full list of these abbreviations.

Acarospora fuscata	Acar fus
A. smaragadula	Acar sma
Aspicilia calcarea	Asp cal
A. cinerea	Asp cin
A. contorta	Asp con
Bacidia muscorum	Bac mus
Buellia aethalea	Buel aet
Caloplaca citrina	Calo cit
C. ferruginea	Calo fer
C. heppiana	Calo hep
C. saxicola	Calo sax
Candelariella aurella	Cand aur
C. vitellina	Cand vit
Catillaria chalybeia	Cat chal
C. lenticularis	Cat lent
Cladonia chlorophaea	Clad chl
C.ciliata v. tenuis	Clad cil
C. coniocraea	Clad con
C. macilenta	Clad mac
C.squamosa	Clad squ
Clathroporina calcarea	Clat cal
Collema tenax	Coll ten
Fusidea cyathoides	Fus cya
Haematomma ventosum	Haem ven
Huilia albocaerultescens	Huil alb
H. macrocarpa	Huil mac

H. tumida	Huil tum
Hypocenomyce scalaris	Hyp scal
Hypogymnia physodes	Hypo phy
H. tubulsoa	Hypo tub
Lecania erysibe	Leca ery
Lecanora atra	Leca atr
L.campestris	Leca cam
L.conizeoides	Leca con
L.dispersa	Leca dis
L.intricata	Leca int
L.muralis	Leca mur
L. polytropa	Leca pol
L.rupicola	Leca rup
Lecidea monticola	Leci mon
L.osrothea	Leci osr
Lecidella scabra	Leci sca
L.stigmatea	Leci sti
Lepraria incania	Lepr inc
Ochrolechia parella	Ochr par
Parmelia glabratula	Parm gla
P. saxatilis	Parm sax
P.sulcata	Parm sul
Peltigera praetextata	Pelt pra
Pertusaria coccodes	Pert coc
P.corallina	Pert cor
P.dealbescens	Pert dea
Physica adscendens	Phys ads
P.caesia	Phys cae
P.tenella	Phys ten
Placynthuim nigrum	Plac nig
Polysporina simplex	Poly sim

Protoblastinia rupestris	Prot rup
Pseaudoevernia furfuracea	Pseu fur
Psilolechia lucida	Psil luc
Rinodina gennarii	Rino gen
Rhizocarpon concentricum	Rhiz con
R. geographicum	Rhiz geo
R.osbscuratum	Rhiz umb
Scoliciosporum umbrinum	Scol umb
Stereocaulon vesuvianum	Ster ves
Tremolecia atrata	Trem atr
Trapelia coarctata	Trap coa
Verricaria baldensis	Verr bald
V.coerulea	Verr coe
V.glaucina	Verr gla
V.muralis	Verr mur
V. nigrescens	Verr nig
Xanthoria candelaria	Xant can
X.parietina	Xant par
X.aureola	Xant aur

Amblystegium serpens	Ambl ser
Barbula convoluta	Barb con
B.fallax	Barb fal
B.rigidula	Barb rig
B.trifaria	Barb tri
B.unguiculata	Barb ung
B.vinealis	Barb vin
Bryum argenteum	Bry arg
B.caespiticium	Bry caes

B.capillare	Bry cap
Ceratodon purpureus	Cera pur
Dicranella heteromalla	Dicr het
Dicranum scoparium	Dicr sco
Ditrichum flexicaule	Ditr flex
Fissidens cristatus	Fiss cri
Grimmia pulvinata	Grim pul
G.torquata	Grim tor
G.trichophylla	Grim tri
Homolothecium lutescens	Homa lut
H.sericeum	Homa ser
Hypnum cupressiforme	Hypn cup
Neckera complanata	Neck com
Orthotrichum anomalum	Orth ano
O.cupulatum	Orth cup
Pohlia carnea	Pohl car
P.elongata	Pohl elo
Ptychomitrium polyphyllum	Ptyc pol
Rhacomitrium fasiculare	Rhac fas
R.heterostichum	Rhac het
Schistidium apocarpa	Schi apo
Tortula muralis	Tort mur
T.subulata	Tort sub
Trichostomum brachydontium	Tric bra
T.crispulum	Tric cri
Weissia controversa	Weis con
Solenostoma triste	Sole tri
Asplenium ruta-muraria	Asp mur
A.trichomanes	Asp tric

Cystopteris fragilis	Cyst fra
Dyopteris oreades	Dryo ore
Polypodium vulgare	Poly vul

Agropyron repens	Agro rep
Agrostis stolonifera	Agro sto
Arrheratherum elatius	Arrh ela
Bromus mollis	Brom mol
Dactylis glomerata	Dact glo
Festuca tennuifolia	Fest ten
F.ruba	Fest rub
Holcus lanatus	Holc lan
H.mollis	Holc mol
Poa annua	Poa ann
P.pratensis	Poa prat
P.trivialis	Poa triv

Acer pseudoplatanus	Acer pse
Coryllus avellana	Cory ave
Sambucus nigra	Samb nig
Sorbus aucuparia	Sorb auc
Ullmus sp.	Ulmus

Achillea millefolium	Ach mill
Anthriscus sylvestris	Anth syl
Bellis perennis	Bell per
Cardamine flexuosa	Card fle
Cerastium fontanum	Cera fon
Chamerion angustifolium	Cham ang
Cirsium sp.	Cirs ium

Convolvulus arvensis	Conv arv
Crepis sp.	Crepis
Cymbalaria muralis	Cymb mur
Epilobium montanum	Epil mon
Erophila verna	Erop ver
Euphrasia officianalis agg.	Euph off
Galium aparine	Gal apa
Geranium robertianum	Gera rob
Geum urbanun	Geum urb
Hedera helix	Hedera
Hieracium sp.	Hierac
Lamuim purpureum	Lam purp
Lapsana communis	Laps com
Matthiola incana	Matt inc
Plantago lanceolata	Plan lan
Rubus fruticosus	Rubus
Rumex acetosa	Rumex
Sedum acre	Sedum
Senecio jacobaea	Senjac
S.vulgaris	Sen vul
Stellaria media	Stel med
Taraxacum officianale	Tara off
Thymus praecox	Thym pra
Trifolium repens	Trif rep
Tussilago farfara	Tuss far
Urtica dioica	Urt div
Viola sp.	Viola
Algae	Algae

The classification of the species by TWINSPAN

The classification is shown in figure II. Species are classified by this method according to similarities in their pattern of occurrences amongst the samples. If most or all of the species within a group are known to show some similar basic characteristic of environmental tolerance then we can reasonably conclude that this attribute is important in determining species distributions, and hence that the related environmental property is an important determinant of community composition. Examination of the species groups in this way enables a clearer interpretation of th classification of samples which the TWINSPAN analysis also provides. The character of the species in each group will now be examined.

Species group A(26spp.) contains many species which were of infrequent occurrence within the survey. They are found in a wide range of habitats and conditions ranging from species found exclusively on limestones such as Verrucaria coerulea and Trichostomum crispulum to those found only on sandstone habitats such as Lecidea osrothea and Catillaria chalybeia. Thus it is difficult to see any distinct characteristics within the group.

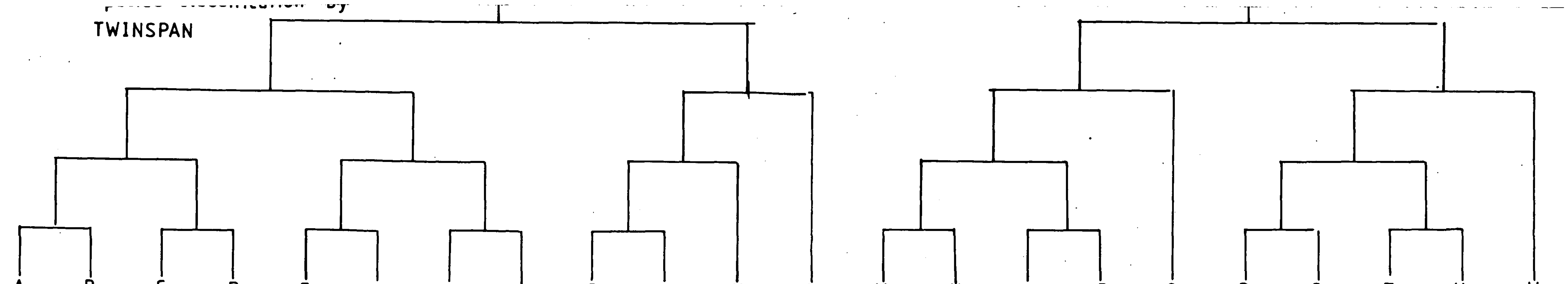
Species group B(32spp.) also contains species with a variety of substrate preferences although the majority tend to be found more on sandstone substrates; species such as Huilia macrocarpa and Rhizocarpon geographicum are good examples of this. Species groups C(1sp.) and D(4spp.) contain only lichen species, all of which favour sandstone conditions. They include Acarospora fuscata, Huilia tumida, Lecanora intricata and L. polytropa all of which were amongst the top ten most frequently encountered species in the survey. They are also all known to show some degree of sulphur dioxide pollution tolerance (Dobson 1979). The TWINSPAN classification of the samples uses these as important indicator species.

Group E(6spp.) contains a mixture of species, some of which were principally found on moister walls, for example Sambucus niger, Coryllus avellana. These typically woodland higher plants showed no particular substrate preferences. Group F(1 taxon) contained "algae" only. Algae was also more often present in large amounts on wetter walls but, perhaps because no attempt was made to distinguish between the species, was indifferent to substrate.

Groups G(3spp.), H(2spp.) and I(1sp.) contain lichen species which were found mainly towards the east end of the transect. Since sulphur dioxide pollution is highest in the east of the county (Gilbert 1968) they may e more tolerant species. Some of them were used as indicator species by TWINSPAN in the classification of the samples.

Groups J(11spp.) and K(4spp.) contain a variety of species but include in particular higher plants found on walls with some soil accumulation, for example Erophila verna, Thymus pratensis, Cirsium sp., lichen species which are known to favour the nutrient-enriched conditions sometimes found on roadside or town walls, for example Physica caesia, Xanthoria parietina (Brightman and Seaward 1977).

TWINSPAN



A
- Leci osr
- Laps com
- Trif rep
- Huil alb
- Grim tor
- Uni 1
- Verr bal
- Clad sqa
- Cyst fra
- Pohl car
- Acar sma
- Cham ang
- Pohl elo
- Verr coe
- Crepis
- Clad ten
- Dicr sco
- Rhiz con
- Orth cup
- Neck com
- Homa lut
- Tric cri
- Cati cha
- Bry caes
- Parm sul
- Hypo phy

B
- Pseudo
- Ulmus
- Huil mac
- Conv arv
- Tort sub
- Weis con
- Poa triv
- Fuci cya
- Hypo sca
- Ptyc pol
- Geum urb
- Holc mol
- Card fle
- Trem atr
- Rhac fas
- Fest ten
- Uni 2
- Fiss cri
- Bell per
- Viola
- Euph off
- Pelt pra
- Ditr fle
- Parm sax
- Cera pur
- Rhiz geo
- Ster ves
- Rhiz obs
- Hypo tub

C
- Leca int

D
- Pert cor
- Huil tum
- Leca pol
- Acar fus

E
- Bry arge
- Samb nig
- Cory ave
- Dicr het
- Baci mus
- Pert coc

F
- Algae

G
- Leca atr
- Clad chl
- Cera arv

H
- Cand vit
- Phys ten

I
- Parm gla

J
- Xant par
- Urti dio
- Phys ads
- Barb rig
- Aspi con
- Cirsium
- Trap coa
- Leca rup
- Poa prat
- Thym pra
- Rhiz umb

K
- Phys cae
- Barb fal
- Ochr par
- Erop ver

L
- Bar bung
- Lec a con

M
- Prot rup
- Schi apo
- Calo hep
- Verr gla
- Cati len

N
- Aspi cal
- Verr mur
- Fest rub
- Gera rob
- Barb vin
- Leci sti

O
- Leci mon
- Rhac het
- Calo sax
- Coll ten

P
- Poly vul
- Agro rep
- Tric bra

Q
- Hypnum
- Homa ser
- Scol umb
- Bry cap

R
- Anth syl
- Clad mac
- Sene vul
- Dryo ore
- Sole tri
- Tara off
- Epil mon
- Sene jac

S
- Poa ann
- Stel med
- Grim pul
- Clat cal
- Dact glo
- Achi mil
- Grim tri
- Leca ery
- Rum

T
- Leca cam
- Sorb auc
- Sedum ac
- Aspl rut
- Aspl tri
- Orth ano
- Agro sto
- Buel aet
- Calo fer
- Tuss far
- Arrh ela
- Brom mol
- Ambl ser
- Xant aur
- Barb tri

U
- Cand aur
- Tort mur
- Calo cit
- Hedera
- Leci sca
- Aspi cin
- Xant can
- Leca dis
- Barb con
- Cymb mur
- Rubus
- Plac nig
- Lami pur
- Leca mur
- Verr nig
- Acer pse
- Plan lan
- Holc lan
- Matt inc
- Rino gen
- Gali apa
- Poly sim

V
- Clad con
- Lepr inc

Group L(2spp.) contains the very pollution tolerant species *Lecanora conizeoides* (Gilbert 1968) which as might be expected was characteristic of the eastern regions of the transect. Amongst sites examined during the survey it also favoured the more shaded walls. Groups M(5spp.) and N(6spp.) contain mainly strictly calcicole species (Dobson 1979, Duncan 1970) which were confined within the survey area to limestone walls, for example *Protoblastinia rupestris*, *Verrucaria glaucina*, *Catillaria lenticularis*. Group N however also contains more non-lichen species, which within the survey were more often found on damper walls or walls with some soil accumulation. Groups O(4spp.) and P(3spp.) again contain mainly calcicole species, but which in some cases also favour moister situations, for example *Polypodium vulgare*, *Collema tenax*.

Group Q(4spp) is another group of species which are known to show considerable pollution tolerance (Gilbert 1968, 1971) and which were found mainly to the east on the transect. Groups R(8spp.) and S(9spp.) have a variety of species, mainly of infrequent occurrence within the survey. The majority are well known as wall dwelling plants (Rishbeth 1948, Darlington 1981)and many are reliant on some moisture or soil presence to grow. No substrate preferences are apparent amongst these species.

Group T(15spp.) contains many calcicole species, for example *Lecanora campestris*, *Sedum acre*, *Asplenium* spp., which also seem to require moist conditions. These species were generally of eastern distribution, hence being found in the more polluted areas surveyed.

Group U(22spp.) also contains species which were found mainly in the east, for example *Candelariella aurella*, *Tortula muralis*, *Placynthium nigrum* are known to be sulphur dioxide pollution tolerant (Gilbert 1968,1971). Some are known to favour nitrogen enriched sites, eg. *Candelariella aurella*, *Xanthoria candelaria*, *Caloplaca citrina* (Brightman and Seaward 1977), and are consequently often associated with urban or roadside walls. Many are calcicoles whilst the the bryophytes and higher plants amongst them are those associated with moister conditions.

Group V(2spp.) contains the highly sulphur dioxide tolerant species *Cladonia coniocraea* and *Lepraria incana* (Gilbert 1968). Both of these species were found primarily on moist, shaded walls in the east of the transect.

Thus the recurrent groups of species identified by the TWINSPAN analysis appear to have be determined by three principal attributes of the habitat, water relations, pollution and substrate type. These can thus be viewed as being amongst the most important ecological factors influencing the plant communities on walls in the area surveyed.

The classification of the samples by TWINSPAN

A summary of the tabular arrangement by TWINSPAN is shown in figure III. It follows that of Adam et al (1975). The diagram shows the overall abundance of members of each species group in the samples of each sample group, the groups being derived from the TWINSPAN classifications. The groups of species and samples are shown in figures II and IV. If each member of a species group occurred in each sample of a sample group the value plotted in figure III would be 100%, and conversly if none of the species group occurred in any of the samples of the sample group it would be 0%. This figure takes no account of the abundance of the species in samples, only their presence or absence. Figure III provides a simple summarisation of the data allowing an easier interpretation. Having already examined the character of the species in each species group it is possible when examining the differences between the species contents of the sample groups to make inferences about the ecological character of samples in these groups.

For example the diagram shows quite clearly the different abundances of many species groups in the two groups of samples first divided by TWINSPAN. The split of groups A to L from groups M to U reflects the abundance of species groups A to L in sample groups A to L and their relative rarity in sample groups M to U.

The indicator species for this first split were <u>Huilia tumida</u>, <u>Lecanora intricata</u>, <u>Parmelia saxatilis</u>, <u>Acarospora fuscata</u> and Algae for groups A to L, and <u>Lecanora dispersa</u> and <u>Tortula muralis</u> for groups M to U. The lichens amongst the indicator species for groups A to L are mainly species of sandstone or other acidic substrates, whilst <u>Lecanora dispersa</u> is more of a calcicole species (Dobson 1979).

The smaller sample groups, M to U, contain about one third of the samples. They contain many of the lower numbered samples, indicating a predominance of eastern samples, the survey having started in the east and worked westwards. Walls in the east were mainly built of calcareous materials and many had calcareous mortar used in their construction. <u>Lecanora dispersa</u> and <u>Tortula muralis</u> show fairly high constancy for this group and particularly for <u>Tortula muralis</u> a high degree of fidelity also. Many of the other species found on these walls are known to be tolerant of, and common in areas with high levels of sulphur dioxide pollution eg. <u>Xanthoria candelaria</u>, <u>Lecanora dispersa</u>, <u>Tortula muralis</u>, <u>Candelariella aurella</u> (Gilbert 1960,1980, Duncan 1970). These species are comparatively rare or absent in samples of groups A to L, samples which come from further west along the transect in the main and are hence subject to lower pollution levels than are encountered in the west of the region (Gilbert 1968,1971).

Within these groups M to U TWINSPAN distinguishes three major subgroups. Group U is first split off from the rest (see figure IV). Group U contained walls with either some shade or a better water suppply, reflected by the abundant presence of <u>Hypnum cupressiforme</u> and of various higher plants. Groups M to P and Q to T were then separated. The indicator

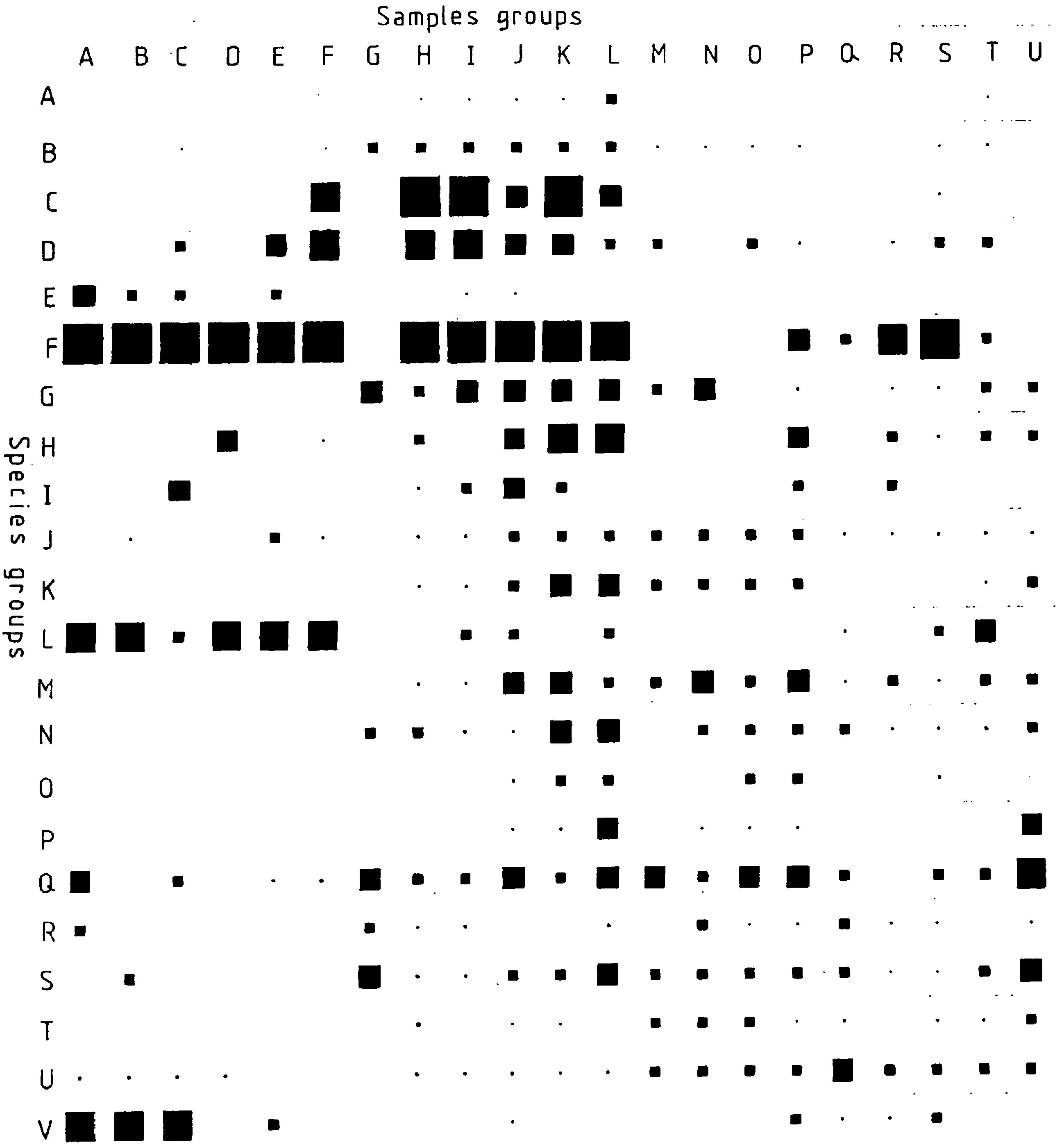


FIGURE III

Summary of TWINSPAN tabular rearrangement

0

1 · >0 - 5%

2 ▪ >5 - 20%

3 ■ >20 - 45%

4 ■ >45 - 60%

5 ■ >60 - 100%

species for this division were *Schistidium apocarpa*, *Hypnum cupressiforme*, *Grimmia pulvinata*, *Lecanora rupicola* and *Protoblastinia rupestris*, in groups M to P and Algae and *Lecanora dispersa* in groups Q to T. In general groups M to P contained damper and more calcareous walls than groups Q to T, the walls either being composed of concrete, limestone or similar materials, or with a considerable amount of mortar present. The great occurrence of calcicoles on these walls reflects their composition. This group was also more western in distribution than groups Q to T, the majority of the sample numbers being between 100 and 200, compared to groups Q to T withall except one sample number below 100. Groups Q to T were generally walls from the most eastern part of the transect, east of Durham. They would thus experience the highest levels of sulphur dioxide pollution (Gilbert 1968) and the lowest rainfalls (see figure VI). These walls generally had the least diverse flora perhaps as a direct result of these conditions. Amongst the species only Algae and species group U acchieve any consistant presence on these walls. Group U contains many species and few of these maintain any consistent presence individually. However *Lecanora dispersa* is almost 100% constant for these walls.

Amongst groups A to L, four main subgroups can be seen. Groups A to F are first separated from groups G to L. Groups A to F have as indicator species *Lecanora conizeoides*, *Lepraria incana* and *Cladonia coniocraea*. The first subgroup, groups A to C, has *Lepraria incana* as a constant species, whilst the second subgroup, groups D to F, has *Lecanora conizeoides* as a constant species. These species are also indicators for these subgroups. Groups A to F contain walls from the east of the transect, with almost all sample numbers below 100. Shading is a feature of these walls and this is reflected by the presence of large amounts of Algae (due to the damper conditions and lessening of direct sunlight) and of species which are known to prefer damper conditions (Dobson 1979, Duncan 1970). Groups M to T thus contain the dryer, and more calcareous eastern walls, whilst groups A to F contain the damper, and more acidic eastern walls.

Groups G to L represent the typical drystone walls of the west of Durham. Sample numbers are generally very high indicating their western distribution. Indicator species were *Huilia tumida*, *Lecanora atra*, *Parmelia saxatilis*, *Lecanora intricata* and *Candelariella vitellina*. Two subgroups within this group consist of groups G to I; generally sandstone walls with the typical sandstone lichens *Lecanora polytropa* and *L. intricata* (Dobson 1979) as indicators; and groups J to I; generally western walls with a mixture of sandstone and limestone in their construction materials. *Protoblastinia rupestris* is a good example of a calcicole lichen (Dobson 1979) which was a particularly good indicator for this group. The limestone influence in this group of walls is also reflected by the large presence of species grpup M (see figure III) which contains many strict calcicole lichen species such as *P. rupestris*, *Caloplaca heppiana*, *Verrucaria glaucina* and *Catillaria lenticularis* (Dobson 1979, Duncan 1970).

This latter subgroup of walls shows the greatest diversity of species, perhaps mainly as a consequence of the walls being generally pollution free. They are also, however, damper than those in the east (see figure VI) and their being of mixed acidic and calcareous substrates will also tend to enhance the species diversity.

Within these two subgroups further subdivisions separate sample groups H and K, generally containing samples from higher altitudes within the county, from sample groups I and J, with samples mainly from lower altitudes, indicating that altitude is another factor determining community composition on walls.

Plotting of the sample groups onto a map of the transect helps to confirm and make clear some of the geographical groupings (see figure V).

East of Durham City there is a mixture of groups Q to S already shown by TWINSPAN to be indicative of high pollution. Few samples were taken in this area as it was felt it would be of lesser interest than the western area, which subsequently proved correct. No particular groups of walls can be seen reflecting the mixture of wall types found in the area.

From Durham City to Wolsingham there is again a mixture of substrates and communities encompassing many small groups. However they tend to come from lesser polluted groups than east of Durham City.

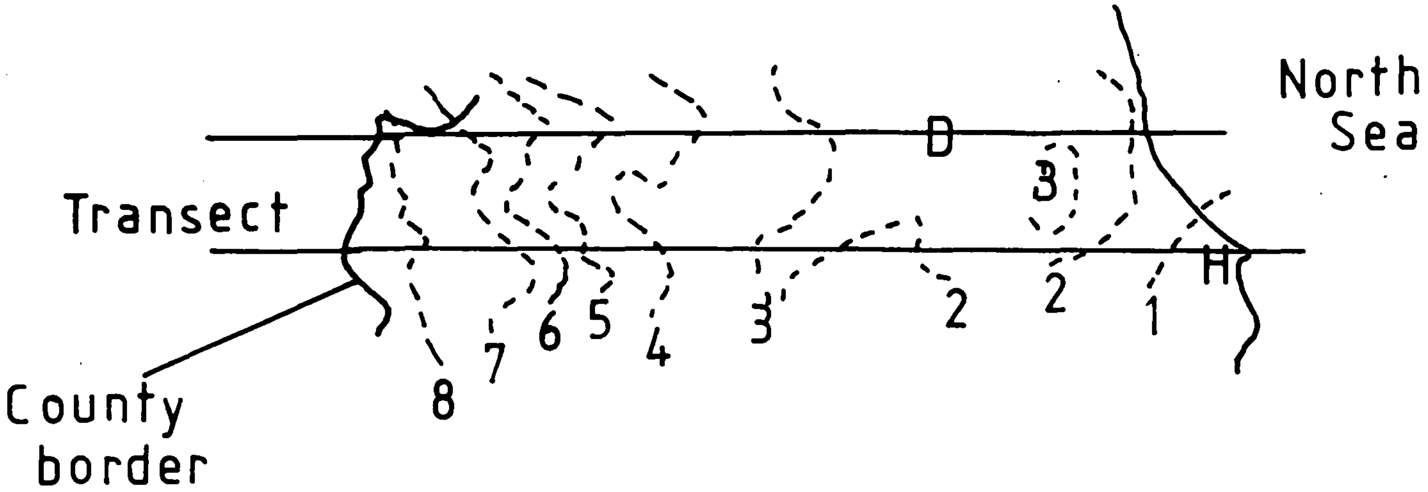
However west of Wolsingham a clear picture emerges. Around Frosterly and Stanhope there is a predominance of groups J and P. These are limestone influenced communities, and there were indeed a large number of limestone walls in the area, carboniferous limestone being particularly available here. At Eastgate the cement works may exert an influence on the surrounding walls. Some examples of limestone species on sandstone walls were found downwind of the works and this area was also remarkable for the striking abundance of Xanthoria sp. and Caloplaca sp. (bright orange coloured lichens) on wall tops. The works does put out a considerable quantity of limestone dust and it is thought that this may influence the local walls. Further investigation of this topic may be interesting.

Group I is a widespread group but appears to be found at higher altitudes away from the Wear valley bottom. Groups K and H are clearly western groups possibly influenced by the moister more oceanic climate (see figure VI), and increasing altitude. Group H tends to occur on the

FIGURE V

Geographical positions of TWINSPAN sample groups

FIGURE VI Rainfall in the transect



1 - 25 inches/year
2 -27·5 "
3 -30 "
4 -35 "
5 -40 "
6 -45 "
7 -50 "
8 -60 "

D = Durham

H = Hartlepool

Adapted from Ordinance Survey map of Annual Average Rainfall 1916 - 50 higher ground, and Tremolecia atrata of species group B is a typical high altitude, pollution intolerant lichen which was found on several of the walls in this group.

The geographical plot helped to further indicate the importance of pollution, substrate and altitude to the flora of walls.

The ordination of the samples by DECORANA

A plot of the sample positions with respect to the first and second ordination axes is presented as figure VII. Although further axes were extracted no interpretable patterns wre found in plots using the third and subsequent axes. Despite the complex picture overall some clear trends can be seen.

Similarities to the classification of samples can be seen in the tendency for low and high sample numbers to segregate, and in a cluster of high sample numbers in the middle left of the plot corresponding to the grouping of samples by the TWINSPAN classification into groups H to K (see figure IV). This can be seen more clearly in figure VIII where the classification group for each sample is plotted rather than its number. Here also the less clear grouping of sample groups M to U can be seen, these samples tending to group on the right hand side of axis 1. The segregation of the high and low sample numbers along axis 1 does suggest again that the east to west position of the sample along the transect is of greatest importance in determining the community represented.

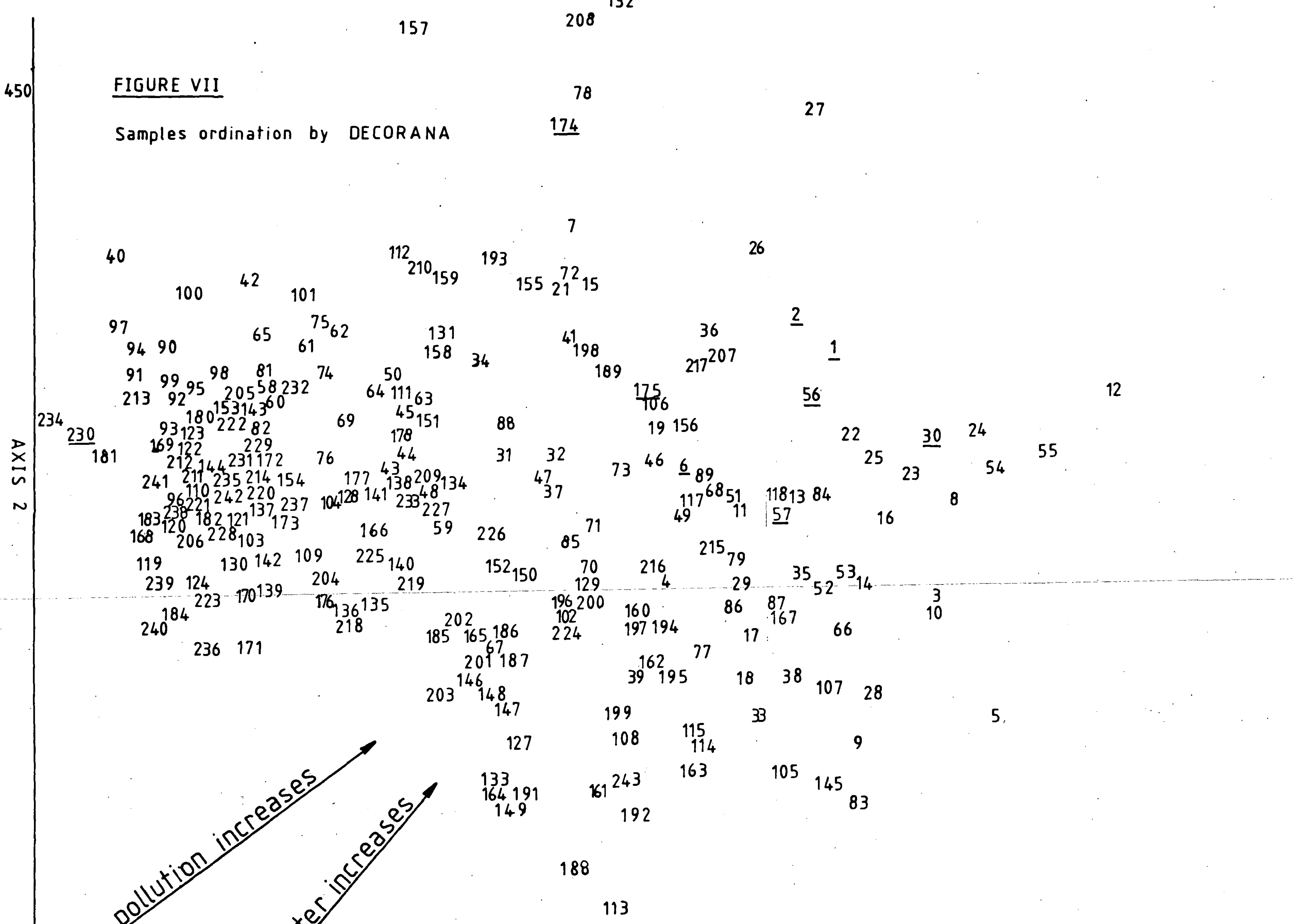
Factors known to vary along the transect line are rainfall, sulphur dioxide pollution, construction materials and altitude. Rainfall is lower in the east of the transect (see figure VI), and higher in the west. The most eastern sample groups are P, Q, R and S and from figure VIII it can be seen that these samples aggregate on the left of axis 1. The group of samples with numbers in the nineties would at first not appear to follow this pattern, but from the TWINSPAN analysis we have already seen that these groups represent samples with affinities to some of the western samples in that they had a higher level of moisture present, often due to shading. I would suggest that water availability follows approximately the arrow shown on figure VII and not axis 1 exactly.

Sulphur dioxide pollution is greater in the east (Gilbert 1968) and decreases to the west. It has a major effect on the flora, particularly on the lichens. From the data it is suggested that sulphur dioxide pollution increases along approximately the line of the arrow shown in figure VII. The important fact to be gathered from this plot is that the east to west position of the sample is of major importance in determining its flora.

Walls of different materials are somewhat clustered in the plot. Sample groups H and I, which were generally constucted of sandstone, are clustered at the left of the plot, whilst groups J and K, with more limestone used in their construction, are gathered to the right of these groups (see figure VIII). Substrate can thus also be seen as an important factor in affecting the flora, although substrate differences are correlated with moisture and pollution gradients to an extent since they vary systematically along the transect.

FIGURE VII

Samples ordination by DECORANA



It is easier to look at the influence of aspect, and the differences between tops and sides of a wall using the ordination plot, than it is using the TWINSPAN classifcation. This is illustrated in figure IX. Calculations

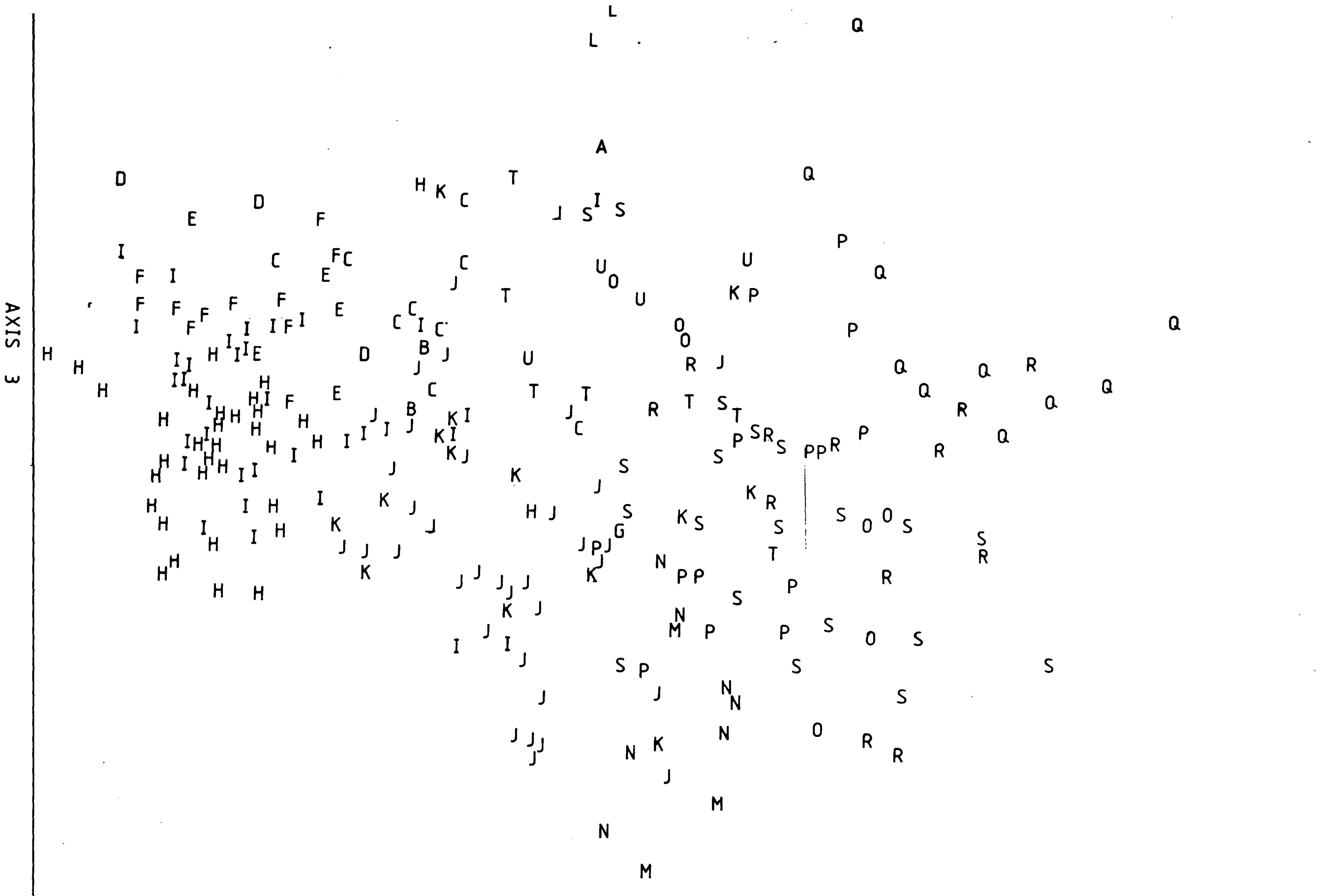
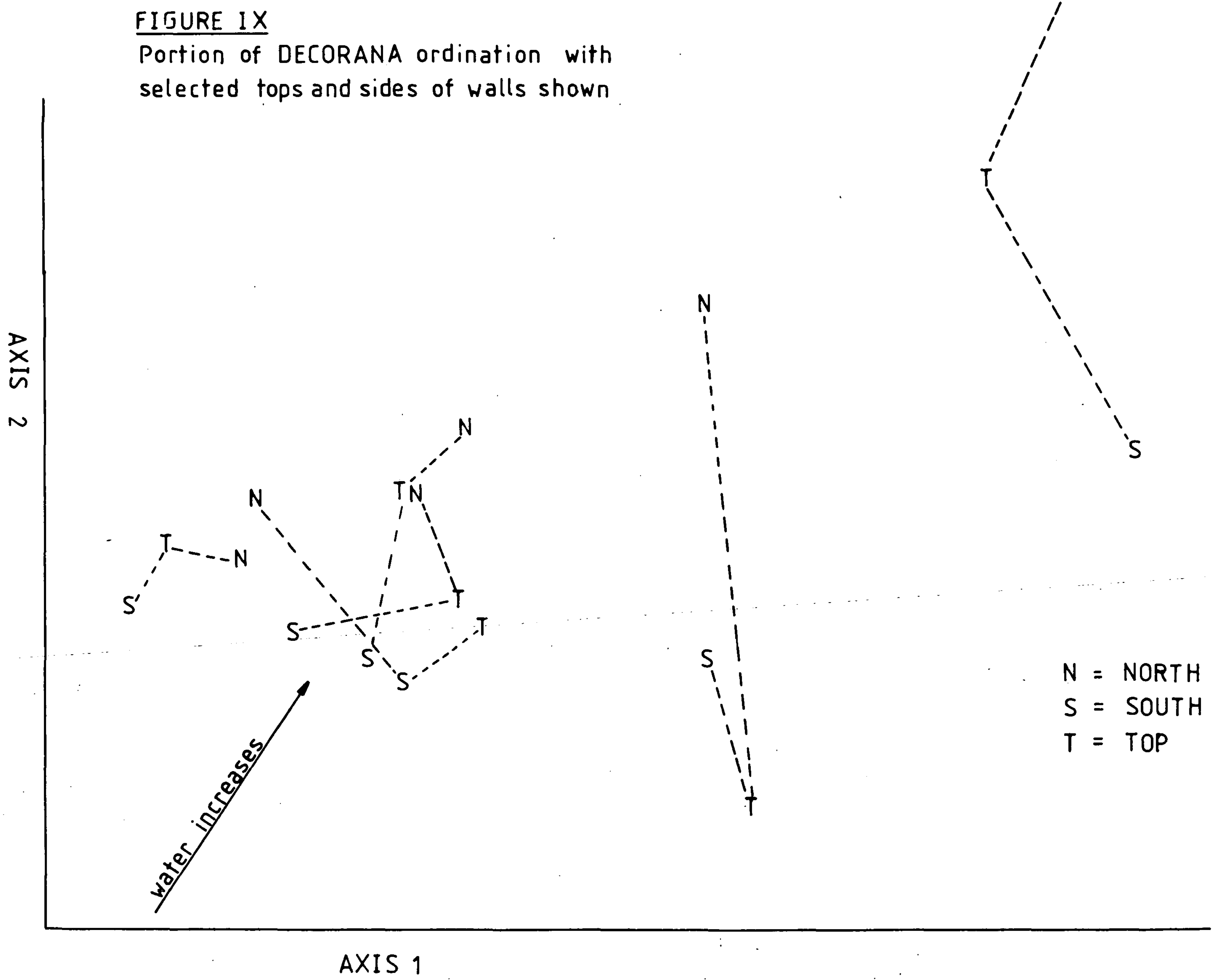

AXIS 3

FIGURE IX

Portion of DECORANA ordination with selected tops and sides of walls shown



of the proprotion of tops and sides in each sample group show no significant deviations from the overall proportion in the survey. However visually in several cases tops of walls were clearly different, an example being the growth of Parmelia saxatilis on many wall tops. Whilst it also grew on wall sides it was far more luxurient and abundant on wall tops. Similarly Pseudoevernia furfuracea was far more abundant on wall tops, often forming a distinct community with Parmelia saxatilis.

By joining the two sides and top of a wall by lines, on the ordination plot it is possible to rapidly see the effect of aspect on walls, and the differences between tops and sides. Bearing in mind the dampness gradient of the ordination from the selected examples on figure IX it is possible to see that the north side of a wall appears to be generally wetter. This would be logical, because the south side would get more direct sunlight, increasing dessication. The top of the wall is variable in relation to the two sides, but I feel generally shows more resemblance to the south facing side, it too getting a lot of direct sunlight. The communities of species which prefer horizontal surfaces, such as Parmelia saxatilis, Pseudoevernia furfuracea, Physica spp. and Lecanora muralis are not strongly brought out in this analysis, but would merit further investigation.

The ordination of the species by DECORANA

This ordination was the least successful of the analyses performed. The most useful plot obtained used the first and third ordination axes; other axes were not interpretable in terms of any known environmental gradient. It appears that the large number of rarities (in terms of the survey) has tended to obscure some of the real trends but it is possible to draw some conclusions from the plot.

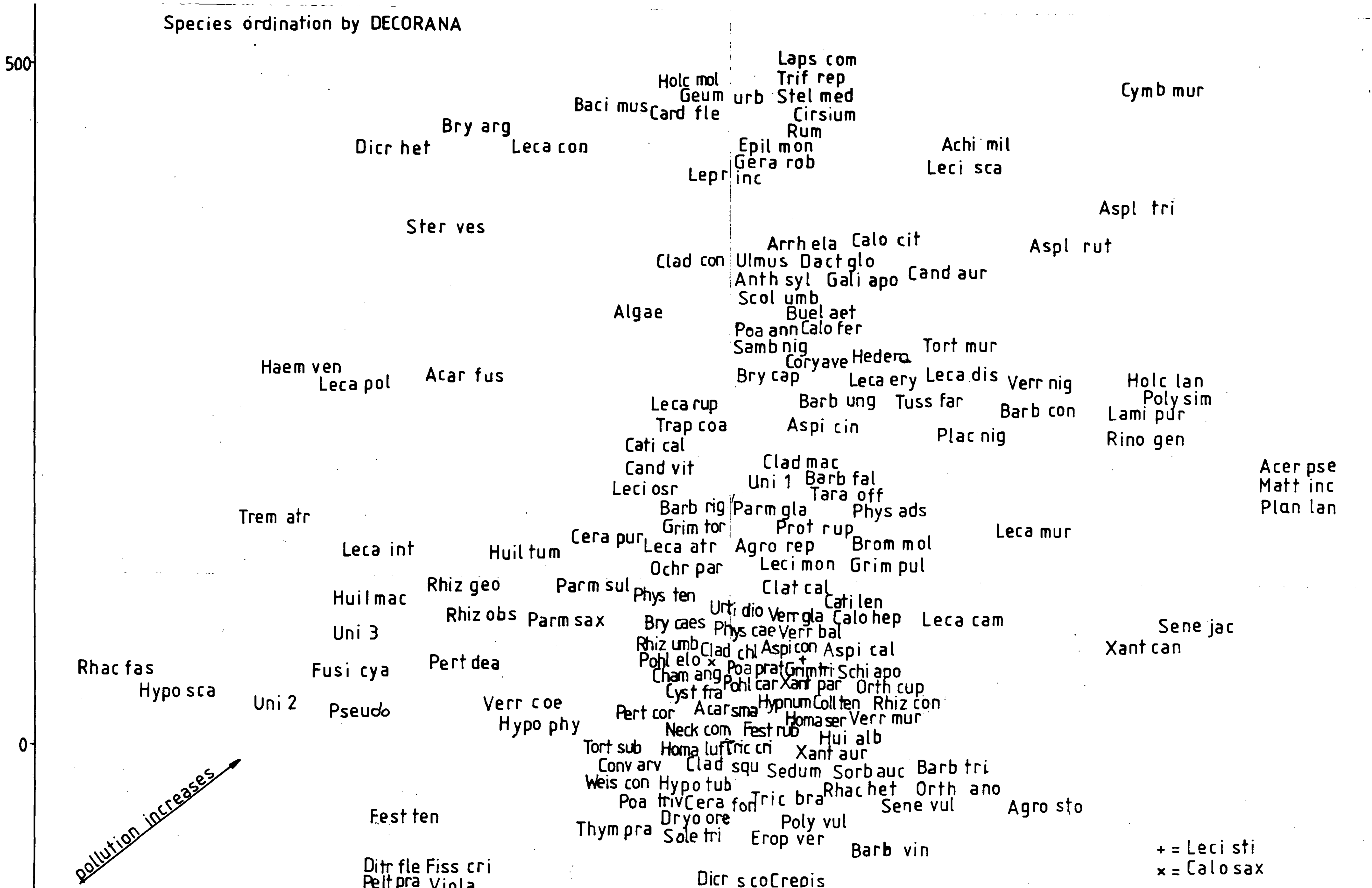
The clearest observable gradient is that of substrate preference. On the far left side of axis 1 are a group of species which were typical of the acidic, sandstone walls eg. Rhacomitrium fasiculare, Tremolecia atrata, Lecidea macrocarpa; species which are known to prefer acidic substrates (Dobson 1979, Duncan 1970). On the far right of axis 1 the species are those which were found on calcareous substrates, eg. Asplenium spp., Verrucaria nigricans, Rinodina gennarii ; again species known to prefer such habitats (Dobson 1979, Duncan 1970). In the centre of axis 1 differentiation between species found on different substrates is not seen.

Superimposing the groups from the TWINSPAN classification of species onto the ordination (see figure XI) helps confirm these interpretations. Species group B, which contained species mainly found on sandstone during the survey, and species group U, which contained species which were almost all found only on calcareous substrates, can be seen to occur on opposite sides of the plot.

A trend in response to sulphur dioxide pollution can also be seen. Species found in the west only of the transect, with lower pollution levels (Gilbert 1968), are often found on the left of axis 1, eg. Tremolecia atrata, Rhizocarpon geographicum, Haematomma ventosum; whilst species which were typical of the more polluted eastern walls eg. Lecanora muralis, Xanthoria candelaria, Lecanora dispersa, Tortula muralis; are principally found on the right hand side of the plot. The arrow shown on figure X represents the infered direction of the gradient of sulphur dioxide pollution through the ordination space.

It is virtually impossible to detect any consistent trend in the effect of moisture; species found only where moisture levels were higher, eg. Acer pseudoplatanus, Festuca tenuifolia, Holcus mollis, Urtica dioica, are spread far and wide on this plot.

Thus it seems from this analysis that sulphur dioxide pollution and substrate are the two most important factors determining the occurrence of species on walls along the transect,and hence their position on this plot.


Species ordination by DECORANA
500
0
Laps com
Holc mol
Trif rep
Geum urb
Stel med
Cymb mur
Baci mus
Card fle
Cirsium
Bry arg
Rum
Dicr het
Leca con
Epil mon
Achi mil
Gera rob
Leci sca
Lepr inc
Aspl tri
Ster ves
Arrh ela
Calo cit
Aspl rut
Clad con
Ulmus
Dact glo
Anth syl
Gali apo
Cand aur
Scol umb
Algae
Buel aet
Poa ann
Calo fer
Samb nig
Tort mur
Hedera
Coryave
Haem ven
Acar fus
Bry cap
Leca ery
Leca dis
Verr nig
Holc lan
Leca pol
Poly sim
Leca rup
Barb ung
Tuss far
Barb con
Lami pur
Trap coa
Aspi cin
Plac nig
Rino gen
Cati cal
Clad mac
Acer pse
Cand vit
Barb fal
Uni 1
Matt inc
Leci osr
Tara off
Barb nig
Parm gla
Phys ads
Plan lan
Trem atr
Grim tor
Prot rup
Leca mur
Cera pur
Leca int
Huil tum
Leca atr
Agro rep
Brom mol
Leci mon
Grim pul
Ochr par
Rhiz geo
Parm sul
Clat cal
Phys ten
Cati len
Huil mac
Urti dio
Verr gla
Calo hep
Leca cam
Rhiz obs
Parm sax
Sene jac
Bry caes
Phys cae
Verr bal
Uni 3
Rhiz umb
Clad chl
Aspi con
Aspi cal
Xant can
Pohl elo
Rhac fas
Poa prat
Grim tri
Schi apo
Fusi cya
Pert dea
Cham ang
Pohl car
Xant par
Orth cup
Hypo sca
Cyst fra
Uni 2
Verr coe
Acar sma
Hypnum
Coll ten
Rhiz con
Pseudo
Pert cor
Homa ser
Verr mur
Hypo phy
Neck com
Fest rub
Hui alb
Tort sub
Homa luf
Tric cri
Xant aur
Conv arv
Clad squ
Sedum
Sorb auc
Barb tri
Weis con
Hypo tub
Rhac het
Orth ano
Poa triv
Cera fon
Tric bra
Sene vul
Agro sto
Fest ten
Dryo ore
Poly vul
Thym pra
Sole tri
Erop ver
Barb vin
Ditr fle
Fiss cri
Dicr sco
Crepis
Pelt pra
Viola
pollution increases
+ = Leci sti
x = Calo sax

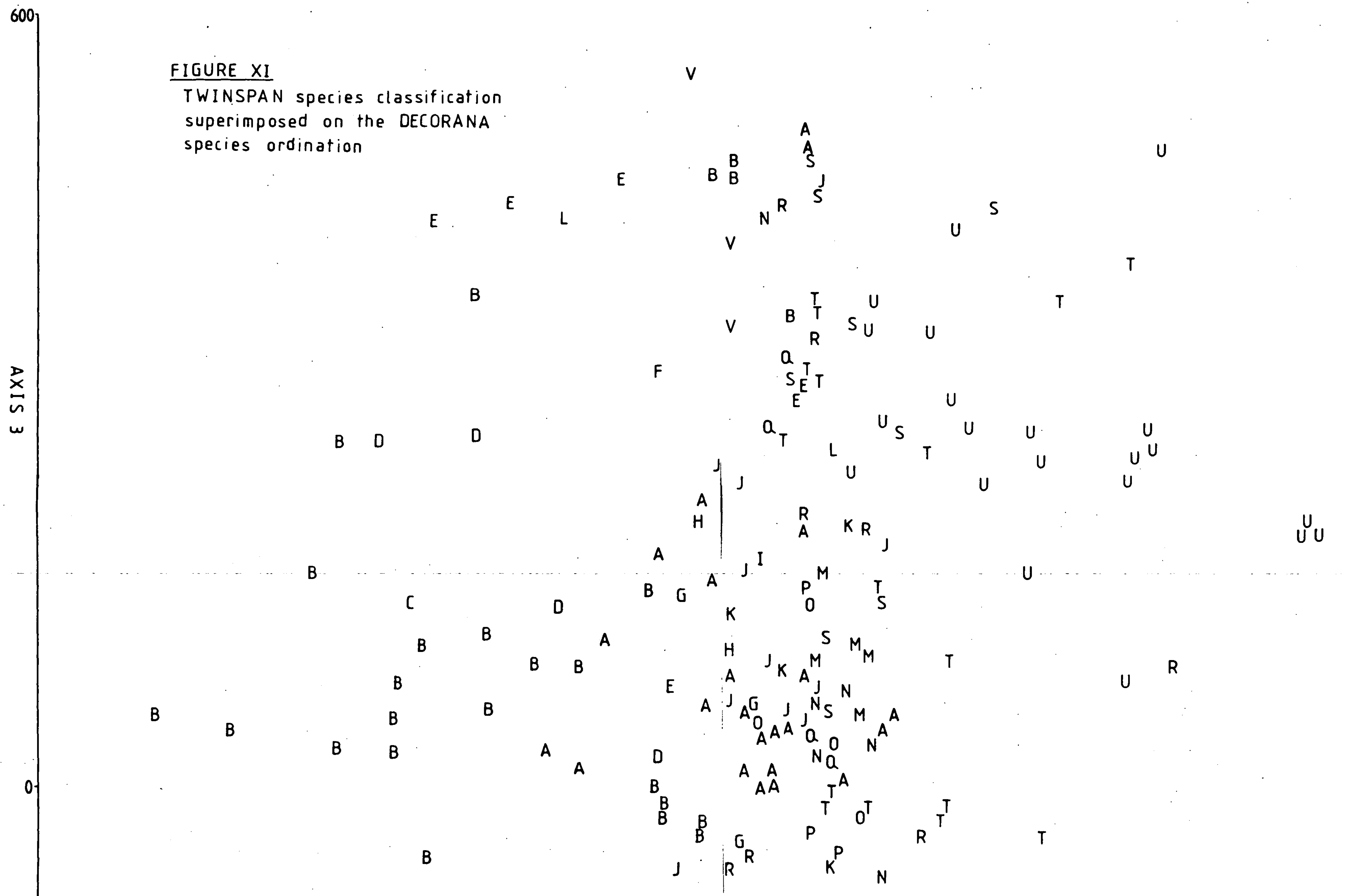


FIGURE XI
TWINSPAN species classification superimposed on the DECORANA species ordination

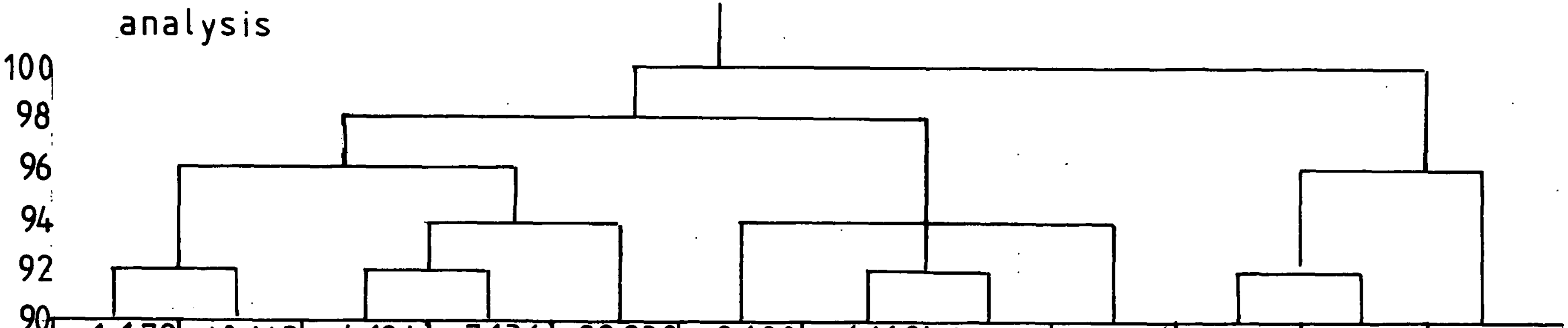
The non-biological data analyses

These analyses were performed in order to discover whether there were distinct groupings of walls on the basis of their non-biological attributes, which could be related to the groups based upon the communities of plants found on the walls. However in general it proved difficult to find such relationships.

The minimum variance cluster analysis classification of the data is shown in figure XII. The results from this analysis were disappointing. Figure XII shows that there was no tendency for low sample numbers to group together as there was with TWINSPAN's classification of the biological data. In fact there was no grouping which in any way resembled a TWINSPAN group and indeed many samples placed close together by TWINSPAN were placed far apart in this analysis.

FIGURE XII

Minimum variance cluster analysis



1,179	10,143	4,124	7,136	29,238	2,180	6,169	17,174	9,216	65,230	13,144	14,103
190, 43	162, 31	105,226	135, 73	151, 34	61,187	100,201	174,182	196, 99	200,126	83,160	54,219
118,174	212,109	57,137	225, 98	159, 77	79,150	23,239	72,224	49,228	227, 27	39,184	69,198
26,155	241, 12	62,211	19, 181	88, 176	97,194	149, 42	25,141	41,121	140, 44	188, 48	221, 16
240, 3	127,122		189, 93	75,115	223, 8	132,220	94,111	45, 67	102,101	170,114	165,214
104, 53	37,217		145,106	120, 192	112,178	52, 70	78,203	215, 5	197,231	186, 21	95,110
237,107	76,108		233, 87	234, 30	51,172	236,116				232,131	175, 33
134, 24	204		163,148	210, 92	80,166	139, 81				86,161	128,191
222, 63			18,218	195,206	243	185, 11				146, 55	235, 40
207, 66			74, 22	36,202		123,125				68,173	85,142
199, 89			158,154	82		28,205				91,209	50,138
59,152			58,213			117,113				32,208	71,153
15,229						157,171				47,168	90
96, 35						193, 20					
64,147						156,242					
56,183						46,119					
129,133						84,177					
						38,167					
						60,130					

The variables which determined the groupings in this analysis are clearly not those which were important in determining the major patterns in the plant communities of the walls. From the previous analyses it has been suggested that these are substrate, moisture, and sulphur dioxide pollution. The non-biological dataset contained 23 variables in all, and it seems that the few variables relating to the substrate, polution levels and water availability have been overshadowed by those relating to less biologically significant features, such as the height and width of the wall.

Plotting the minimum varience cluster analysis sample groups onto a map of the transect did not reveal any links between the geographical position of the sample and its grouping. Similarly plotting the groups onto the DECORANA ordination of samples using the biological data revealed no patterns. These figures are not included in this report.

The ordination of samples by principal coordinates analysis using the non-biological data proved more useful. The plot which showed the clearest patterns amongst the samples was that of the second and third ordination axes. Again, however close examinaion showed no similarity to te patterns in thr biological data. Axis 2 divided the samples according to whether they came from the or side of a wall, whilst axis 3 split the samples into two groups mainly using the shade and moisture variables. Despite the biological significance of these factors the overall lack of biological significance in the groups is probably explained by the fact that the biologically more significant factors of substate and sulphur dioxide pollution were not significantly reflected in this analysis.

The most useful plot in terms of biologically significant pattern was that of axes 1 and 3. Superimposition of the TWINSPAN sample groups onto this plot (figure XIII) demonstrates this; there is considerable clustering of samples within these groups derived using the biological data. On te right hand side of the plot there is a cluster of sample groups H, I, J and K. These sample groups were placed together by the TWINSPAN classification and have been similarly related by the principal coordinates analysis. Most of the TWINSPAN sample groups O, P, Q and R are loosely clustered on the opposite side of the plot. This is a situation paralleled by the DECORANA ordination of the samples (see figure VIII). Here these groups are also placed apart on the ordination. Thus we can postulate that the non-biological data variables which separate the samples along the first axis in the principal coordinates analysis do have some importance in determining the biological flora of the walls.

Axis 4 appears to show some relation to wall substrate. The substate tends to change along it as follows. At the bottom of the axis walls tend to be constucted of coarse sandstones, then of medium sandstone, in the middle of fine sandstone and further up of calcareous materials, while at the top are mixtures of sandstone and limestone. Whilst not yielding as much insight as was hoped, the analyses of the non-bilogical data have helped emphasise the importance of east ot west position along the transect, independant of the abiotic properties of the wall, in determining wall flora. They have also illustrated the important role of

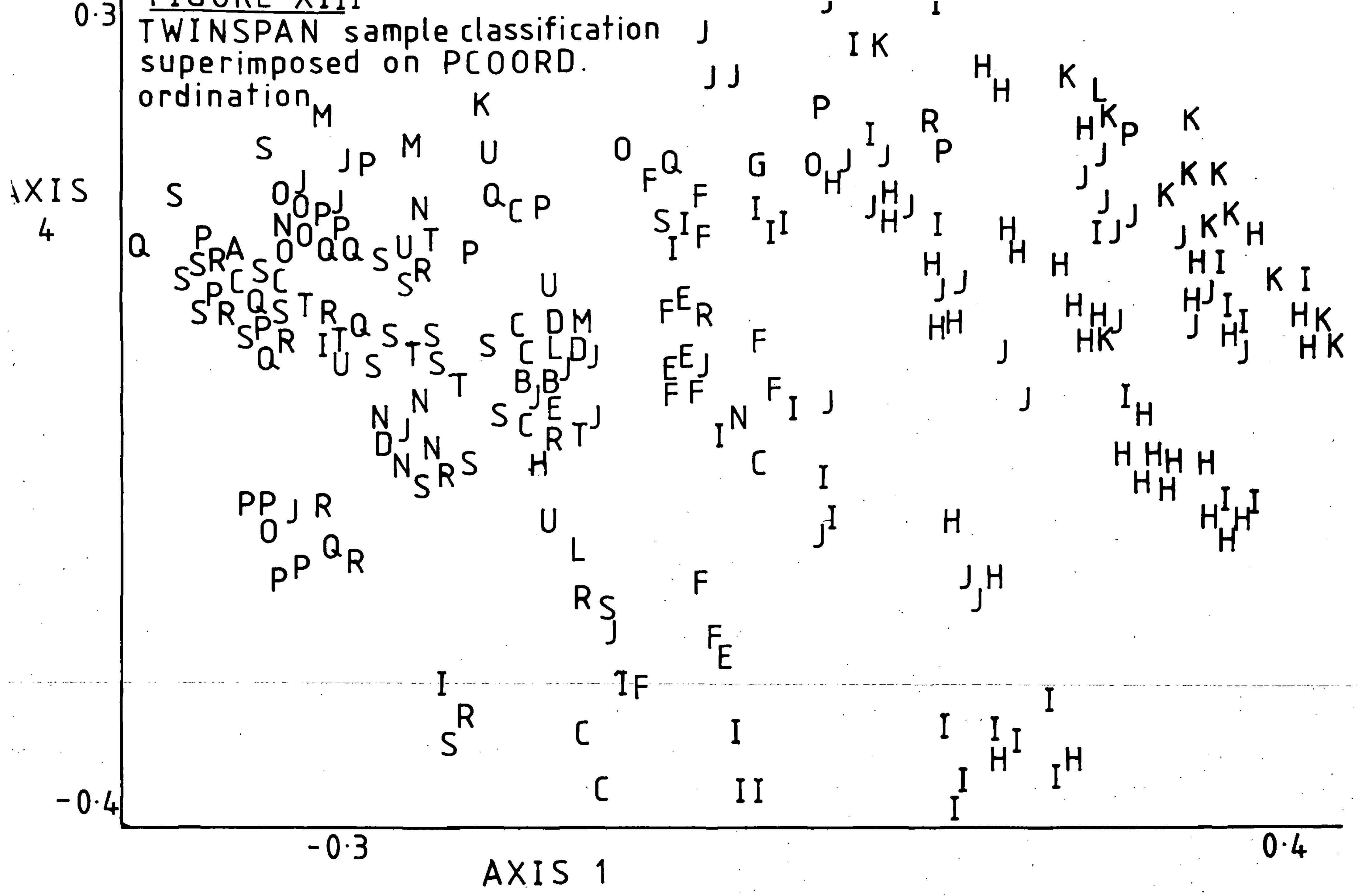


FIGURE XIII

TWINSPAN sample classification superimposed on PCOORD ordination the wall constuction materials in determining its flora.

The typical wall communities in Co.Durham.

Sandstone walls

With the high sulphur dioxide pollution in the east of the transect typical sandstone communities are very simple. Algae and Lecanora conizeoides are perhaps the two commonest organisms. Lecidea tumida, Candelariella vitellina and Scoliciosporum umbrinum are also frequent. Where conditions are damper or more shaded, algae tend to increase their dominance and Lepraria incana can occur. Caloplaca citrina and Hypnum cupressiforme also prefer moister conditions out of direct sunlight. Where there is any soil build up Cladonia coniocraea and C.macilenta will often colonise. Mosses such as Barbula convoluta and Bryum capillare are found on tops of walls and ledges where conditions are damp enough.

Mortar when present on a wall can act as a refuge for several calcicole species. Xanthoria candelaria, Lecanora dispersa and Protoblastinia rupestris can all be found on mortar and Tortula muralis is a moss often growing from mortar. Asplenium ruta-muraria and A.trichomanes can also grow from cracks in mortar on sandstone walls.

In the area from the east of Durham City to Wolsingham pollution is more moderate and other species are able to colonise sandstone walls, while the species described above will still be frequent. Lecanora polytropa, L.intricata and Acarospora fuscata become extremely common and abundant, found on virtually every sandstone wall. Parmelia saxatilis becomes abundant on wall tops and is often accompanied by Pseudoevernia furfuracea. Both of these species prefer horizontal surfaces and have difficulty in colonising vertical wall sides. Lecidea tumida increases in frequency and Lecanora rupicola becomes an occasional species. Lecanora atra and L.campestris are not uncommon on wall sides. Where soil builds up Cladonia chlorophaea is often found. In damper conditions Hypnum cupressiforme and Homalothecium sericeum can cover large areas of walls. Mosses such as Dicranella heteromalla, Barbula fallax, B.vinealis and Ceratodon pupureus are occasional. When mortar is present species such as *Xanthoria candelaria*, *Protoblastinia rupes* *Verrucaria nigrescens*, *V.muralis* and Tortula muralis will be found.

In the cleaner air west of Wolsingham the above sandstone species are still found although some are much less frequent. *Lecanora conizeoides* is virtually lost to walls for example. *Acarospora fuscata*, *Lecanora polytrop* *L.intricata* and *Lecidea tumida* are all sill very abundant but other species also occur. *Fusidea cyathoides* becomes fairly frequent, *Lecidea macocarpa* increases towards the west, *Rhizocarpon geographicum* is found on virtually every sandstone wall although never in vast quantities and *Rhizocarpon obscuratum* becomes very frequent.

On damper lowland wall tops *Parmelia sulcata* and *Hypogymnia* spp. can be found with *Parmelia saxatilis*. At the highest altitudes *Tremolecia atrata* is a distinctive species.

Calcareous walls

This heading includes a variety of types of substrate, but the most consistently met was lower carboniferous limestone. Some magnesian limesto walls were however found in the east but these did not have a particularly rich flora. This was probably due to local air pollution and the unsuitability of the substrate itself. Typical species from the few walls examined appear to be *Lecanora dispersa*, *Verrucaria muralis*, *Placynthium nigrum*, *Xanthoria candelaria* and *Verrucaria nigrescens*. Other lichens such as *Protoblastinia rupestris* and *Rinodina gennarii* were also found. Amongst the non-lichens *Tortula muralis* and *Taraxacum officianale* seem to be common. The substrate appears to be generally too soft and unstable to support a rich flora. Slower growing lichens would find difficulty in staying attached to the crumbling material.

The species mentioned above are all typical limestone species. In the most polluted areas *Lecanora dispersa*, *Placynthium nigrum*, *Candelariell* *aurella* and *Xanthoria candelaria* are the most frequent species. *Tortula muralis* is often the only moss. Where pollution is slightly less *Tortula* muralis is often joined, particularly on wall tops by Grimmia pulvinata and Schistidium apocarpa. These three mosses are a commonly recognised wa community (Darlington 1981, Watson 1968). All the above species can be found on limestone, on mortar and on other calcareous substrates.

Barbula convoluta, Bryum capillare and B.caespiticium are also not uncommon mosses on calcareous walls particularly where some moisture is available. Algae are found on calcareous walls but appear to prefer the less alkaline walls. Clathroporina calcarea is often found in polluted areas on limestone walls but only in its sterile thin crustcse form.

As pollution decreases west of Durham City the above species are still common, but others are able to colonise. Aspicilia calcarea and A.contort are found and Protoblastinia rupestris and Verrucaria muralis become more common. Physica spp.are now found but only become fertile further west. Physica spp. when common can be indicators of nutrient enriched conditions, and like Lecanora muralis find concrete a suitable substrate.

Further west, around Wolsingham Rinodina gennarii and Candelariella aurella become less common. The mosses Tortula muralis, Grimmia pulvinata Schitidium apocarpa can still be found on wall tops, but are joined by othe species the most common of which are Orthotrichum anomalum and Trichostomun brachydontium.

At Wolsingham and westwards Ochrolechia parella is found and will cove quite large areas on many walls. Catillaria lenticularis is found for the first time, and Aspicilia calcarea and A.contorta increase in frequency.

Typical limestone walls west of Wolsingham particularly around Stanhop have Verucaria muralis, V.glaucina, Clathoporina calcarea, Protoblastinia rupestris and Lecidea monticola which becomes more common further west.Lecan dispersa,Placynthium nigrum and Xanthoria candelaria are still found but ar not as abundant as in the east.

Around Eastgate under the influence of the cement works on wall tops

Xanthoria parietina, X. aureola and Caloplaca sp. are very abundant, and Protoblastinia rupestris generally increases its surface coverage. In the far west Rhizocarpon umbilicatum becomes occasional and the uncommon Verrucaria coerulea was found, and may be a constituent of wall communities in the area.

Little mention has been made of higher plants in this look at typical wall communities; this is not an oversight. Higher plants were generally not typical members of wall communities in this survey area as can be seen from the list of the most common species.

The importance of individual factors

Substrate

This is possibly the most important factor. Whilst factors such as pollution and water can drastically alter a walls flora, the ultimate constraint upon the flora is to some subset of that set of species which are able to grow on the particular substrate(s) of which the wall is composed. Lichens are most affected by substrate and the members of acidophile and calcicole groups have already been discussed. Angiosperms are probably the least affected because of the adaptable nature of the species which are able to colonise walls.

As has been seen already the substrate of walls is closely related to the local geology. However in urban areas this becomes less clear with the proliferation of substrates such as brick, and rendered surfaces for example. Substrate is not just important for its pH. The other characteristics of the materials are important too. For example soft rock will be easier to colonise than hard rock. Rock that is too soft however may not provide a stable enough habitat, and this may be the case with some of the magnesian limestone walls in the present study. The availability of particular nturients in different materials is also important. The speed and manner of decay of a material affects the flora. Many species are able to colonise cracks and crevices in stone resulting from weathering, but if the stone does not weather in this way then this microhabitat is not available. For example in this survey the thinly bedded carboniferous sandstones cracked freely along the bedding planes, in contrast to the solid carboniferous limestone blocks which are not prone to such weathering.

Mortar on a wall is an important substrate. A mortared sandstone wall will have a more diverse flora than a comparable drystone wall, because of the availability of the calcareous substrate as well as the acidic one.

Atmospheric pollution

The obvious effects of air pollution seen during this survey testify to its importance. The effects of sulphur dioxide pollution on lichens are well known, but mosses too are affected and recent work on higher plants suggests that they may be affected in other ways than just presenc or absence from polluted areas such as the east of the transect (Mansfiel 1976).

The species found in this survey cover a wide range of pollution tolerances, and Gilbert (1968) has shown how wall species can be used to monitor pollution levels. Pollution does not just affect the presence or absence of individual species, but affects the diversity of whole communities. For example the 10 most easterly samples in this survey averaged only 6.3 species each, while the 10 most westerly samples averag 15.1 species each.

Sulphur dioxide is not the only pollutant. Smoke, soot, car exhaus nitrates and lead, waste from lead mines, and even the type of calcareous dust emanating from the Eastgate cement works can all affect the flora of a wall.

Water

This is another extremely important factor, mainly for taxa other than lichens. It tends to determine whether a wall supports many mosses or indeed any higher plants. Many wall species are adapted to resist dessication, as shown by the mosses *Barbula* spp.*Bryum* spp. and *Grimmia* sp However some wall species do have a particular requirement for at least s periods of wetness, such as theferns, especially for the success of their prothallus stage. Particularly successful wall plants such as *Cymbalar* *muralis*, *Parietaria* spp. and *Sedum* spp. are all well adapted for drought conditions.

The method of construction of a wall

Walls are built in a variety of ways and this clearly affects the possible flora. For example a shoddily built wall full of cracks and holes and uneven surfaces will offer far more opportunities for plants than a smooth well built wall. Another feature of importance is the presence of horizontal surfaces. Many of the typical drystone walls of Weardale have lines of larger stones which stick out of the side of the wall and act as steps. These stones provide horizontal surfaces upon which mosses and some lichens such as *Physica* spp. and *Parmelia saxatilis* are often able to grow and so colonise the 'side' of the wall.

As has already been mentioned the use of mortar offers more opportunities to colonising organisms. Modern hard cement mortars are not so good, but older lime mortars which decay more rapidly can provide cracks in which plants can grow, as well as providing a calcareous substrate. Some walls are built with soil filled centres and this can allow higher plants an opportunity for a more reliable water supply with their roots in this soil. A few walls, but an unhappily decreasing number are built with a layer of turf underneath the top row of stones. These walls as a result have an excellent flora on their tops. As an example one wall of this kind had 5 species of higher plants and 4 mosses growing on it, as well as a fine selection of lichens.

Thus it is possible to build a wall in a particular way and with the right materials so that it would be ideal for plants to grow on. Perhaps such a policy could be adopted by nature reserve managers, or other conservation minded bodies, and this could only improve sites.

Age

From the data in this survey it is impossible to comment on the effect of age. Succession on walls has been covered by previous workers in the field (Segal 1969, Darlington 1981). On almost all of the walls in this study it was impossible to fix on age.

Shade

Shade is important in two respects. Firstly it affects the water relations of a wall as already discussed and secondly when a wall is shaded species which prefer shaded conditions to direct sunlight can grow. Examples of such species are Lepraria incana, Geum urbanum and Cardamine flexuosa. Algae tend to increase their dominance in such shaded sites and lichens tend to disappear.

Surrounding area

The type of surrounding area affects the species available to colonise a wall. However, as has already been discussed, moorland species are generally unable to colonise walls well even when walls are situated on moorland. Thus it is probably the characteristics of individual species rather than the local communities which are most important. The surrounding is important in terms of the conditions the wall offers to colonising plants. For example a wall built in marshy ground will tend to offer better water relations for plants than one built on a dry bank.

Altitude

This is a factor which affects other conditions on a wall. At higher altitudes the air tends to be less polluted. Walls are likely to be wetter for longer. They will be more susceptible to frost and tend to be colder. All these factors combine to make this quite an important feature of a wall.

Aspect

Aspect has already been shown to be of some importance to the flora of a wall. Rishbeth (1948) also demonstrates its importance. As an example from this survey the different floras of the two sides of one wall are given. This was a mixed sandstone and limestone wall close to Eastgate.

Southern aspect

Algae	3 (Domin scale)
Lecanora rupicola	3
L. atra	4
Lecidea tumida	2
Pertusaria dealbescens	2
Rhizocarpon geographicum	1

Northern aspect

Algae	6
Lecidea tumida	1
Lecanora atra	2
Lecanora rupicola	2

The amount of algae is increased and of the lichens decreased. Visually the differences of the white lichens on different sides of a wall were often quite spectacular. Whereas one side of a wall could be almost white the opposite side would be dark green coloured. The lichen species above would appear to prefer bright sunlight rather than the shaded side of a wall.

Northern sides of walls were commented upon by Rishbeth (1948) as being generally damper and more suitable for mosses and higher plants. This can also be substantiated from the present survey. For example while the southern aspect of wall number 77 had only lichens, the northern aspect had *Ceratodon purpureus*, *Cerastium fontanum* and *Festuca tenuifolia*.

Thus aspect is important, but only in a local sense. Factors such as pollution, substrate and water are more important in determining the type of flora. Aspect will affect the abundance and location on the wall of the species.

Further possible work on walls

Further delineation of the typical communities is possible. Work which concentrated on one area of the current survey, for example unpolluted sandstone walls or polluted limstone walls, would certainly reveal more about the importance of local factors.

An interesting area to study would be the area around the cement works at Eastgate in order to examine more closely the effects of that works on the local area. This work could extend well beyond an examination of walls and spread even to the fauna.

Observations throughout the survey suggest that walls are generally have a large number of spiders on them. A study of the typical spiders of walls may well prove interesting.

A comparison of the northern walls in Durham with the walls of the the south of England would be interesting. As the lichen flora has been so little examined previously this would I feel be the area to concentrate upon.

Further work on the lichens on walls at higher altitudes in the upper parts of Weardale and Teesdale would I think result in the finding of several less common species.

Conclusions

1) Many different factors acting together are responsible for determining the flora of walls in Co.Durham.

2) The three most important factors operating on a wide geographical scale are substrate of the wall, atmospheric pollution and water supply. Atmospheric pollution and water supply change systematically along the east to west line of the transect.

3) Other factors including local water supply, method of wall construction, aspect and surrounding area are important to individual walls.

4) Lichens are the most common and widespread group of wall organisms. Mosses occur frequently, but other groups of species are mostly dependent on the presence of a good water supply on the wall.

5) Acrocarpous mosses are better adapted to resist water loss than most pleurocarpous mosses and so are better able to colonise walls.

6) Typical higher plants of walls are adaptable opportunist species and many are common weeds or wasteground species.

7) Retaining walls are generally damper than freestanding walls and as a result have a richer higher plant flora.

8) Wall communities in sulphur dioxide polluted areas tend to be less diverse than those in unpolluted areas.

9) Wind dispersal is the most common method of 'seed' dispersal of plants growing on walls (taking into account lichens, pteridophytes, bryophytes and angiosperms). Amongst the angiosperms many species have no special mechanism of dispersal.

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