THE FLORA AND VEGETATION OF WALLS
IN COUNTY DURHAM

by

P.J. Wright

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Dissertation
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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, timber 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), Beyl 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 (Ritchie 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 many 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 pollution, 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, Collema cristatum, Rhizocarpon distinctum, Staurothelia rugulosa, Thelidium incavatum, Toninia coerulescens 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 species 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 x 100 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 identification 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 hierarchical 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

<table>
<thead>
<tr>
<th>Species</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Acarospora fuscata</td>
<td>L. stigmata</td>
</tr>
<tr>
<td>A. smaragdula</td>
<td>Collema tenax</td>
</tr>
<tr>
<td>Aspicilia calcarea</td>
<td>Fusidea cyathoides</td>
</tr>
<tr>
<td>A. cinera</td>
<td>Haematomma ventosum</td>
</tr>
<tr>
<td>A. contorta</td>
<td>Huilia albocaeruleascens</td>
</tr>
<tr>
<td>Bacidia muscorum</td>
<td>+ H. macrocarpa</td>
</tr>
<tr>
<td>+ Buellia aethalea</td>
<td>H. tumida</td>
</tr>
<tr>
<td>Caloplaca citrina</td>
<td>Hypocenomyce scalaris</td>
</tr>
<tr>
<td>C. ferruginea</td>
<td>Hypogymnia physodes</td>
</tr>
<tr>
<td>C. heppiana</td>
<td>H. tubulosa</td>
</tr>
<tr>
<td>C. saticola</td>
<td>Lecania erysibe</td>
</tr>
<tr>
<td>Candelariella auella</td>
<td>+ Lecanora atra</td>
</tr>
<tr>
<td>+ C. vitellina</td>
<td>L. campestris</td>
</tr>
<tr>
<td>Catillaria chalybeia</td>
<td>+ L. coniceoides</td>
</tr>
<tr>
<td>C. lenticularis</td>
<td>+ L. dispersa</td>
</tr>
<tr>
<td>Cladonia chlorophaca</td>
<td>+ L. intricata</td>
</tr>
<tr>
<td>C. ciliata v. tenuis</td>
<td>+ L. muralis</td>
</tr>
<tr>
<td>+ C. coniocraea</td>
<td>+ L. polytropa</td>
</tr>
<tr>
<td>C. macilenta</td>
<td>L. rupicola</td>
</tr>
<tr>
<td>C. squamosa</td>
<td>Lecidea monticola</td>
</tr>
<tr>
<td>Clathroporina calcarea</td>
<td>L. osrothea</td>
</tr>
<tr>
<td>Lecidella scabra</td>
<td>Rhizocarpon concentricum</td>
</tr>
</tbody>
</table>
R.geographicum
R.obscuratum
+ Lepraria incana
Ochrolecia parella
Parmelia glabrata subsp.fuliginosa
+ P.saxatilis
+ P.sulcata
Peltigera praetextata
Pertusaria coccodes
P.corallina
P.dealbescens
+ Physica ascendens
+ P.caesia
P.tenella
+ Placynthium nigum
Polysporina simplex
+ Protoblastinia rupestris

Pseudoevernia furfuracea
+ 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 'eukaryote' 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 sulfur dioxide pollution tolerant lichens (Scoliciosporum umbrinum, Caloplaca citrina, Candelariella aurella, C. vitellina, Cladonia coniicacea, C. macilenta, Lecanora dispersa, L. muralis, L. conizeoides, Lepraria incana, Placynthium nigrum, Xanthoria parietina) to pollution intolerant lichens (Fusidea oya thoides, 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 osrothea, 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. Hypocephomyce 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 I can be compared is that compiled 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

<table>
<thead>
<tr>
<th>Complete species list of mosses found</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:† Amblystegium serpens</td>
</tr>
<tr>
<td>† B. convoluta</td>
</tr>
<tr>
<td>† B. fallax</td>
</tr>
<tr>
<td>† B. rigidula</td>
</tr>
<tr>
<td>B. trifaria</td>
</tr>
<tr>
<td>0 B. unguiculata</td>
</tr>
<tr>
<td>† B. vinealis</td>
</tr>
<tr>
<td>0:† Bryum argenteum</td>
</tr>
<tr>
<td>0:† B. caespiticium</td>
</tr>
<tr>
<td>† B. capillare</td>
</tr>
<tr>
<td>0:† Ceratodon purpureus</td>
</tr>
<tr>
<td>Dicranella heteromalla</td>
</tr>
<tr>
<td>Dicranum scoparium</td>
</tr>
<tr>
<td>† Ditrichium flexicaule</td>
</tr>
<tr>
<td>Fissidens cristatus</td>
</tr>
<tr>
<td>0:† Grimmia pulvinata</td>
</tr>
<tr>
<td>G. torquata</td>
</tr>
</tbody>
</table>

0:† 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 argenteum 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 florals 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 pleurocarpous 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 inhabiting 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

<table>
<thead>
<tr>
<th><em>O</em></th>
<th>Asplenium ruta-muraria</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>O</em></td>
<td>A. trichomanes</td>
</tr>
<tr>
<td><em>Cystopteris fragilis</em></td>
<td></td>
</tr>
<tr>
<td><em>Dryopteris oreades</em></td>
<td></td>
</tr>
<tr>
<td><em>Polypodium vulgare</em></td>
<td></td>
</tr>
</tbody>
</table>

* 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 officinarum*, *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.

*Cystopteris 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).

*Dryopteris oreades* 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 contaminated 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>
<thead>
<tr>
<th>Complete species list of angiosperms found</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>O:</em> Agropyron repens</td>
</tr>
<tr>
<td><em>O:</em> Agrostis stolonifera</td>
</tr>
<tr>
<td>0: Arrhenatherum elatius</td>
</tr>
<tr>
<td>0: Bromus mollis</td>
</tr>
<tr>
<td><em>O:</em> Dactylis glomerata</td>
</tr>
<tr>
<td>Festuca tenuifolia</td>
</tr>
<tr>
<td><em>O:</em> Festuca tenuifolia</td>
</tr>
<tr>
<td><em>O:</em> Poa annua</td>
</tr>
<tr>
<td><em>O:</em> P. pratensis</td>
</tr>
<tr>
<td><em>P:</em> P. trivialis</td>
</tr>
<tr>
<td><em>O:</em> Acer pseudoplatanus</td>
</tr>
<tr>
<td><em>O:</em> Coryllus avellana</td>
</tr>
<tr>
<td><em>O:</em> Sambucus nigra</td>
</tr>
<tr>
<td><em>O:</em> Sorbus aucuparia</td>
</tr>
<tr>
<td>*!: Ulmus sp.</td>
</tr>
<tr>
<td><em>O:</em> Achillea millefolium</td>
</tr>
<tr>
<td>Anthriscus sylvestris</td>
</tr>
<tr>
<td>0: Bellis perennis</td>
</tr>
<tr>
<td>Cardamine flexuosa</td>
</tr>
<tr>
<td>Cerastium fontanum</td>
</tr>
<tr>
<td><em>O:</em> Chamomion angustifolium</td>
</tr>
<tr>
<td><em>O:</em> Cirsium sp.</td>
</tr>
<tr>
<td><em>O:</em> Convolvulus arvensis</td>
</tr>
<tr>
<td>*!: Crepis sp.</td>
</tr>
<tr>
<td>*O: Cymbalaria muralis</td>
</tr>
</tbody>
</table>

| *O:* Epilobium montanum                   |
| *!: Erophila verna                       |
| Euphrasia officianalis agg.              |
| *O:* Galium aparine                      |
| 0: 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                           |
| 0: Trifolium repens                      |
| 0: Tussilago farfara                     |
| *O:* Urtica dioica                       |
| *!: Viola sp.                            |
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>
<thead>
<tr>
<th>Table V</th>
<th>The normal habitats of wall plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat</td>
<td>Number of species found in this habitat</td>
</tr>
<tr>
<td>Walls</td>
<td>8</td>
</tr>
<tr>
<td>Waysides</td>
<td>18</td>
</tr>
<tr>
<td>Hedges</td>
<td>15</td>
</tr>
<tr>
<td>Grassland</td>
<td>25</td>
</tr>
</tbody>
</table>
Table V cont'd

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

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 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 incana 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 propagules 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

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

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

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

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 officinale* 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.
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 moorland 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.

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acarospora fuscata</td>
<td>Acar fus</td>
</tr>
<tr>
<td>A. smaragadula</td>
<td>Acar sma</td>
</tr>
<tr>
<td>Aspicilia calcarea</td>
<td>Asp cal</td>
</tr>
<tr>
<td>A. cinerea</td>
<td>Asp cin</td>
</tr>
<tr>
<td>A. contorta</td>
<td>Asp con</td>
</tr>
<tr>
<td>Bacidia muscorum</td>
<td>Bac mus</td>
</tr>
<tr>
<td>Buellia aethalea</td>
<td>Buel aet</td>
</tr>
<tr>
<td>Caloplaca citrina</td>
<td>Calo cit</td>
</tr>
<tr>
<td>C. ferruginea</td>
<td>Calo fer</td>
</tr>
<tr>
<td>C. heppiana</td>
<td>Calo hep</td>
</tr>
<tr>
<td>C. saxicola</td>
<td>Calo sax</td>
</tr>
<tr>
<td>Candelariella aurella</td>
<td>Cand aur</td>
</tr>
<tr>
<td>C. vitellina</td>
<td>Cand vit</td>
</tr>
<tr>
<td>Catillaria chalybeia</td>
<td>Cat chal</td>
</tr>
<tr>
<td>C. lenticularis</td>
<td>Cat lent</td>
</tr>
<tr>
<td>Cladonia chlorophaeae</td>
<td>Clad chl</td>
</tr>
<tr>
<td>C. ciliata v. tenuis</td>
<td>Clad cil</td>
</tr>
<tr>
<td>C. coniocraea</td>
<td>Clad con</td>
</tr>
<tr>
<td>C. macilenta</td>
<td>Clad mac</td>
</tr>
<tr>
<td>C. squamosa</td>
<td>Clad squ</td>
</tr>
<tr>
<td>Clathroporina calcarea</td>
<td>Clat cal</td>
</tr>
<tr>
<td>Collem a tenax</td>
<td>Coll ten</td>
</tr>
<tr>
<td>Fusidea cyathoideas</td>
<td>Fus cya</td>
</tr>
<tr>
<td>Haematomma ventosum</td>
<td>Haem ven</td>
</tr>
<tr>
<td>Huilia albocaerultescens</td>
<td>Huil alb</td>
</tr>
<tr>
<td>H. macrocarpa</td>
<td>Huil mac</td>
</tr>
</tbody>
</table>
Hypocenomyces 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
Lecidella scabra
L. stigmatea
Lepraria incanla
Ochrolechia parella
Parmelia glabratula
P. saxatilis
P. sulcata
Peltigera praetextata
Pertusaria coccodes
P. corallina
P. dealbescens
Physica adscendens
P. caesia
P. tenella
Placynthium nigrum
Polysporina simplex
Protoblastinia rupestris
Pseundoevernia furfuracea
Psilolechia lucida
Rinodina gennarii
Rhizocarpon concentricum
R. geographicum
R. obscuratum
Scoliciosporum umbrinum
Stereocaulon vesuvianum
Tremolecia atrata
Trapelila coarctata
Verricaria baldensis
V. coerulea
V. glaucina
V. muralis
V. nigrescens
Xanthoria candelaria
X. parietina
X. aureola

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

Bry cap
Cera pur
Dior het
Dior sco
Ditr flex
Fiss cri
Grim pul
Grim tor
Grim tri
Ho ma lut
Ho ma ser
Hypn cup
Neck com
Orth ano
Orth cup
Pohl car
Pohl elo
Ptyc pol
Rhac fas
Rhac het
Schi apo
Tort mur
Tort sub
Tric bra
Tric cri
Weis con
Sole tri
Asp mur
Asp tric
Cystopteris fragilis
Dyopteris oreades
Polypodium vulgare
Agropyron repens
Agrostis stolonifera
Arrhenatherum elatius
Bromus mollis
Dactylis glomerata
Festuca tenuifolia
F. rubra
Holcus lanatus
Holcus mollis
Poa annua
P. pratensis
P. trivialis
Acer pseudoplatanus
Coryllus avellana
Sambucus nigra
Sorbus aucuparia
Ulmus sp.
Achillea millefolium
Anthriscus sylvestris
Bellis perennis
Cardamine flexuosa
Cerastium fontanum
Chamerion angustifolium
Cirsium sp.
Convolvulus arvensis
Crepis sp.
Cymbalaria muralis
Epilobium montanum
Erophila verna
Euphrasia officinalis agg.
Galium aparine
Geranium robertianum
Geum urbanum
Hedera helix
Hieracium sp.
Lamium purpureum
Lapsana communis
Matthiola incana
Plantago lanceolata
Rubus fruticosus
Rumex acetosa
Sedum acre
Senecio jacobaea
S. vulgaris
Stellaria media
Taraxacum officinale
Thymus praecox
Trifolium repens
Tussilago farfara
Urtica dioica
Viola sp.
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 the classification of samples which the TWINSPAN analysis also provides. The character of the species in each group will now be examined.

Species group A(26 spp.) 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 crisipulum 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(32 spp.) 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(1 spp.) and D(4 spp.) 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(6 spp.) contains a mixture of species, some of which were principally found on moister walls, for example Sambucus nigra, Corylus 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(3 spp.), H(2 spp.) and I(1 spp.) 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 be more tolerant species. Some of them were used as indicator species by TWINSPAN in the classification of the samples.

Groups J(11 spp.) and K(4 spp.) 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 Physcia caesia, Xanthoria parietina (Brightman and Seaward 1977).
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 glauca*, *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 nigroum* are known to be sulphur dioxide pollution tolerant (Gilbert 1968, 1971). Some are known to favour nitrogen enriched sites, eg. *Candelariella aurella*, *Xanthoria candelaria*, *Caloplaça 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 been 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 conversely 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 Huilia tumida, Lecanora intricata, Parmelia saxatilis, Acarospora fuscata and Algae for groups A to L, and Lecanora dispersa and Tortula muralis 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 Lecanora dispersa 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. Lecanora dispersa and Tortula muralis show fairly high constancy for this group and particularly for Tortula muralis 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. Xanthoria candelaria, Lecanora dispersa, Tortula muralis, Candelariella aurella (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 supply, reflected by the abundant presence of Hypnum cupressiforme 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

| Samples groups | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
| A              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| B              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| C              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| D              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| E              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| F              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| G              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| H              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| I              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| J              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| K              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| L              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| M              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| N              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| O              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| P              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Q              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| R              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| S              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| T              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| U              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| V              |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

0   >=0 - 5%
1   >=5 - 20%
2   >=20 - 45%
3   >=45 - 60%
4   >=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 with all 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 achieve any consistent 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). 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 group M (see figure III) which contains many strict calcicole lichen species such as P. rupestris, Caloplaca heppiana, Verrucaria glauca 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 VI  Rainfall in the transect

Transect
County border

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 were 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

AXIS 1

污染增加

水增加

188

113
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 TWINSPLAN classification. This is illustrated in figure IX. Calculations
FIGURE IX
Portion of DECORANA ordination with selected tops and sides of walls shown.

N = NORTH
S = SOUTH
T = TOP

AXIS 1

AXIS 2

water increases
of the proportion 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 luxuriant 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 inferred 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.
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
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, pollution 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 variance 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 examination showed no similarity to the patterns in the 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 substrate 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 the 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 substrate tends to change along it as follows. At the bottom of the axis walls tend to be constructed 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-biological data have helped emphasise the importance of east of west position along the transect, independent of the abiotic properties of the wall, in determining wall flora. They have also illustrated the important role of
FIGURE XIII
TWINSERAN sample classification superimposed on PCOORD.

ordination

AXIS 1

AXIS 4
the wall construction 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 Pseudevernia 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 purpureus are occasional. When
mortar is present species such as Xanthoria candelaria, Protoblastinia rupeste
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 polytropi,
L.intricata and Lecidea tumida are all still 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 wall 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 crustose form.

As pollution decreases west of Durham City the above species are still common, but others are able to colonise. Aspicilia calcarea and A.contorta 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 Schistidium apocarpa can still be found on wall tops, but are joined by other species the most common of which are Orthotrichum anomalum and Trichostomum brachydontium.

At Wolsingham and westwards Ochrolechia parella is found and will cover 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 Verrucararia muralis, V.glaucina, Clathroporina calcarea, Protoblastinia rupestris and Lecidea monticola which become more common further west. Lecan dispersa, Placynthium nigrum and Xanthoria candelaria are still found but are 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 nutrients 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 presence or absence from polluted areas such as the east of the transect (Mansfield 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 averaged 15.1 species each.

Sulphur dioxide is not the only pollutant. Smoke, soot, car exhaust, 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 some periods of wetness, such as the ferns, especially for the success of their prothallus stage. Particularly successful wall plants such as Cymbalaria 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 Physcia 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 limestone 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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References


