Natural Environment Research Council

MERLEWOOD RESEARCH STATION

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THE NATURE CONSERVANCY

site factors) is widening our understanding of the ecological amplitude of species, and the pattern of vegetation distributions. Separate, though convergent, studies of meteorological factors are aimed at contributing to such interpretations. On the other hand very much less is known about the habitat needs or preferences of our native fauna. The studies of animals being carried out as part of the monitoring at Stone Chest (see below) and of Grey squirrels in relation to hardwood damage represent the start of a programme of more intensive research in this field.

Finally, research has been undertaken into the taxonomy of individual species, selected for a number of reasons: cases in which the distinction between species has apparently become blurred through introgression, e.g. oaks and birches; species in which the native gene pool is at risk of becoming mixed with that from foreign introductions of the same species, e.g. Scots pine, Red deer and Red squirrel; and in the case of elms, where problems of taxonomy have assumed greater practical significance under the threat of Dutch elm disease. All the taxonomic work is based on morphometric methods incorporating multivariate analyses.

The Woodland Research Section's work is dependent not only on the authors of the contributions which follow, but to a large extent on the careful help provided by their assistants. Credit is therefore due to Mrs. Wendy Bowen, Mrs. Joyce Brocklebank, Mrs. Carole Helliwell and Miss Madeline Robertson for help with field and laboratory work, including the ordering and punching of data, and computing.

NATIONAL SURVEY OF SEMI-NATURAL WOODLANDS

The main objectives of this project are:

1. To develop an efficient user-orientated method of classifying semi-natural woodland ecosystems in Britain.
2. To develop a complementary method of phytosociological classification for semi-natural woodlands.
3. To use, or assist in the use of, these classifications in the fulfilment of the Nature Conservancy's aims and policies for wildlife conservation.

As described in the Report for the years 1967-69, the project commenced with the analysis of species data from 2463 woodlands throughout Britain, designed as a basis for extracting a limited number of sites on which to carry out intensive survey. The results of the association analysis however proved to be capable of ecological interpretation beyond the requirements for the selection of sites; the 103 groups at a $\chi^2 = 20$ level were therefore compared with the means of 12 topographic and climatic variables, obtained from maps for all the sites in each of the 103 groups. These data were then analysed by principal component analysis in order to explore the inter-relationships between topography, climate and vegetation and to examine the overall trends present within the data.

An important conclusion was that the main site factors, such as land-form, geology, climate and soil types, are so closely inter-correlated on a national scale that interpretations based on single factors are to a large extent impossible. The main trend was from groups in which the climate was sub-continental, with relatively flat landforms and soils of high nutrient status on which species with lowland preferences were growing, to groups with extreme oceanic climates, generally steep contours, shallow acidic soils and with many Atlantic species. The secondary trend was from groups with a climate approaching a sub-boreal type, on which poor, often peaty, soils were present with many calcifuge species, contrasting with those with a more Lusitanian climatic regime, with gentle contours, deep rich soils and appropriate complements of lowland species. The same environmental data were then used to extract representative sites for further intensive study by carrying out a principal component analysis on each group separately and using the component values to calculate the site nearest the centre of the cluster. Aberrant sites, either because of error in the original data or because of their unusual character, were thus excluded.

METHOD OF SURVEY

The method of sampling in the intensive survey was determined by the primary aims of the project, which were: to produce a user-orientated, objective method of classification of woodland ecosystems; to define the range of variation within them; and to further understand the relationships between animals and plants and the environment. The procedure finally adopted was based on previous survey experience, incorporating an important element of advice from continental phytosociologists.

The 103 sites were plotted on Ordnance Survey maps ($2\frac{1}{2}$ in. = 1 mile) and 16 random sampling positions were marked on each site. This intensity of sampling, which was carried out in all woods regardless of size in order to have a standard sample for comparative purposes, was determined partly by previous experience, but also by limitations of time and manpower. Great importance was attached to the accuracy of the data to be collected and, before the start of the survey, a special course for training field surveyors was held at Merlewood. In addition, a comprehensive handbook of field methods was provided to all participants for subsequent reference in the field.

The sample points were located as accurately as possible in the field by using ground control points and compass bearings obtained from the map. Particular stress was laid on the importance of avoiding a subjective choice of exact sampling points. This was achieved by strict adherence to the predetermined compass bearing and distance (short only of endangering life and limb).

At each sample point, the following data were collected:

(a) cumulative records of vascular plants from five consecutive (and superimposed concentrically) quadrat sizes (4, 24, 50, 100 and 200 m²) plus an estimate of per cent cover abundance in the largest of these quadrats;

(b) a collection of bryophytes from the full 200 m² quadrat (from the soil surface only);

(c) measurement of diameters at 1·3 m (dbh) of all trees (over 5 cm diameter) in the 200 m² plot, and of saplings (under 5 cm diameter) and shrubs for the diagonally opposed quarters of the same plot, together with the height of the tree with the largest dbh;

(d) completion of a check list of attributes relating to management, regeneration, habitats and animals, within the 200 m^2 plot, measurement of slope and aspect, and the preparation of a profile sketch of the plot; and

(e) recordings of a shallow exposure of the soil profile at the plot centre, with examination of the deeper horizons by auger, together with a soil sample.

A more extensive check list of attributes was completed for the entire site in the course of locating the sample points.

These data were collected from the 103 sites (1648 plots) by eight survey teams between July and September 1971. The data, amounting to nearly 500,000 items of information, were translated to computer-readable form on paper tape.

METHODS OF ANALYSIS

For the purposes of analysis, the combined presence and absence of vascular plants, trees, saplings, shrubs and bryophytes within the largest (200 m^2) quadrat were considered to be the primary data, upon which the main classification was to be based. All other data were considered to be secondary, their main purpose being in validation, interpretation, and provision of a descriptive background. The detailed rationale for this method of organisation is given in Bunce and Shaw (In press), the main reason being that the vegetation, by virtue of its close inter-relationship with environment and as the primary producer upon which nearly all other organisms depend, is an excellent indicator for the ecosystem as a whole.

The primary data thus consisted of 1648 plots and 377 species (approximately 50,000 records), those species with under five records being excluded. Originally it was planned to use association-analysis to carry out a preliminary analysis, this being one of the few methods available at the time which was capable of tackling such a large data set. By such an analysis, it is possible to reduce the original number of sets to about one quarter the number of groups (at $\chi^2 = 3{\cdot}84$). Each of the assumed homogeneous groups could then be reclassified using a polythetic agglomerative method, which also provides for an investigation of the spatial relationships of the groups. Another advantage of this composite technique, i.e. employing a monothetic divisive technique in combination with a polythetic agglomerative method, is the rectification of misclassifications which can occur in association-analysis. The extremely useful dichotomous key produced by association-analysis can be retained as a multi-path key to the re-ordered groups.

As a result of difficulties with association-analysis programs available on other computers (because the data set was too large, would take too long to run or would cost too much) the method was programmed for the Digital PDP 8/I computer at Merlewood where it was successfully run in slack time (i.e. overnight and at weekends) taking about 400 hours. The program (now further improved) written in DEC FORTRAN II is available on request. The use of various similarity coefficients and clustering strategies was also investigated in some detail, again using the Merlewood computer. A satisfactory polythetic agglomerative technique was developed in the form of standardised Euclidian distance (Orloci, J. Ecol. 55, 192-206,

1967) combined with minimum variance clustering, using the recombinatorial solution of Pritchard and Anderson (J. Ecol. 59, 727-47, 1971).

During the latter part of this work, contact with M. O. Hill (Nature Conservancy, Bangor Research Station) revealed that he was developing a series of new methods based on the technique of reciprocal averaging, which is an ordination method in some ways similar to principal component analysis (Hill, J. Ecol. 61, 237-49, 1973). More recently Hill had also produced a polythetic divisive method of classification, based on the same procedure of reciprocal averaging, in which, with further development, he was able to incorporate the provision of a multi-attribute key, with advantages similar to those given by the composite methods independently developed at Merlewood.

The performance of the two methods was compared using a rather smaller set of data from the Native Pinewood Survey, (see p. 14). The results were found to be comparable, but the use of reciprocal averaging and its polythetic divisive derivative was thought to have a number of theoretical and practical advantages and was adopted. The theoretical advantages are explained by Hill (1973), but practical considerations, such as the simultaneous production of stand and attribute ordinations with their inbuilt property of reciprocity, are also important. The classification method probably also emphasises natural discontinuities and produces more readily interpretable groupings, than do clustering methods in general. The multi-species key has proved to be accurate and extremely easy to use, the overall rate of misclassification being no greater than 5%. The whole method is adaptable, and techniques for detecting and rectifying misclassifications, checking on the existence of new types outside the range of original population, and for measuring heterogeneity based on the information from the five quadrat sizes have been developed. The main shortcomings of the Merlewood composite method lay in the failure of association-analysis to produce sufficiently homogeneous groups, reflecting the complexity of the data.

Classification at both the plot (200 m^2) and site levels (frequency data from 16 random plots) has so far been produced by Hill's method. A third classification of associated species, taken from the smallest (4 m^2) is also being produced.

GENERAL OBSERVATIONS

Apart from the results from the multivariate analyses, which are described below, some general conclusions of interest have emerged from the summaries made of the data.

Few of the woodlands surveyed showed evidence that they were being intensively managed for the production of hardwood timber and such yields as were being obtained appeared to be largely incidental. The main objectives of management appeared to be for amenity, sport and shelter.

Many of the woods had at least small areas of planted conifers within them. Such planting, sporadic felling for estate purposes, and operations designed to increase the sporting interest were the main forms of active management.

Another interesting and important finding to emerge is that, contrary to general opinion, woodland regeneration does not appear to be lacking. Natural regeneration of native species (and some exotics) was present in every wood sampled, although infrequent in heavily-grazed or densely-shaded areas, indicating that woodland is still an aggressive vegetation type over much of Britain, despite its present depleted state. Neither was there evidence of widespread deterioration in tree cover—woodlands "dying on their feet"—as is often suggested. Of the dead trees recorded, few were large, suggesting that the main source of mortality is natural competition among smaller individuals.

Another early conclusion, which will be amplified at a later stage in the analyses, is that the range of true woodland species is quite narrow. Of the 488 species of vascular plants recorded in the ground flora, probably only about 100 are capable of living in dense woodland.

PRELIMINARY ANALYTICAL CONCLUSIONS

The interpretation of the groups that have resulted from the analysis of the 200 m^2 quadrats, which will be termed *standardised vegetation units*, indicates that there are very great discontinuities between them. The units show marked geographical distributions, suggesting parallels with the primary analysis of site environmental data described above.

The importance of the inter-relationship between the two scales, at the entire site level involving the cartographic units and at the phytosociological level, i.e. at a 200 m^2 scale, is emphasised. The scales will be kept distinct, but the site classification will be interpreted through its component vegetation units; for example, some sites will be characterised as consisting of a single unit, whereas others will have complexes of different units. The data in the intensive survey are capable of more detailed analysis than the original set and it is hoped to identify the influence of environmental factors to a greater degree.

Definitions of the standardised vegetation units will be given and a multiple species key based on five indicator species will be provided to identify any newly-surveyed vegetation in a similar way to an artificial floristic key. The important point from the user's point of view is that a knowledge of a relatively few species will enable any woodland vegetation to be assigned to a named description, placing it in the national context without the necessity of any experience of vegetation survey. Similarly, whole woodlands will have a parallel key. The names of the units will not be of a traditional type but will be assigned by the habitat description of the areas they occupy, emphasising the use of vegetation as an indicator of environment rather than as an end in itself.

The extent to which the range of woodland vegetation has been covered needs further investigation through examination of known extremes. However, it is thought that few, if any, species combinations for British woodlands have not been sampled. Studies of stability are also needed, but preliminary investigations suggest that replicate sampling gives reasonable reproducibility.

(*R. G. H. Bunce and M. W. Shaw*)