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Site Classification and Classification of Lake District Woodlands

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Introduction

In the Merlewood Programme Conference (November 1968) the importance of a woodlands site classification was recognised and given high priority. A variety of applications were envisaged for a general classification and the report below describes the first stages to demonstrate some of the steps towards the eventual complete project.

The objectives of the classification are:

1. The classification should enable the criteria upon which sites are considered to be of conservation value to be clarified and stated in an objective manner that forms the basis of policy decisions.

2. There must be means of defining the units of the classification in the field without considerable experience in phytosociology (cf. Webb (1954)).

3. Results must be comprehensible to staff who are to translate research into practical policies. Therefore the final analysis, whilst utilising numerical techniques, must be presentable at various levels so that any interested person may apply the results.

4. Regional studies of sites to provide classifications of local importance are also desirable.

Outline of proposed procedures

The Woodland Cards of the Reserve Review contain data on species composition in a large number of woods on a national basis. As the most recent and comprehensive survey of site attributes it is desirable to use data from these cards, although of a low information content in the sense of Lambert & Dale (1962). Detailed quantitative ecological studies into the relationship between environmental and vegetational trends are essential to the development of a classification defined by the objectives. However these studies are time consuming and are inevitably limited to few sites which must be selected, as far as possible, by an objective procedure.

From a consideration of the classification objectives and the techniques available (see Methodological Review p 3) the following sequence of analyses is planned.

1. Presence and absence data, extracted from the Woodland Cards of the Reserve Review, are to be used in Association-Analysis programmes. A separate analysis is to be carried out for each of the regions of the Conservancy (providing that cards are available and are of sufficient number and quality). It may be necessary to subdivide some regions where large numbers of woods have been surveyed. From each of these analyses regional classifications will be produced, suitable as local reference systems.

2. The final groups (probably 30-40) of the regional analyses will then be subjected to partial nodal analysis, a development of Association-Analysis, which objectively selects a single representative site from each of the groups.

3. The original data (from say, 3,000 woodland sites) will thus be reduced to about 400 sites on a national basis. Data from these sites will then be subjected to a further Association-Analysis to provide a national classification.

4. Partial nodal analysis of the final groups of the national survey will produce a list of, probably 40-50, sites representative of variation in species content of woodlands throughout Britain.

5. The sites defined by the partial nodal analysis, are based on extensive records of low information content and in addition to providing a broad classification are also suitable for future detailed studies. Within these sites, therefore, intensive ecological studies of soil, vegetation and climate will be made. Analysis of the data (using ordination and component analysis procedures) will relate vegetational trends to environmental gradients and will lead to an objective study of the dominating influences in woodland growth and structure.

Within each of the steps outlined above, certain factors are important in determining the feasability of the project. Therefore, before committing resources to a national project, it was decided to test the procedures on a limited scale in the Lake District.

The present paper describes the first stage in this part of the project, i.e. step 1. of the plan outlined above.

The relevant factors in the analysis of the Woodland Cards of the Reserve Review are:

1. Association-Analysis has usually been applied to groups of quadrats of defined sizes, although Proctor (1966) applied the procedure to vice-counties, and Bunce (1968) to rock ledge vegetation with ledges of various sizes as the basic units. The woodlands sampled in the Reserve Review vary greatly in size and one of the criticisms of Association-Analysis has been that sample size can effect the results seriously. Gittins (1966) and Ivimey-Cook & Proctor (1966) have both emphasised that, beyond a reasonable size limit, determined by practical considerations, this objection is not serious. However, it is an important point that needs verification.

2. The field work for phytosociological studies has, in most cases, been carried out by either one worker or by small trained groups. The data from the Reserve Review has been compiled by observers of widely varying field ability and it was important to examine whether this would reduce the efficiency of the analysis.

3. The position of sample points has been widely discussed (e.g. Lambert & Dale (1962)). In the present context no difficulties are encountered as the woodlands surveyed are cartographic units.

4. Species on the Woodland Card were selected to demonstrate certain floristic features of woodlands, and consequently could be considered to bias the results. However, the species were not selected for Association-Analysis, and the presence of species

groups as shown on the card may be examined in the inverse Association-Analysis (in which the species are classified into groups on the basis of the stands in which they occur).

5. A general impression is that the data are so crude as not to warrant sophisticated statistical procedures and that anyway these would show only the obvious. As Lambert & Williams (1962) have pointed out, Association-Analysis will certainly demonstrate primary groups that could be established by visual examination of the data, but in addition, aspects of the data frequently emerge which would not have otherwise been considered. A final overriding consideration is that the large amount of data (perhaps from as many as 3,000 sites) require a mechanical procedure to sort it efficiently.

The data for the results presented in the present study were taken from 200 woodlands in the Lake District, direct from Woodlands Survey Cards, compiled by a number of observers. Of the 136 species available from the cards only 108 were used in the analysis the remainder being present on less than 5 sites.

Methodological Review

British ecologists generally use Tansley (1949) as a basis for fitting individual sites into a wider system. Within Tansley the classification is based on dominant species and the seral state of communities, with a general convergence to a climatic climax assumed. However, the reliance upon dominance often leads to a conflict between numbers and size. The assessment of the seral state of a community and the directional movement that is taking place towards the climax, pose problems of a projection into both past and future and involve subjective extrapolation. Further, any one site often contains not only a mixture of seral stages but also of climax types in the broad sense. Consequently it is often impossible, except in extreme cases cited in Tansley, to place an individual site in the reference system without subjective divisions being made within it.

Continental phytosociologists have developed a highly organised system for classification of communities based on the work of Braun-Blanquet (1951) in Switzerland; Scandinavian workers, e.g. Dahl (1956) have developed similar procedures. Sites are classified on the basis of the floristic composition from defined homogeneous areas. Poore (1955a, b, c) has reviewed and interpreted the procedures involved and McVean & Ratcliffe (1962) have applied the system, adapted from Braun-Blanquet by Poore, to Scottish Mountain vegetation. Moore (1962) has criticised the interpretation given by Poore of the Braun-Blanquet system, in that the concept of "Faithful" species is over-emphasized. As Webb (1954) has pointed out, the continental system relies heavily upon the phytosociological experience of the observers and upon the adoption of homogeneous sites and minimal areas. The selection of homogeneous stands is based on the assumption of discrete communities and consequently forms an important bias, as emphasized by Lambert & Dale (1962).

In the present context reliance upon experience makes the approach untenable, as the data from the Reserve Review is from observers with widely varying field ability, The sites are also not homogeneous.

The Continental system does however, produce a workable classification and Groenewoud (1965) and Ivimey-Cook & Proctor (1966) have

found that comparable results may be obtained in comparison with statistical procedures. At some stage in the present study it may be valuable to carry out an analysis using the Braun-Blanquet system, so that direct comparisons may be made between British vegetation and that of the Continent.

Williams & Lambert (1959, 1960, 1961a), demonstrated the successful application of the classificatory procedure based on presence and absence of species. The basis of the procedure is to calculate all associations between species and to divide the sites on the basis of those that have the highest degree of association. A hierarchical classification is produced (monothetic), that may be interpreted easily on the presence or absence of key species at different stages of the analysis. Species may also be classified according to which site they are present in. By combining the two analyses "noda" may be produced characterising groupings of species occurring within site groups.

Greig-Smith (1964) regards qualitative data as an extreme form of quantitative data, whereas Lambert & Dale (1962) consider that quantitative data is superimposed upon the underlying qualitative pattern. Williams & Dale (1962) developed a procedure, partial correlation analysis, to examine the information content of qualitative and quantitative data. Lambert & Dale (1962) quote some unpublished results, demonstrating that within a set of test data, the information in the qualitative element greatly exceeded that in the quantitative element.

A number of studies, e.g. Goldsmith (1966) and Gittins (1965), have shown that the broad ecological interpretations of results from quantitative and qualitative data are directly comparable. The latter has emphasised the application of Association-Analysis in obtaining a rapid analysis of data in primary survey.

Lambert & Dale (1962) have pointed out that even when species are subjectively selected for an analysis the study will often be objective in the sense that decisions on species content are often based on factors largely irrelevant to the actual system under study.

Ivimey-Cook & Proctor (1966) have discussed the application of Association-Analysis to phytosociological studies. They confirmed that the broad features of the arrangement of data arrived at by traditional methods was also achieved by Association-Analysis and that improvements and re-arrangements were made in detail. The most striking result was the success of the Analysis in recognition of faithful and differential species. In Continental phytosociological studies 'kennarten' (faithful species) are probably arrived at by a mental process of correlation weighting which is explicit and mechanical in the selection of division species in Association-Analysis.

Almost all published uses of Association-Analysis have been methodological studies. Proctor (1966) is an exception, using the procedure to classify hepatic assemblages from vice-counties in Britain, and achieving meaningful results.

The other main line of recent research into classification of vegetation has been that of ordination (a term first used by Goodall (1954), originating from the German, Ordnung). There has been considerable arguement, e.g. Anderson (1963) as to the relative merits of "ordination" and "classification", but essentially the techniques

are similar in defining the relationship between vegetational units. Ordination procedures are based on the application of factor and component analysis, but some of the procedures adopted, e.g. Bray & Curtis (1954) and Whittaker (1956) provide simpler methods of approximation. Gittins (1965) demonstrated the use of the former technique to an intensive study of limestone grassland and successfully showed correlations between environmental and vegetation gradients. Orloci (1966) and Austin & Orloci (1966) presented further improvements on the original Bray & Curtis technique. Austin (1968) has further demonstrated its use in classificatory work. Other examples of the application of similar techniques are Yarranton (1966) Ivimey-Cook & Proctor (1967) and Kershaw (1968).

These procedures are, however, more complex than Association-Analysis and the results are more difficult to present. Essentially these techniques require detailed quantitative information of site characteristics and are therefore more suited to second-phase, intensive studies.

Several studies have also been made demonstrating the use of Association-Analysis in conjunction with ordination. Gittins (1965) emphasises the complementary nature of the techniques and Greig-Smith et al (1968) have further shown how the two techniques may be used in conjunction.

Results

1. Normal Analysis (classification of sites on basis of species content). The hierarchy is given in Figure 1 and the site groups in Table 1.

The species on which the early divisions are made have definitive ecological amplitudes. Mercurialis perennis is confined to base-rich soils, either as extensive ground cover on limestone or in flushes within acid areas. The success of the analysis in extracting, as a primary division, a species of such well-known ecological requirements indicates that, despite the limitations of the data, the associations between species are sufficiently strong for significant divisions to emerge. Within the + Mercurialis group, the next division is made upon Ranunculus flammula, a species confined to streamsides or water edges and the significance of which is emphasised when limestone sites with internal drainage are considered.

Blechnum spicant is a marked calcifuge and is associated either with acid sites or with sites in which microhabitats with marked acid conditions occur. Brachypodium sylvaticum is a constant component of limestone woods, and although occurring in flushes elsewhere, is strongly associated with other limestone species.

Within the acid sites, defined by the absence of Mercurialis, Lonicera periclymenum is the first divisive species. Although having a wide amplitude, this species is absent from extremely poor sites. Viola spp. (predominantly V. riviniana) are limited to flushed areas in the acid woodlands and delimit sites in which small flushes occur within the acid facies. Cirsium palustre also provides an interesting

TABLE 1.

ASSOCIATION ANALYSIS - LAKE DISTRICT WOOD 1968

KEY TO FINAL GROUPS

1. Old Park
   Roudsea
   Witherslack

2. Kilnstones
   The Park
   Above Steers Pool
   Woodlands Station Vicinity
   Marthwaite Park
   Beech Hills

3. Black Brow Close
   Green Hills
   Birks Brow
   Hartbarrow

4. N. T. Tilberthwaite
   High Bowkerstead
   N. T. Coniston
   Old Hall Colton
   ?

5. Spring Hag
   Under Crag
   Skelghyll
   Johnnys Wood

6. Roebundle Forest

7. Bank Wood
   Irton Park (Esk)
   Bishops Wood (Esth)
   Nr. Esthwaite Lodge (Esth)
   Waterside (Esth)

8. Sales Bank
   Peer Howhill
   Side End

9. Nr. High Bowkerstead

10. Bowers Wood
    Eggerslack

11. Park Fell
    Bigland

12. Below Bracelet Hall
    Nr. Duddon Bridge

13. Scroggs
    Foxfield (Eskdale)
    Low Coppice
    Low Ludder Burn
    Haile Great Wood
    Kye Wood (Machell Coppice)
    Nr. Outgate

14. Nibthwaite
    Ickenthwaite
    Force Forge
    Winster Ho.
    Vicerage

15. N. of Stribers
    Hoggs
    Tarn Hows
    Nr. Strawberry Bank

16. Claife
    Arklid
    Low Skelghyll
    Hall End
    Townend
    Near Plantation

17. Larkrigg Spring
    Holeslack
    Honey Bee
    Whitbarrow
    Smardale
    Humphrey Head

18. Plumpton Hall
    Whitbarrow
    Whitbarrow
    Whitbarrow

19. Larkrigg
    Nr. Derby Arms
    N. of Grassgarth
    Lodore Troutbeck

20. Shieling (Silverdale)
    Back House
    Arnside Knott
    Little Thorphinsty

21. Whitbarrow
Glencoyne
Heald Brow
Gaitbarrow + New Park
Eaves Wood

22. Castle Head
Cockshott

23. Above Newby Bridge
Scrithwaite
Climbstyle
Well Wood
Barton Hall
Sea Wood

24. Above New Ridding
Addyfield

25. Claife
Water
Bridge House
Elleray

26. Beck Pane
New Close
Gowbarrow
Raven Crag
Martindale
Low Hartsop
Rowbarrow

27. Oxenthwaite
Low Out Wood
Below the Hall Kentmere
Nr. Tufton Lodge

28. High Bowkerstead
Birch Hills
Low Hows

29. Chapel Stile
Hell Gill
Fowe Park
Overside
Swinside

30. Miterdale
Skinners Pasture
Stangends
Cross Hawse
Haverigg Holme
Great Knott

31. Seatle
Birks Wood
Green Gate
Lowfell
Nr. Haile Hall

32. Park House
Low Dale Park
Spring
Lamb Howe

33. Park Coppice
Torver Common

34. Above Rusland
Above Thwaite Head
Wall End
Nicholls
Nr. Bank House

35. N. of Settle
Black Beck
Brant Hows

36. Moss Rigg
Scale Green
Haverthwaite (i)
Haverthwaite (ii)
Brandlehow Park
Manesty Park
High Wood

37. Low Wood
Low Eskholme
Low Miterdale
Oldwythes
Hill Wood

38. Bishop Woods (Graythwaite)
Low Wood

39. Muncaster
Irton Park
Milkinstead
Heald Wood
Tarn
Crag Howe

40. Nr. Spark Bridge
Kailpot Crag

Greenodd
Shap Wood
Park Wood

41. S. Side Borrow Beck
N. Side Borrow Beck (i)
N. Side Borrow Beck (ii)
Barton Park
Frith Wood
Skarton Wood

42. Dobbin
Above the Hall Kentmere
Wetsleddale
Whiteside
Martindale
Watendlath Fell
Miterdale Head

43. Elterwater
Brothers Water
Wandale Beck
Under Millbeck Common

44. Bull Close
Intake
Bays Brown
Hill Fell Pln.

45. Routing Gill

46. Deer Howse
Copple Howe
Linstey Hall
Stonethwaite Fell
Low Yew Dale

47. Birkrigg
Keskadale A
Keskadale B
Gilpin Park Pln.
School Knott
Crag House
Scales Wood

division of the extreme acid woods into a wet and dry group.

Many of the other species, on which the divisions are based at a lower level in the hierarchy, are also significant ecologically, e.g. Alnus glutinosa and Salix spp. It is interesting to note that many of the lower divisions reflect woodland structure to the extent that shrub species, e.g. Corylus avellana and Prunus padus, form the basis of several groups.

An important feature of the analysis is that the major divisions are based on herbaceous rather than tree species, indicating that the ground flora is of greater importance than the tree composition in determining the classification. Tree populations are affected rapidly by management procedures whereas ground flora species may remain as relict groups after the woodland cover has been removed or altered. Examples of relict woodland species groups are provided by grikes in limestone pavements, and by rock ledges in mountain cliffs. Also within the Lake District woodlands, the main tree species are almost obiquitous, as shown by the grouping of the Inverse Analysis (see below).

Association-Analysis has made the divisions into groups on the basis of species that have definable ecological amplitudes. The species used are all easily identified and may be used to obtain an approximate classificatory position of a given site by following the presence or absence of observed species down the hierarchy given in Fig. 1.

Group definition

Although the data were divided into 47 groups, these may be summarised conveniently at a level of maximum $\bar{X}^2$ of 18.0 giving seven broad groups.

(1) Groups 1-9

Generally large, diverse woods with a wide range of species groupings. Often geographically situated by the large lakes, rivers and estuaries. Present on the complete range of geological strata in the area, i.e. limestone, slates and volcanic series, and typified by a diversity of edaphic conditions.

(2) Groups 10-16

Usually valley woods, extending from hillsides on to valley bottoms. More widespread through the Lake District than the previous group owing to the more frequent combination of habitat conditions.

(3) Groups 17-21

With two exceptions all the woods in the group are on limestone in the southern Lake District. Only two sites, outside Groups 1-9 were on limestone and placed outside this group.

(4) Groups 22-27

Essentially neutral woods without marked acidic or basic affinities.

(5) Groups 28-35

Generally large, predominantly acidic woods with limited flushed areas.

(6) Groups 36-40

Markedly acid woods, mainly small on valley sides at low altitudes with very limited flushing.

(7) Groups 41-47

Extreme acid woods the majority of which are a high altitude, at the heads of Lakeland valleys.

Within the broad groups defined above, various facies are selected by divisions at lower levels in the hierarchy, e.g. within group (7), Cirsium palustre provides a primary division between wet and dry upland woods, with Ilex aquifolium, forming a further division within the wet group into sites with rock outcrops. The number of sites in each group provides a guide to the frequency of a particular type of woodland within the region.

The analysis has therefore been successful in re-arranging the data from the species content of the Woodlands Survey Cards into a practical classification, that is ecologically meaningful. The position of any woodland may be established approximately in relation to the 200 woods in the survey by following down the hierarchy the presence and absence of the key species on which the divisions are based.

Although certain groups, e.g. the high altitude woods, are recognisable in Tansley many of the groups bear little relation to the classical picture, because the woodlands are treated as sites rather than separated into arbitrary divisions.

Inverse Analysis

(Classification of species according to the sites in which they occur).

The hierarchy of the Inverse Analysis is given in Fig. 2 and the species groups in Table 2. The species groups separated on the Woodlands Survey Cards have not emerged as pronounced groupings in the Analysis. The Inverse Analysis provides a broad separation into abundance classes and divides the classes into ecologically meaningful groups.

Group definition

Groups 1-3

The species within the groups are virtually ubiquitous within the Lake District and show no immediate ecological amplitude within the scope of the analysis. However the presence of the main tree species within these groups demonstrates why tree composition does not form the basis of divisions within the Normal Analysis.

Group 4

The three species in the group are all frequent throughout the Lake District but are particularly characteristic of open-scrub association, often within a matrix of closed woodland cover.

TABLE 2. SPECIES GROUPS

STAND INVERSE ANALYSIS

108 SPECIES 200 STANDS

Group 1. Fraxinus excelsior
Quercus robur and petraea
Sorbus aucuparia
Oxalis acetosella
Pteridium aquilinum

2. Acer pseudoplatanus
Betula pendula and pubescens
Corylus avellana
Rubus fruticosus (agg.)

3. Ilex aquifolium
Digitalis purpurea
Endymion non-scriptus

4. Crataegus monogyna
Lonicera periclymenum
Teucrium scorodonia

5. Deschampsia flexuosa
Galium saxatile

6. Salix spp.
Circaea lutetiana

7. Viola spp.
Geranium robertianum
Mercurialis perennis
Ajuga reptans
Filipendula ulmaria

8. Alnus glutinosa
Lonicera periclymenum (Shrub)
Potentilla erecta
Blechnum spicant
Vaccinium myrtillus
Deschampsia caespitosa
Polytrichum commune

9. Ranunculus repens

10. Holcus mollis
Holcus lanatus
Cirsium palustre

11. Glechoma hederacea

12. Prunus avium
Rosa spp.
Sambucus nigra
Taxus baccata
Ulmus glabra
Brachypodium sylvaticum
Potentilla sterilis

13. Athyrium filix-femina
Juncus effusus
Sphagnum spp.

14. Fagus sylvatica
Larix decidua
Tilia cordata
Primula vulgaris
Fragaria vesca

15. Pinus sylvestris
Picea spp.
Ranunculus flammula

16. Hedera helix
Allium ursinum
Chrysosplenium oppositifolium

17. Aesculus hippocastanum
Prunus padus
Anemone nemorosa
Veronica chamaedrys
Arum maculatum
Carex sylvatica
Ranunculus ficaria

18. Malus sylvatica
Prunus spinosa
Luzula pilosa
Veronica officinalis
Calluna vulgaris
Galium palustre

19. Rhododendron ponticum
Sarothamnus scoparius
Ulex europaeus
Erica cinerea
Geum rivale
Molinia caerulea

20. Melampyrum pratense
Succisa pratensis
Sanicula europaea
Valeriana officinalis
Carex nigra
Viola palustris

21. Viburnum lantana
Asperula odorata

22. Orchis ericetorum
Carex echinata
Carex rostrata
Crepis paludosa

23. Populus tremula
Carex remota
Iris pseudacorus
Thelypteris palustris

24. Juniperus communis
Sorbus aria (agg.)
Listera ovata
Phyllitis scolopendrium

25. Euonymus europaeus
Rhamnus cathartica
Carex panicula
Potentilla palustris
Eupatorium cannabinum
Carex pendula

26. Ribes nigra
Convallaria majalis
Dryopteris spinulosa
Erica tetralix
Equisetum telmateia
Calamagrostis epigejos

Group 5

Both species are closely associated in similar habitats both under woodland cover and in spaces within the canopy.

Group 6

Many of the acid woodlands have small streams running through them and both these species occur under these conditions.

Group 7

A natural group characteristic of many of the base-rich flushes in the acid woodlands in the region.

Group 8

A group of species associated with woodlands bordering on moorlands and heaths throughout northern England. Often found at the upper limit of local woods.

Group 9

An isolated species, perhaps because of confusion between R. repens and R. acris.

Group 10

Species typical of damp, acid conditions. Although H. mollis and H. lanatus do have similar ecological requirements, the identification of these species may also have been confused.

Group 11

A species with a specific requirement, in the Lake District, for base-rich, stony conditions.

Group 12

These species are often associated with flushed glades in many of the acid woods, although Brachypodium is also characteristic of woods on limestone.

Group 13

A natural group of species occurring under conditions where surface water is often present.

Group 14

The first three species are probably introduced and it is possible that the conditions under which they are planted, are associated with Primula and Fragaria, e.g. larch and beech are often planted in limestone areas in which both Primula and Fragaria, would be expected to occur.

Group 15

Pinus and *Picea* are introduced but it is difficult to see the coincidence with *R. flammula*.

Group 16

A natural group of species limited generally to base-rich river-side sites.

Group 17

An interesting group common to intermediate sites in regard to base status.

Group 18

These species are common to woods with clearings in which scrub development has taken place - although *G. palustre* does not fit into this general category.

Group 19

A group of species generally associated with conditions under which colonisation by woody species is occurring. *Molinia* is often associated with these conditions, as many of the sites are marginal areas in which agriculture is declining. *Geum rivale* is perhaps misclassified.

Group 20

With the exception of *Sanicula* generally characteristic of wet, acid conditions.

Group 21

Generally typical of limestone areas.

Group 22

Widespread heath species, generally in damp open, wet conditions.

Group 23

A natural group of species requiring very wet, base-rich conditions.

Groups 24-25

Although generally associated with limestone or at least base-rich sites, these species are in such low frequencies that interpretation would not be justified.

The interpretation demonstrates the success of the analysis in providing ecologically meaningful groups of species. In particular, some species are placed according to their edaphic requirements and others upon their seral status, depending on the strength of the associations within the data. Elsewhere in Britain different groupings may well result owing to the dominating influence of other ecological

factors. For example Tansley (1949) considered that ash occurs widely in the north-west England in a range of sites in which it does not occur further south. Consequently ash does not appear as an important species in the present analysis owing to its ubiquitous status in the survey.

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