THE DEVELOPMENT OF THE SYSTEM OF VEGETATION SEGMENT DELIMITATION.

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Introduction.

These notes are a condensation of Bulletin 86* of the Forests Department and are designed to inform officers who will be required to apply the concepts developed therein to field mapping of vegetation. The research which was the basis of Bulletin 86 is to be understood when the words 'the study' are used below.

The Need For The Study.

Information about the natural resources of the designated area was required as a basis for sound management. The information needed to be gathered quickly and economically, subject to its being sufficient to make sensible decisions about a range of resources. These resources are:

1. Prime hardwood timber.
2. Water for domestic, industrial and irrigation purposes.
3. Softwood timber, from plantations of varying quality.
4. Bauxitic ore within long-term mining tenements over virtually the entire area.
5. Recreational potential, as the nearest area of hilly, forested country to the Perth Metropolitan area.
6. Conservation value, as the best refuge for flora and fauna threatened by agricultural clearing to the west and to the east.

The Study Technique.

It must be stated that the technique was developed by conscious decisions made towards a workable method which would simplify a complex situation, rather than from a purely investigative study without immediate practical application.

Reasons for the Adoption of a Vegetation Study.

Various other methods which enable the extrapolation of estimates of site potential from known areas are land-form mapping, soil mapping, mapping of climatic zones, and combinations of these. Vegetation was studied for the following reasons:

1. Soil data at a sufficient level of detail are scarce, and the work involved in acquiring the information would be great.
2. Climatic data at a sufficient level of detail are not, and would rarely be, available.
3. Vegetation presents an integrated result of the interaction of site and climatic factors.
4. Vegetation is itself a factor influencing land use.
5. The method had been developed and successfully applied to evaluation of land on the coastal plain, albeit for the single use of mapping potential value for pine production.

*Site - Vegetation Mapping in the Northern Jarrah Forest.
1. Definition of Site-Vegetation Types by J.J. Havel.

Possible Obstacles to the Use of Vegetation.

1. Disturbance by a century of logging.
   This was not thought to be a problem because timber extraction had been on a selection basis rather than by clear-felling. The only observable changes have been an increase in the density of Banksia grandis and Albo-casuarina fraserama in some places.

2. Disturbance due to fire.
   With the exception of some known "fire-weeds", changes are in the total amount of vegetation rather than in the proportional representation of species. Fire history was therefore not thought to be a problem.

3. Local disturbance by disease.
   This was evident and had to be accepted.

Method of Describing Vegetation.

Three possible aspects of vegetation which could be studied are the morphology or form of the plants, the structure of the vegetation assemblage and the floristic composition of the assemblage.

Morphology of plants tends to change only with marked climatic or broadscale environmental change, and on the study area the same morphological types were common throughout.

Structure ie., the density and combination of the possible life-forms such as overstorey trees, understorey trees, shrub layer and herb layer, similarly tends to vary only over broad distances. These two characteristics are therefore more suited to mapping on a continental scale.

The floristic composition or combination of species present at a site is therefore better suited to mapping at a regional or local scale. Having decided this there were then two possible alternatives.

Recording of vegetation could be qualitative ie., simple presence or absence of species. For statistical reasons this is best suited to an area where there are clearly defined associations of species, and this condition is common on a landscape with a long history of disturbance by human activity. It has the advantage that it leads to an heirarchical, or downward branching, classification which is easy to understand.

The alternative is quantitative recording, ie., making an estimate of relative abundance of each species. It is best applied to vegetation which approximates an indivisible continuum, that is it responds in a gradual way to changing combinations of the factors which affect plant growth, and portions of the continuum have not been eliminated by human activity. The only success in early studies of Western Australian vegetation at the local scale had been based on quantitative recording.

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However, the mathematical handling of such data should be by an ordination method, which produces a result which is more difficult to interpret than an heirarchical classification.

Whereas a class with a name is easier to conceive and can be associated on a map with an area which it occupies, the site-determined relationships between species which are identified and displayed in numerical form by an ordination procedure are difficult to visualize. On a map, change in one dimension of the continuum could be represented only by a series of iso-lines similar to elevational contour lines or rainfall iso-hyets. Representation of change in several dimensions of the continuum would entail several series of iso-lines, and interpretation of the resultant maze of lines would be almost impossible.

However it is possible to display the principal components of variation within the continuum by means of models. It is then possible to divide the continuum visually into segments, without precise boundaries, and to represent each segment by a list of the species which it contains.

A further disadvantage of an ordination technique is that new observations are difficult to allocate without repeating all the computations, which means that extension of the system to new areas is difficult.

In the light of these advantages and disadvantages, a decision was made to conduct the study by both classificatory and ordination procedures.

Objectives of the Study.

At this stage the objectives could be defined as follows:

1. To define vegetation types (species groupings) which can be assumed to be biologically equivalent irrespective of where they occur in the survey area.
2. To elucidate the reasons for their occurrences in terms of controlling environmental factors.

Field Methods.

Plots measuring 20m x 20m (0.16ha) were accurately surveyed and marked in the following situations:

1. Coinciding with permanent hardwood growth study plots.
2. Within and adjacent to pilot plots of pine species. Each adjacent plot for study of indigenous vegetation was placed on a site judged equivalent to the corresponding pine measurement plot, on the basis of soil profile and residual indigenous species under the pines.
3. In unmeasured virgin forest (a few plots only).

Diameters and various measures of height were recorded for tree species, and percentage cover of shrub and perennial herb species were recorded on sixteen 1 metre square quadrats evenly spaced within each plot.

The topography was described and description and sampling carried out on one soil profile in each plot.

There were 320 plots, on which 364 shrub and herb species, and 18 tree species, were recorded.

Data Analysis.

Classification of data by various methods produced the results that those methods whose decision sequences were simple to follow gave poor species groupings while one which gave distinct groupings of readily-intelligible environmental significance had a decision sequence too complex to follow. The potential advantage of easy allocation of new observations was therefore not realized.

The ordination procedure produced meaningful arrangements both of species and of plots and is therefore described briefly below.

First the programme analysed abundance data to determine correlations between species. It then identified successively smaller ranges or components of tendency to associate with other species, resulting in a component loading numeral (positive or negative) for each species on each component. Then a plot component score could be calculated by combining species component loading with the departure of the species abundance on the plot from its mean abundance, and summing for all species on the plot.

Data Interpretation.

Species component loadings can be used to model part of the continuum in two dimensions at once as in Figure 1 and Figure 2. Species relationships can be better visualized by making different combinations of components. Visualization is further improved by construction of a three-dimensional model on which a fourth component can be codified in a restricted range of colours (similar to Plate 1 of Bulletin 86).

Plot distribution in relation to four components is illustrated by the model pictured in the above illustration. Distribution in relation to two components at a time was displayed by a programme which printed a matrix of 20 x 20 cells, each occupied cell containing plots whose co-ordinate scores were closest and contributed to the mean score for the cell. For one species at a time mean abundance data could be printed for each cell in which it was present (see Figure 3). These diagrams aided understanding of which species were contributing most to the placing of particular plots in the continuum.

FIGURE 1: Distribution within component space of Sunkland indicator species, components 1 and 2 (see Appendix IV for species key).

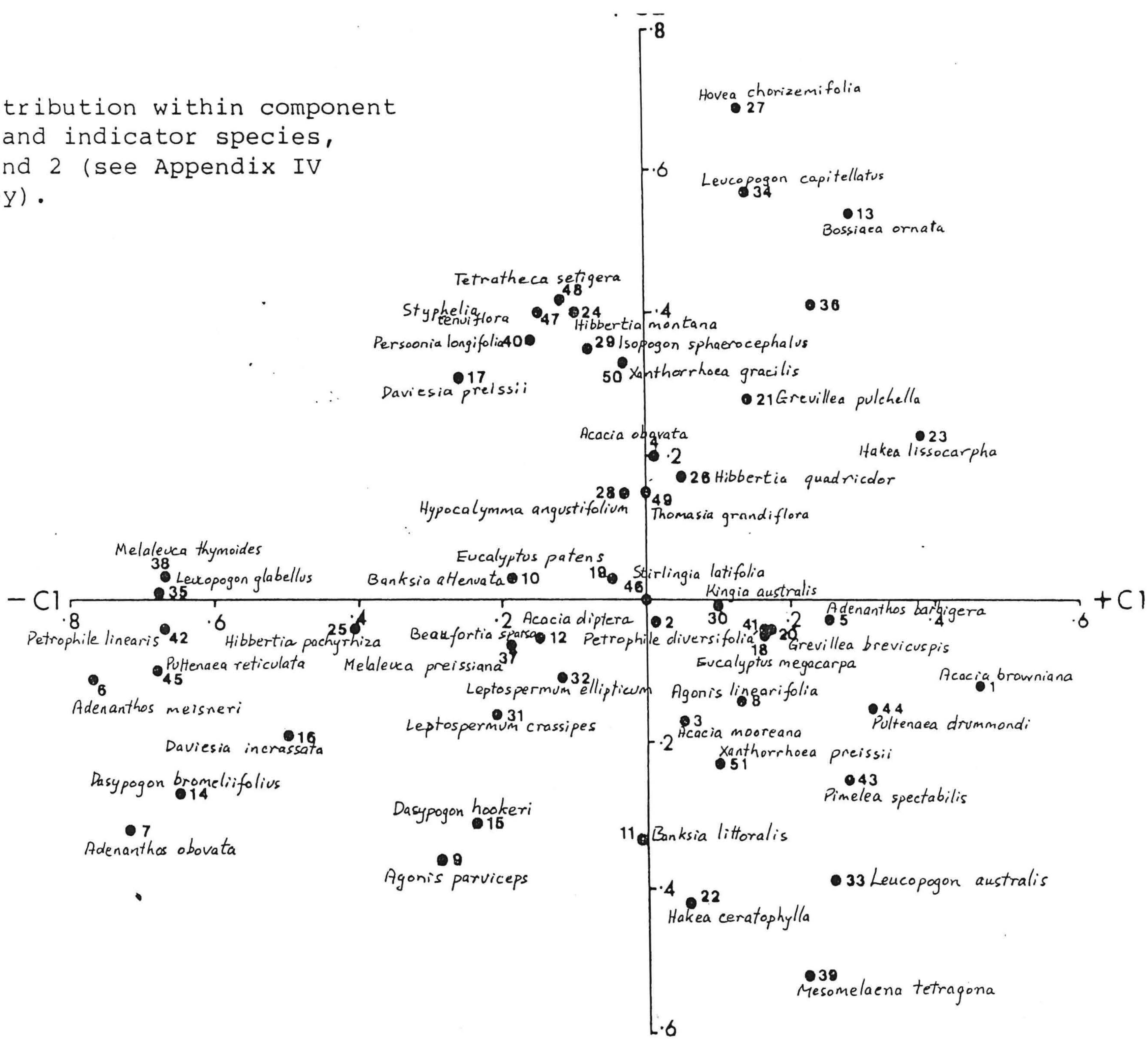

FIGURE 2: Distribution within component space of Sunkland indicator species, components 3 and 4 (see Appendix IV for species key).

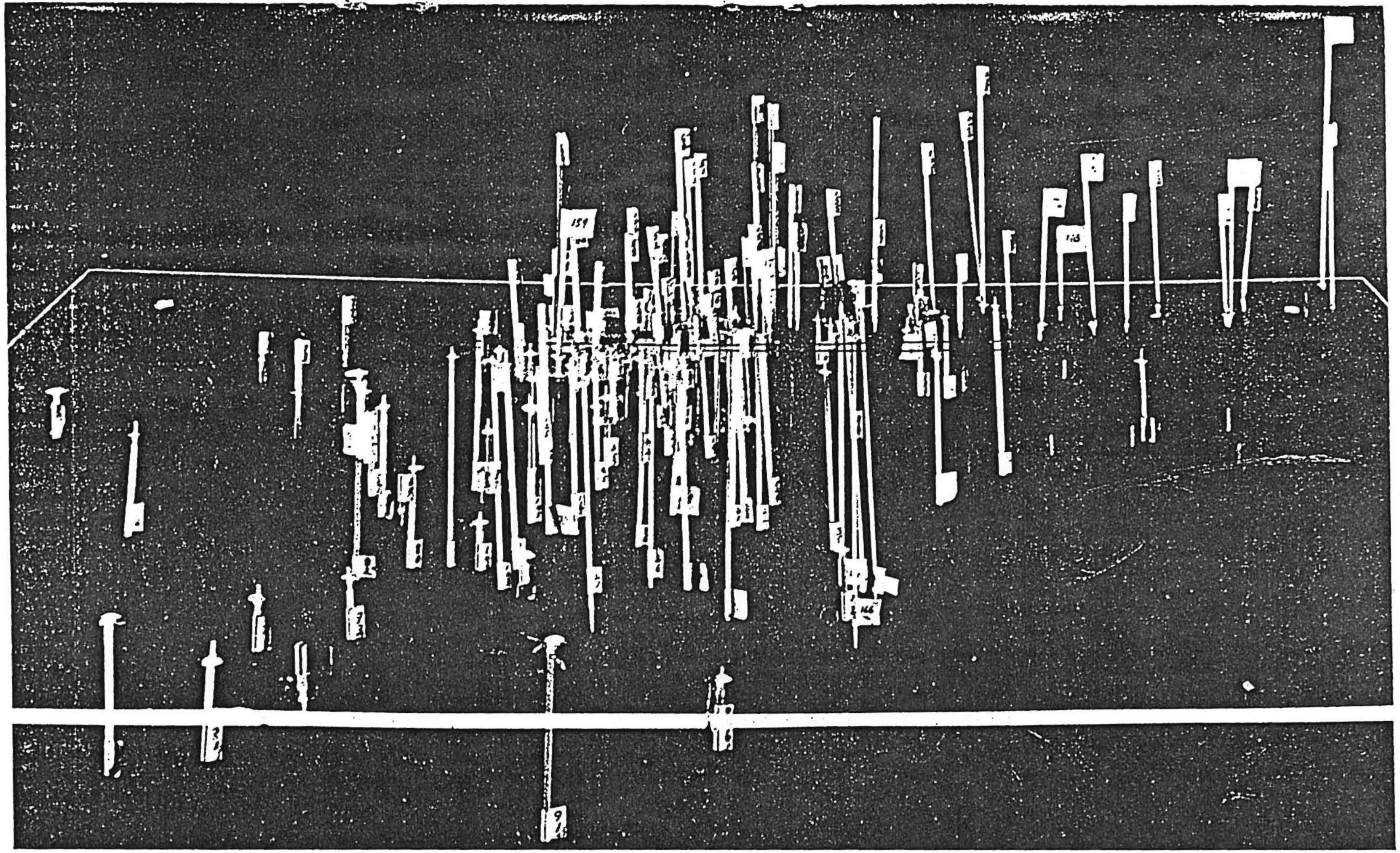

PLATE 1. Four-dimensional model of ecological relationships in the northern jarrah region. Each coloured stick represents an ecological sample plot. The arrangement of components derived by principal component analysis is as follows:

(a) Left to right, — F_1 to + F_1
(b) Front to back, — F_3 to + F_3
(c) Up + F_4, down — F_4
(d) Blue, high — F_2; green, low — F_2; yellow, low + F_2; red, high + F_2

Figure 3. Distribution of plots in relation to their scores on Components 1 & 2; distribution of one species on the plots.

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PRODUCED BY PROGRAM CORD ON  81/10/23

PINESITE DATA - GRAHAM MCCUTCHEON - SHRUBS
        FACTORS       1 AND 2           XANTHORRHOEA PREISSII              SET 4
4.3       *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
                                                      1.0
4.0       *    0    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0*

3.7       *    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0*

3.4       *    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0*

3.1       *    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0*

2.9       *    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0*
                                  2.0
2.6       *    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0*

2.3       *    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0*

2.0       *    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0*
                        4.0                                                                   1.0
1.7       *    0    0    1    0    1    0    1    0    0    0    0    0    0    0    0    0    1    0    0    0*

1.4       *    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0*

1.1       *    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0*

.81       *    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0*
                             3.0       2.0                                                                   3.0
.52       *    0    0    0    1    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    1*
                                                      1.0  1.0  2.0
.23       *    0    0    0    0    0    0    1    0    1    1    1    0    0    0    0    0    0    0    1    1*
              5.0                      3.0  1.0       .5                       1.0
-.61E-01  *    1    0    1    0    0    1    1    0    2    0    0    0    0    1    0    0    0    0    0    1*
              4.0            3.0  2.0  1.5            2.0
-.35      *    1    0    0    1    2    2    0    0    2    0    0    0    0    0    0    1    0    0    0    0*
                             4.0  3.0  3.5                                2.0       1.0
-.64      *    0    0    0    1    2    2    1    1    2    0    0    0    2    1    2    0    0    0    0    0*
                                       1.0       .5                       1.0
-.94      *    0    0    0    1    0    2    0    2    1    1    0    0    1    0    2    0    0    0    0    0*
                             4.0            2.0
-1.2      *    0    0    0    1    0    1    1    0    0    0    0    0    0    0    0    0    0    0    1    0*

-1.5      *    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0*
          *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
          ↑         ↑         ↑         ↑         ↑         ↑         ↑         ↑         ↑         ↑         ↑
        -1.7      -1.3      -.90      -.50     -.87E-01 .32       .73       1.1       1.5       2.0       2.4
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Component 2 →

Component 1 →

Further, the ability to overlay on the matrix cell means for any environmental attribute recorded assisted in linking those attributes with plot and with species distribution.

The species groupings determined were given mnemonic code names which were abbreviations of habitat characteristics (see Appendix 2 of Bulletin 86). The plot groupings regarded as representing segments of the continuum were identified by letters of the alphabet. Figure 16 represents a summary of the groupings of species, plots and environmental characteristics.

Data Collection on a Broad-Scale Survey.

The detailed method of data collection employed for the study would be uneconomic if applied over a large area of land. A simple 0-5 abundance rating scale was adopted with the abundance definition for trees different from that for shrubs and perennial herbs. The indicator species were listed alphabetically along the top of a field recording sheet on which the abundance scores on a plot could be recorded in the columns under the represented species.

Allocation of New Data to Groups.

The simpler way of describing abundance meant that component loadings derived from the study could not be applied to allocate each record of a broad-scale survey to a place in the continuum. Considerable testing of new computer programmes to do this led to the conclusion that while satisfactory results could be achieved, the time required to convert human judgement in an inter-active way into a precise set of definitions was excessive.

A method of mentally matching each site record species by species against defined "normal" composition patterns was therefore adopted (see Figure 20 of Bulletin 86). A knowledge of site-species relationships is desirable to do this in order to allow for species which are less precise indicators than others. This method allows sites to be typed reliably, if slowly, by relatively untrained people, and more quickly by experienced personnel. A helpful later development has been a revised field form which relists the species into environmentally meaningful groups.

Because of the continuum nature of the vegetation, site types are difficult to delineate clearly; there may be overlap of species. However the degree of mis-typing of a site is usually small and the effect is not likely to be serious in a management context.

APPENDIX 2

Enumeration of indicator groups

(1) *Dasypogon bromeliaefolius*, *Adenanthos obovata*. SAnds, Moist, heavy ORGanic matter incorporation in topsoil—SAMORG.

(2) *Banksia attenuata*, *Caustis dioica*, *Conospermum stoechadis*, *Hibbertia polystachya*, *Leucopogon cordatus*, *Nuytsia floribunda*, *Patersonia occidentalis*. SANds, strongly LEAched—SANLEA.

(3) *Hakea cyclocarpa*, *Isopogon dubius*, *Sphaerolobium medium*, *Stirlingia latifolia*. EAstern Gravelly SANds—EAGSAN.
Stirlingia latifolia had a somewhat narrower range on the second component, not occurring on plots with high +F2. It was included here to avoid creating too many groups.

(4) *Daviesia pectinata*, *Hakea ruscifolia*. DRY SAndy Gravels—DRYSAG.

(5) *Casuarina humilis*, *Dillwynia cinerascens*. DRy soils of INtermediate Fertility—DRINF.

(6) *Acacia strigosa*, *Patersonia rudis*, *Pimelea suavolens*, *Styphelia tenuiflora*. DRY GRAvels—DRYGRA.

(7) *Casuarina fraseriana*, *Grevillea wilsonii*. SANdy GRAvels, medium rainfall zone—SANGRA.

(8) Jarrah (*Eucalyptus marginata*) has, in view of its importance, been retained as a group, though its wide range of occurrence makes it of limited use as an indicator. There are several understorey species, such as *Hibbertia montana* and *Xanthorrhoea gracillis*, whose range is very similar.

(9) Marri (*Eucalyptus calophylla*) has been retained for the same reasons as *E. marginata*. Understorey species with a comparable range of occurrence are *Bossiaea ornata*, *Dryandra nivea* and *Xanthorrhoea preissii*.

(10) *Adenanthos barbigera*, *Banksia grandis*, *Hovea chorizemifolia*, *Persoonia longifolia*. GRAvels in MEDium rainfall zone—GRAMED.

(11) *Acacia urophylla*, *Bossiaea aquifolium*, *Lasiopetalum floribundum*. GRAvels in HIgh Rainfall zone—GRAHIR.

(12) *Leucopogon capitellatus*, *Leucopogon propinquus*, *Macrozamia riedlei*, *Phyllanthus calycinus*, *Trymalium ledifolium*. FREsh GRAvels (maximum development on admixture of lateritic gravels and fresh soils developed from underlying rocks)—FREGRA.

(13) *Leucopogon verticillatus*, *Pteridium esculentum*. HIgh rainfall, predominantly GRAvelly soils—HIGRA. *Pteridium* differs slightly from *Leucopogon* in that it has a broader edaphic range, extending further on to fertile soils (high-F4).

(14) *Hakea lissocarpha*. (*Kennedia coccinea* appears to have a comparable range, but has not been fully tested). BROad tendency towards higher FERtility—BROFER.

(15) Wandoo (*Eucalyptus wandoo*) retained as a separate group because of its overall importance; closely resembles BROFER.

(16) *Diplolaena drummondii*, *Hibbertia lineata*, *Gastrolobium calycinum*. DRY FERtile soils—DRYFER. *Gastrolobium calycinum* has a broader range than the other two species, and is intermediate between groups DRINF, BROFER and DRYFER.

(17) *Trymalium spathulatum*. (*Chorizema ilicifolium* has a comparable, though somewhat narrower, range and is less common). FErtile loams in HIgh RAinfall zone—FEHIRA.

(18) *Acacia extensa*, *Eucalyptus patens*, *Hypocalymma angustifolium*. FERtile MOist soils—FERMO.

(19) *Agonis linearifolia*, *Eucalyptus megacarpa*. (*Lepidosperma tetraquetrum* and *Grevillea diversifolia* have comparable ranges, but have not been fully tested). *Eucalyptus megacarpa* occasionally extends on to drier ground. WET ALluvium—WETAL.

(20) *Baeckea camphorosmae*, *Dampiera alata*. BROad tendency towards FErtile Moist soils.—BROFEM.

(21) *Kingia australis*, *Mesomelaena tetragona*, *Synaphea petiolaris*, *Lepidosperma angustatum*. BROad tendency towards MOist sites—BROMO. *Kingia australis* differs from the rest in having a narrower range on the second component, being absent from plots with high +F2.

(22) *Leptocarpus scariosus*, *Leptospermum ellipticum*. BROad tendency towards WET sites—BROWET. The range of *Leptospermum* is slightly narrower than that of *Leptocarpus*.

(23) *Banksia littoralis*, *Hakea ceratophylla*, *Hakea varia*, *Melaleuca preissiana*. (*Astartea fascicularis* has a comparable range, but has not been fully tested). VERy WET sites—VERWET.

DEFINITION OF SITE-VEGETATION TYPES.

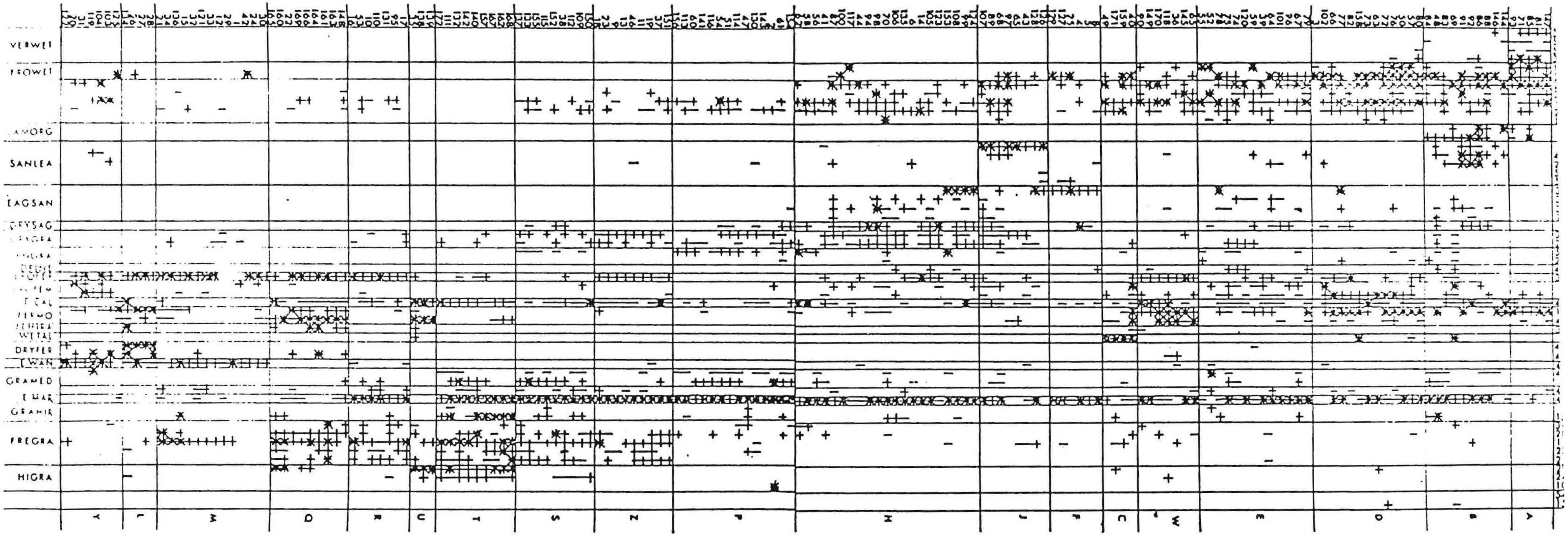

Figure 16

Two-way table of ecological sample plots and indicator species, arranged in groups cn the basis of principal component analysis (second approx mation, varimax scores). The level of occurrence, as indicated by cover of shrub species and basal area of tree species, is shown as follow n, low; cross, medium; asterisk, high. The individual indicator species are enumerated by their reference numbers on the right; the individu ts are enumerated horizontally above the table. Species groups are described on the left by their mnemonic names and plot groups a shown horizontally below the table by their reference letters.

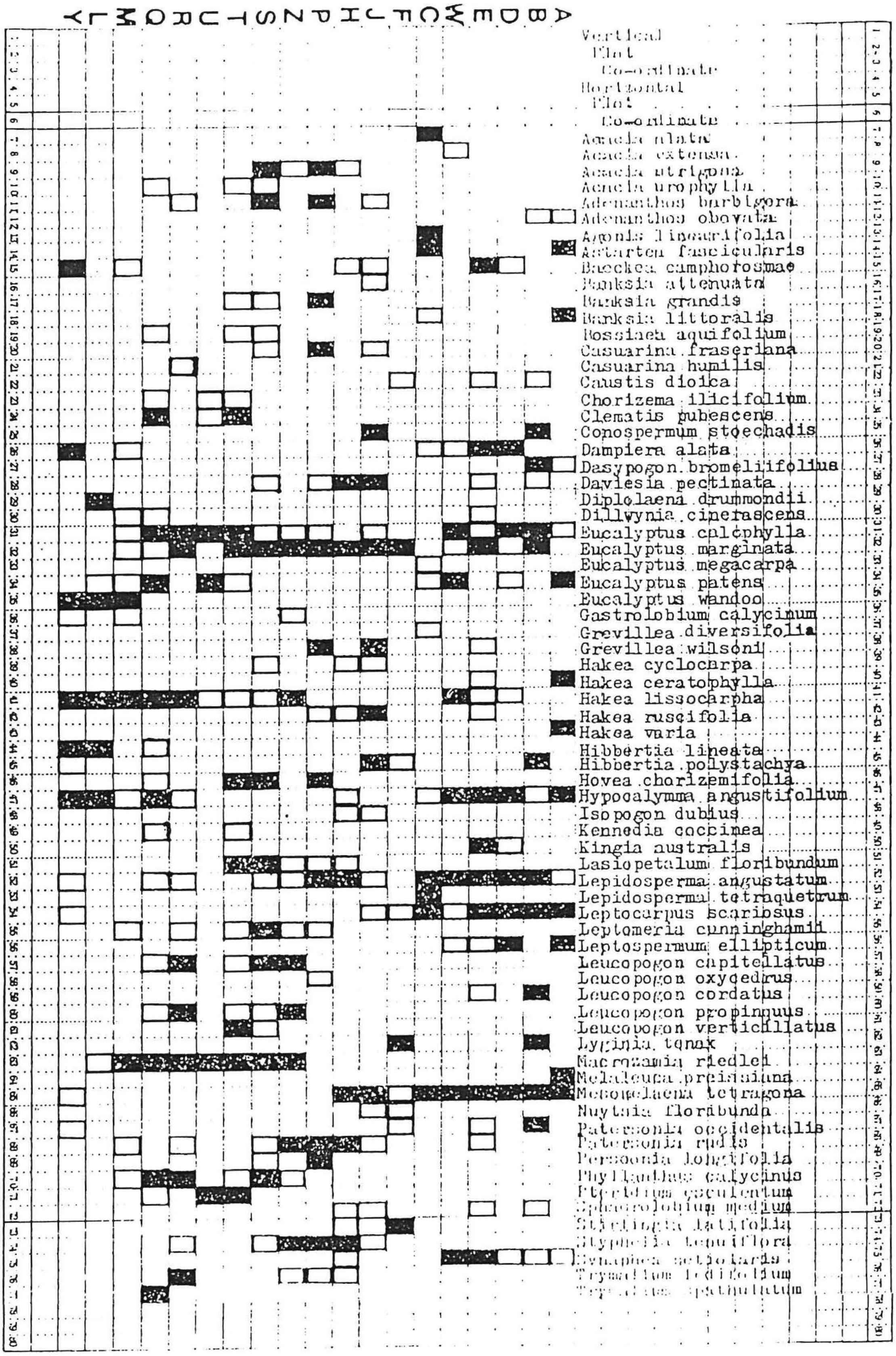

Figure 20

Table of indicator species used in allocation of new field observations to appropriate site-vegetation types by matching. Three levels of occurrence are used as follows:

a) completely blank species should be absent
b) outline only species should be present but absence not critical;
c) outline filled species should be present