A STRUCTURAL-FUNCTIONAL CLASSIFICATION OF THE FYNBOS VEGETATION OF THE BAIN'S KLOOF AREA

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ABSTRACT

Structural-functional vegetation data from 37 plots sampled in the Bain's Kloof area were subjected to 10 different numerical analyses. The use of the relativized Czekanowski coefficient on log-transformed data produced the best classifications. Non-stratification of growth-form attribute data results in a broad classification consisting of 5 major structural types; these can be further divided into sub-types by using stratified data. A structural classification of the vegetation of the Bain's Kloof area, incorporating environmental and floristic data, is presented.

INTRODUCTION

Linder and Campbell (1978) have recently expressed the need for a classification of fynbos types as a first step towards solving problems in conservation and resource management, and as a reference tool for detailed research in a wide range of disciplines. However, the great floristic diversity of the fynbos~~, which is expressed in all four components - alpha, beta, gamma and delta (Whittaker, 1960)~~, and the lack of recent taxonomic treatments of the flora render a floristic classificatory approach infeasible. For these reasons there has been a recent emphasis on the possibility of using structural-functional information to classify fynbos (Moll et al, 1976; Linder and Campbell, 1978; Campbell, pers. comm; Kruger, in prep.). Structure is defined as the spatial arrangement of the plant biomass, and includes vegetation physiognomy (the external appearance of the vegetation); function refers to those features of the plants that are apparent adjustments to the environment, for example leaf size.

not the correct reference Whittaker 1972 mentions alpha beta + gamma but delta diversity appears to be a local word, perhaps invented by Kruger.

Linder and Campbell (1978) envisage the use of computer-based classificatory methods for sorting the data. These workers concluded that as the variation ranges and occurrence of structural-functional characters in fynbos are not yet understood in detail, and as the theoretical and logical nature of these attributes has not yet been elucidated, some experimentation with methods of data transformation and with similarity coefficients would have to accompany attempts at basing a classification on these data. In the present work I have attempted to use structural-functional information to erect a classification of the fynbos vegetation of an area in Bains Kloof. The merits of the methodology suggested by Linder and Campbell have been investigated, and a variety of numerical techniques have been tested.

THE STUDY AREA

The study was conducted in the neighbourhood of the Bain's Kloof Village at the top of Bain's Kloof Pass in the Slanghoek Mountains, an altitude of 900 to 1200 metres, latitude 33° 37' and longitude 18° 37'. The area of the study site was approximately four square kilometres. The substrate is uniform, all the soils being derived from the sandstone rocks of the Table Mountain Series. Within this small area all topographical aspects are present; there is a range of sites from xeric to riverine, and a range from deep sands to rock outcrops. Bain's Kloof falls within the winter-rainfall climatic belt, ~~a major factor in the development and ecology of the fynbos-vegetation type.~~

this sentence only adds mystery.

METHODS

Data collection

Thirty-seven 10 x 10m plots were subjectively located in visually homogeneous stands. ~~Sampling was conducted according to the Braun-Blanquet principles (Mueller-Dombois & Ellenberg, 1974)~~ ~~and~~ At each plot the following habitat parameters were recorded : aspect, slope, topography, size of rocks and their percentage cover, estimates of average soil depth and drainage.

rather omit this as readers may think that you have used a floristic approach.

The a priori choice of the structural ~~and~~ functional characteristics to be recorded was made on the basis of the recent works by Linder and Campbell (1978) and Kruger (in prep.). The 24 'growth-forms' (23 woody and 10 herbaceous) that were ~~used are~~ present in the study area are shown ~~presented~~ in Table 1. The percentage projected canopy cover of ~~every~~ the growth-forms was recorded in each of six predetermined height classes : 0-0,25m; 0,25-0,5m; 0,5-1m; 1-2m and 2-5m. The leaf sizes are those of Raunkiaer (1934). ~~Thus, altogether it was proposed to collect in each plot 33 structural attributes (23 woody and 10 herbaceous), stratified into six height classes where these were applicable.~~ Each plot took about 15 minutes to record.

correct these numbers

5 or 6 - you only mention 5.

[TABLE 1]

the ~~33~~ 24 'growth-forms'

TABLE I. ~~Growth-form attributes~~ recorded in the study.

Leave out those growth forms that were not found in the study area.

- **Herbaceous**
  - 1. Restioid
  - Graminoid
    - 2. terete
    - 3. rolled/narrow = 0,5cm wide
    - 4. medium = 0,5 - 1,5cm wide
    - 5. broad = >1,5cm wide
  - Perennial forbs
    - 6. parallel-veined
    - 7. net-veined
  - 8. Annual forbs
  - 9. Parasitic climbers
  - 10. Succulents

leave some spaces between herbaceous and woody.

- **Woody**
  - Narrow sclerophyll
    - 11. ericoid
    - non-ericoid
      - 12. leptophyll
      - 13. nanophyll
      - 14. microphyll
      - 15. mesophyll
  - 16. Cupressoid
  - Orthophyll
    - 17. leptophyll
    - 18. nanophyll
    - 19. microphyll
    - 20. mesophyll
  - 21. Aphyllous
  - 22. Climbers
  - Broad sclerophyll
    - isobilateral
      - seed regenerating or coppicing from the ground
        - spinescent
          - 23. leptophyll
          - 24. nanophyll
        - non-spinescent
          - 25. leptophyll
          - 26. nanophyll
          - 27. microphyll
          - 28. mesophyll
      - coppicing above ground
        - non-spinescent
          - 29. microphyll
    - dorsiventral
      - non-spinescent
        - 30. leptophyll
        - 31. nanophyll
        - 32. microphyll
        - 33. mesophyll

Explain why these ~~classes~~ growth forms were combined

(~~Classes~~ Growth-forms 25 and 30; and 26 and 31 were combined, see text)

Problems were encountered with certain of the growth-form attributes. The difference between dorsiventral and isobilateral leaves is not clear-cut. Neither is the distinction between ground and stem regeneration easy to determine. In fact, finally only Protea arborea was placed as a stem regenerator, but at the end of the survey specimens of both Diospyros glabra and Maytenus oleoides were noticed coppicing high above ground level following a light fire. Another problem concerns the definition of the term 'narrow'. Taxonomically narrow is defined as a length that exceeds the width fourteen times. As this definition is too restrictive other measures are often used in ecological surveys. When using a nine-times criterion both Protea repens and Leucadendron salignum are classed as narrow-sclerophyllous-leaved woodies, although by normal definition proteoid elements are considered as being broad-sclerophyll.

Difficulty was also experienced placing certain species. Stoebe, which has minute leaves that are adpressed to the stem, was classified as ericoid, although in future surveys it might well be considered as cupressoid. Due to the fact that Stoebe is common in drier areas this is an important consideration as it might serve to separate wet and dry ericoid sites without stratification data, a matter dealt with at greater length later. The definition of 'orthyphyllous' is also uncertain. Plants such as Serruria florida and Psoralea pinnata have soft, pinnate leaves, while those of Helipterum canescens are soft, entire and pubescent. There is surely some ecological differentiation, and I feel that a pubescent-leaved class should be established, instead of lumping this form with glabrous types, which often have divided leaves. Pubescence is another important consideration in distinctions between wet and dry fynbos sites. The last problem noted is the placing of such species as Asparagus scandens. This woody plant has a climbing habit, narrow-sclerophyllous leaves and stem spines. Which feature is ecologically most important and should take preference in the record? Annuals were not recorded in the present study, but could be useful indicators in other more xeric study sites.

Data analysis

Classification

The polythetic agglomerative method of group-average sorting (Campbell, 1978) was used to construct the numerical classifications of the 37 plots. These are represented as dendrograms. Due to the fact that not all leaf sizes were encountered for each growth form in the field, a total of 24 attributes for six height classes, where applicable, were used.

Ten analyses were carried out varying :

1. the data matrix (by deletion and combination of ~~attributes~~ growth-forms);
2. the type of data transformation;
3. the similarity coefficients. These ~~steps in data manipulation~~ analyses used are ~~summarized~~ shown in Table 2.

The first edited data matrix, matrix 1., consisted of 82 ~~growth-forms~~ attributes (growth-forms in height classes) ~~attributes~~ and three analyses were run using this set. The second step involved a combination of those growth forms and height classes whose distinction was felt (by field experience) to serve no purpose. Thus, for example, the terete and narrow-leaved graminoids growth-forms (2 and 3); both lepto- and nanophyll, and micro- and mesophyll leaf sizes; and all the height classes for such individual forms as 'cupressoid' (16) and 'stem-regenerating' (29) were combined. Matrix 2 consisted of 61 ~~growth form~~ ~~attributes~~ attributes and was similarly used for three analyses. Lastly, all height classes were combined and matrix 3 consisted of 18 ~~growth form~~ attributes; it served as the basis for a further four analyses.

Three different transformations of the data were used for various analyses : log transformation, Coetzee & Werger (1973) transformation, and conversion to an ordinal scale (Campbell, 1978). Log transformation removes the effects of the dominant species but retains the relative order of importance - perhaps an advantage when using the abundance-weighted Czekanowski coefficient. Both Coetzee & Werger and ordinal transformation also remove abundance-weighting, and are based on the well-known alpha-numerical scale

TABLE 2. Factors applied in ten numerical analyses of fynbos structural - functional data.

Analysis number	Data Number	Matrix G.F. Attributes	Trans-formation of data	Similarity Coefficient	Relativization yes	Relativization no
1	I	82	log	Cz		+
2	I	82	log	Cz	+	
3	I	82	C & W	Cz	+	
4	II	61	-	Cz		+
5	II	61	ord	Can		+
6	II	61	ord	Cz		+
7	III	18	-	Cz		+
8	III	18	log	Cz		+
9	III	18	-	Cz	+	
10	III	18	log	Cz	+	

C & W = Coetzee and Werger (1973)

ord = ordinal scale

Cz = Czekenowski

Can = Canberra

There is hardly any data analysis discussion on these methods in the text.

of Braun-Blanquet (Mueller-Dombois & Ellenberg, 1974). The Coetzee & Werger scale runs from 1 to 50, the ordinal scale from 1 to 9. Thus, the latter gives the least weight to the high cover species.

The Bray and Curtis (Czekanowski) coefficient was used both in its relativized and unrelativized forms. The formulae for these coefficients are given in Campbell (1978) and they are the ones used by Linder & Campbell (in press). The Czekanowski coefficient is an abundance-weighted (= cover-weighted) coefficient, and therefore when using it attributes with a high abundance value will contribute more to the similarity assessment than those with low abundance. The Canberra measure is not abundance-weighted. Both have given varying measures of success in recent analyses (Campbell & Moll, 1976; Campbell, 1978; Linder & Campbell, in press).

Ordination

The ordination technique of reciprocal averaging (Hill, 1973) was used. This has been highly recommended by Gauch & Whittaker (1972). ~~Triple sets of~~ Three ordination axes were extracted from matrices 1 and 3. The ~~combinations~~ results chosen to be represented in figures 3A and 3B were considered most accurate in accounting for a large portion of interstand ~~similarity.~~ variability. The initial plot (Figure 3A) showed that plots such as those on boulder outcrops were so different that they caused others dominated by restioid-ericoid-proteoid vegetation to fall into a tight group. ~~Such~~ The outlying plots were progressively removed from consideration in order to gain a better expression of ~~the similarities between these plots,~~ group structure in the major groups, i.e. a better spread of points. Thus, Figure 3B has had all boulder-ridge, rocky outcrop and riverine ~~vegetation~~ plots removed.

[but these ordinations are of different matrices, why?]

RESULTS AND DISCUSSION

Methodology

A favourable point relating to the data collected is that none of the ten analyses produced ~~was~~ results that were ecologically ~~absolutely~~ meaningless; i.e. if plots were 'misplaced' ~~then this~~ they could be explained. This fact makes scoring the cluster analyses extremely difficult (Campbell, 1978; Linder & Campbell, in press). All the interpretations show an early divergence into two groups : on the one hand those non-proteoid plots consisting of tall stands of predominantly dorsi-ventral-leaved species (boulder outcrop and riverine plots) and on the other the mountain slope plots. There were two exceptions to this split; a riverine plot (17) with a very high ericoid element (Berzelia lanuginosa) was sometimes placed with moist Erica hispidula plots; and a rocky outcrop plot (4, more a rocky ridge) in which the quadrat was laid down as 20 x 5m^2 and contained a large component of the neighbouring mountain-slope type, was not placed with the other rocky outcrop plots.

Transformation of the data onto an ordinal scale did not produce a successful cluster analysis with the Canberra measure; the groupings were formed more distinctly and more accurately with the Czekanowski co-efficient, contrary to the results obtained by Linder & Campbell (in press). A comparison between logarithmic and Coetzee & Werger transformations proved difficult: while the latter was slightly easier to interpret, the log transformation gave better placings of the two difficult plots, 4 and 17. The Czekanowski co-efficient in its relativized form gave consistently better results than in its ~~unrelativized~~ form. This again supports the view of Gauch and Whittaker (1972) and Campbell (1978) that there is an advantage in the normal use of the relativized form.

The major differences between the dendrogram classifications revolve around the form taken by the data matrix. Figures 1 and 2 are presented as comparisons between the full (matrix 1) and final (matrix 3) growth-form attribute matrices, respectively. They have been subjected to the same numerical treatment, i.e. log-transformation and the relativized Czekanowski co-efficient (analyses 2 and 10). The second dendrogram is certainly the easier to interpret. In it the mountain slope plots are divided into restioid, ericoid-restioid, ericoid and proteoid structural types. Although these basic distinctions are made in figure 1, the groupings are subdivided and the subdivisions often scattered along the length of the abscissa. The reason for this is the presence of the height factor; while analysis 2 takes the height of the community into account, analysis 10 simply compares growth form attributes and their cover. Two examples will serve to indicate the effect that this has on similarity interpretation :

1. Plot 5 is a badly-drained depression dominated by Restio curviramus. Plot 6 is a taller restioid community, apparently slightly better drained. Plot 37 is a bed-rock slope, similarly seasonally waterlogged and with a sparse cover of R. curviramus. All these plots are colloquially termed 'seeps'. Their treatments in the two analyses ~~figures~~ are very different : analysis 2 places the two R. curviramus plots as 50% similar, and very different to the rest of the plots, including plot 6. On the other hand, analysis 10 places plots 5 and 6 as over 90% similar due to their very high restioid components; plot 37 is more distantly related, while still on the main restioid stem. If one divided the restioid growth form into two separate attribute classes - straight-stemmed and wavy-stemmed restioids, then seasonally waterlogged (and permanently moist situations containing Restio perplexus) situations would be separated from those with a drier moisture regime.
2. This example concerns three ericoid-dominated plots. In those analyses using height as an attribute plots 7 and 9 are similar due to high cover of tall Erica hispidula, as they occur in damp situations.

Plot 19 is a very dry north-facing slope with ~~a~~ the vegetative cover dominated by short ericoid species such as Eremia totta and Stoebe plumosa. Yet in analysis 10 plots 19 and 9 are placed 93% similar because height is not taken into consideration. Important factors to be noted are firstly possible distinctions between pubescence and non-pubescence, and secondly separation of Stoebe from normal ericoid forms. If these ~~factors~~ other characteristics had been ~~computed~~ used then the moist and drier plots may well have been separated.

It has been said repeatedly of numerical methods that their success rests upon the choice of data used. In fact, should sampling be rendered more complex by the gathering of stratification data?

Is the magnitude of the inaccuracies just noted significant? Can they be compensated for by the addition of extra attributes similar to those already suggested? In fact, the differences between ~~(environmentally governed)~~ vegetational sub-types, such as tall and short ericoid or restioid structural types, are so obvious in the field that confusion should not result; a simple rider in the classification to the effect that tall vegetation is normally indicative of moist situations would serve to overcome most difficulties. The objectives of the survey should be considered; if one is seeking a very simple method of vegetation classification for veld management or to assist other disciplines then non-stratification is probably adequate, and all the time and effort involved in stratifying growth forms is not going to repay itself with increased information. In the opinion of Kruger (in prep.) : "since the structure of any fynbos community is in a state of fairly rapid change, due to development after fire, structural description should not rely too heavily on such characters as height". This is an important complication to consider. Plots 12 and 34 in this survey were located in an area thought to have been burned within the last eight years.

In my own opinion, however, an efficient survey requires the use of both approaches. Without subdivision into height classes one could construct the major structural types of the classification, for example restioid, restioid-ericoid, ericoid, proteoid communities, etc. Stratification would then yield a more detailed breakdown of these major groups and, in addition, would give an insight into the progress in regeneration after a burn.

STRUCTURAL TYPES

Figure 2 indicates that there are five major structural types within the fynbos vegetation of the Bain's Kloof area. ~~Three of these can be further divided into subtypes.~~ Environmental data (aspect, slope, rock cover and estimated moisture regime) super-imposed onto the ordination diagrams show somewhat indefinite trends. Combination of factors by coding and addition or multiplication, provided these are used vigilantly, is more successful. One such example is the use of the mesic-xeric aspect gradient of Whittaker (1967) coded from 17 (no aspect) to 1 (full north-facing slope) and then combined with other estimates.

Within the different structural types there are certain indicator species of environmental conditions. While epiphytic lichens indicate exposed situations, various restioids give an indication of moisture regime, for example <u>Restio</u> <u>curviramus</u> = seasonally waterlogged and <u>Restio</u> <u>perplexus</u> = permanent moisture.

The following is a classification of the vegetation of Bain's Kloof based on structural-functional, environmental and floristic data:

STRUCTURAL TYPE 1 : Non-proteoid, broad-leaved woody communities. Tall (often over 5 metres) shrubs with dorsi-ventral leaves.

Habitat : This structural type occurs in areas where fires are infrequent - on rock outcrops, screes or riverine sites.

<u>Sub-type A</u> : Rocky outcrop community.

Habitat : Exposed boulder outcrops. Soil limited to interstices between the rocks.

Dominant species : <u>Widdringtonia</u> <u>nodiflora</u>, <u>Heeria</u> <u>argentea</u>, <u>Hartogia</u> <u>schinoides</u>, <u>Ehrharta</u> <u>aphylla</u>, (usually associated with epiphytic lichens) <u>Oscularia</u> <u>deltoides</u>.

Sub-type B : Boulder ridge community.

Habitat : Boulder (bedrock) outcrops. A moister situation than rocky outcrops.

Dominant species : *Heeria argentea*, *Maytenus oleoides* and *Maytenus acuminata*, *Knowltonia capensis*, *Secamone alpinii*, ferns, climbers and epiphytic lichens.

Sub-type C : Riverine scrub community.

Habitat : A permanently wet situation, with deep alluvial soils or boulders.

Dominant species : *Brachylaena neriifolia*, *Metrosideros angustifolius*, *Myrica serrata*, *Psoralea pinnata*, *Berzelia lanuginosa*, *Elegia capensis*.

STRUCTURAL TYPE 2 : Proteoid communities. (Proteoid stratum between 2 and 5 metres in height).

Habitat : Sites with intermediate slope, rockiness and moisture regime. Soils well-drained, from 5 - 20cm in depth.

Dominant species : *Protea laurifolia*, *Protea repens*, *Chondropetalum paniculatum* (*Thamnochortus*, *Willdenowia* and other restioid species), *Leucadendron salignum*, *Erica plukinetti*, *Erica hispidula*; *Erica nudiflora* in moister and *Eremia totta* in drier situations.

STRUCTURAL TYPE 3 : Ericoid communities.

Sub-type A : Tall (1 - 1,5 metres) ericoid communities.

Habitat : Moist situations with deep soils.

Dominant species : *Erica hispidula*, *Willdenowia sulcata*, *Restio sieberi*, *Restio perplexus*, some riverine shrubs, for example *Psoralea pinnata*.

Sub-type B : Short (0,5 - 1m) ericoid communities.

Habitat : Very dry sites, rocky with shallow soil, for example north-facing slopes.

Dominant species : Eremia totta, Protea arborea (emergent), Stoebe plumosa, Metalasia muricata, Cymbopogon marginatum.

STRUCTURAL TYPE 4 : Ericoid-restioid communities (Approximately equal proportions of ericoid and restioid growth form types).

Habitat : Fairly high rock cover and shallow soil, intermediate moisture regime. More characteristic of south and west-facing slopes.

Dominant species : Chondropetalum paniculatum and other straight-stemmed restioids. Erica hispidula, E. nudiflora and other ericoids. Cliffortia ruscifolia; graminoids in drier situations; Cliffortia dregeana and Restio perplexus in moister situations, (for example east-facing slopes).

STRUCTURAL TYPE 5 : Restioid communities.

Sub-type A : Short (0 - 0,5m) restioid communities.

Habitat : Seasonally waterlogged situations - 'seeps'.

Dominant species : Restio curviramus, Crassula spp., Cliffortia ruscifolia.

Sub-type B : Tall (0,5 - 1,5m) restioid communities.

Habitat : Better-drained sites, soils 10-20cm, slopes or flats.

Dominant species : Various straight-stemmed restioid species, especially Chondropetalum; scattered ericoids, e.g. Erica plukinetti.

CONCLUSIONS

The most successful numerical classification procedure in this study was the use of the relativized - Czekanowski co-efficient on log-transformed data. Successful classification of fynbos ~~thus~~ appears to rest on the nature of the data matrix. According to a number of authors it is preferable that numerical studies employ as many attributes as possible; for example Sneath & Sokal (1973) recommend at least 60 attributes. On the other hand, according to Williams (1967) "there is no golden numerical road to the selection of attributes, and I am unable to agree with the implied suggestion of Sokal and Sneath (1963) that there is safety only in sufficiently large numbers; we have obtained excellent results with as few as six attributes when these have been collected by an experienced taxonomist". The grounds of this claim are confirmed by Sokal & Rohlf (1970, in Sneath & Sokal, 1973) who imply that characters defined by untrained technicians could lead to acceptable classifications if enough characters are considered, because most dimensions of variation would be captured. The deciding factor seems to be whether the worker is trained or has no experience in the particular field of operation. Thus, a classification of vegetation consisting of fewer, very meaningful attributes erected by an experienced ecologist should be satisfactory for habitat-assessment. If one insists on numerous attributes, then these could be provided by numerous height classes or by increasing the number of growth-forms ~~attributes~~ (branching habit, degrees of pubescence, ~~leaf~~ d~~ivision of~~ compound leaves vs simple leaves, etc.). That height classes are necessary for the sub-division of major structural types with a restricted number of growth form attributes has been shown. However, 1974 or 1975 not 73

in order to obtain the initial groupings, combination of strata is recommended. According to Walker (1973): "it is generally worthwhile to perform ... more than one kind of analysis on more than one transformation of the data, and to compare and combine the information from each". This is also the opinion expressed by Linder & Campbell (1978). In this way one can detect plot misplacement; it enhances one's understanding of the ecology of the study area.

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WILLIAMS 1967 ? ?

Captions for Figures.

FIG. 1. - Analysis 2. (Data matrix 1; Log-transformed data; Relativized Czekanowski co-efficient).

Dendrogram showing group average relationships of the relevés.

FIG. 2. - Analysis 10. (Data matrix 3; Log-transformed data; Relativized Czekanowski co-efficient).

FIG. 3. - Ordination diagrams. A, Full ordination; matrix 1. B, Outlying plots (rocky outcrop, boulder ridge, riverine) removed; matrix 3.

You have not really commented on these figures in the text hence they serve little value.

FIG. 1. - Analysis 2. (Data matrix 1; Log-transformed data; Relativized Czekanowski co-efficient).

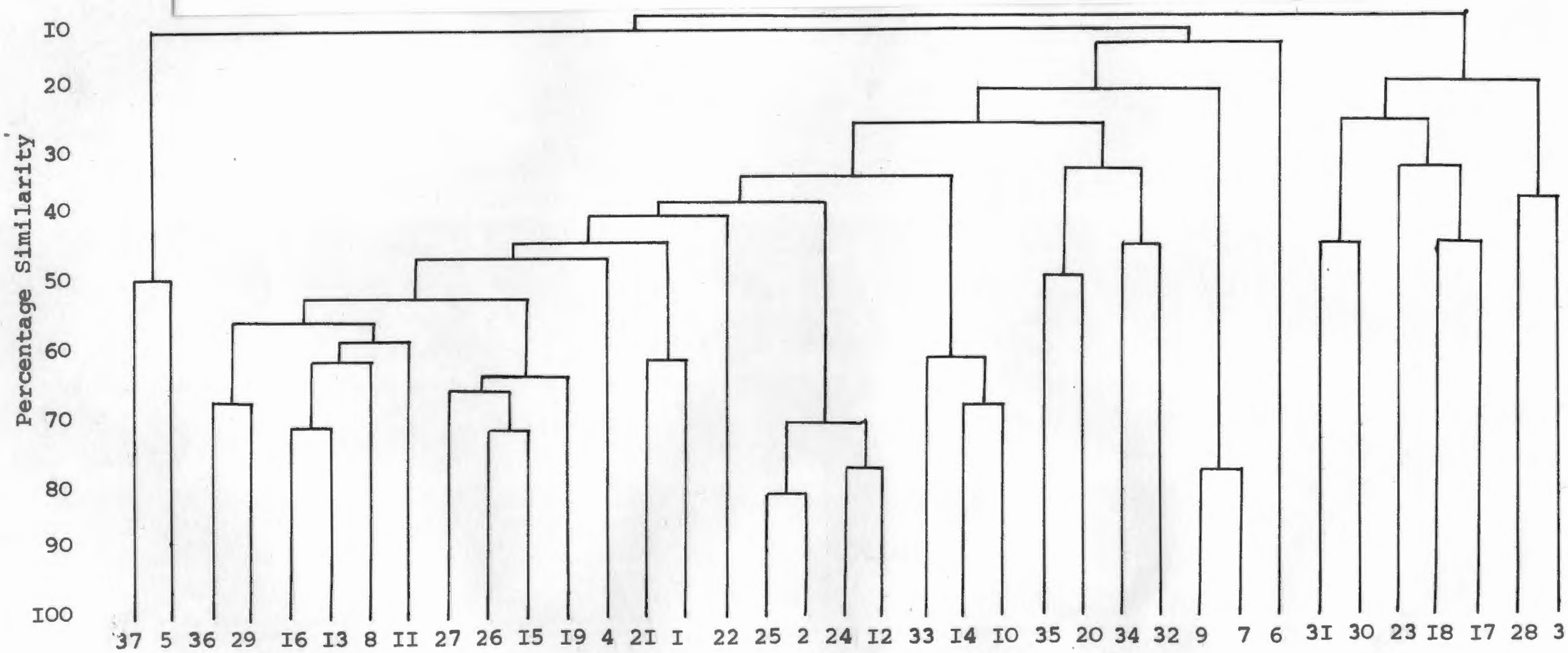

FIG. 2. - Analysis 10. (Data matrix 3; Log-transformed data; Relativized Czekanowski co-efficient).

NON-PROTEOID TALL WOODY

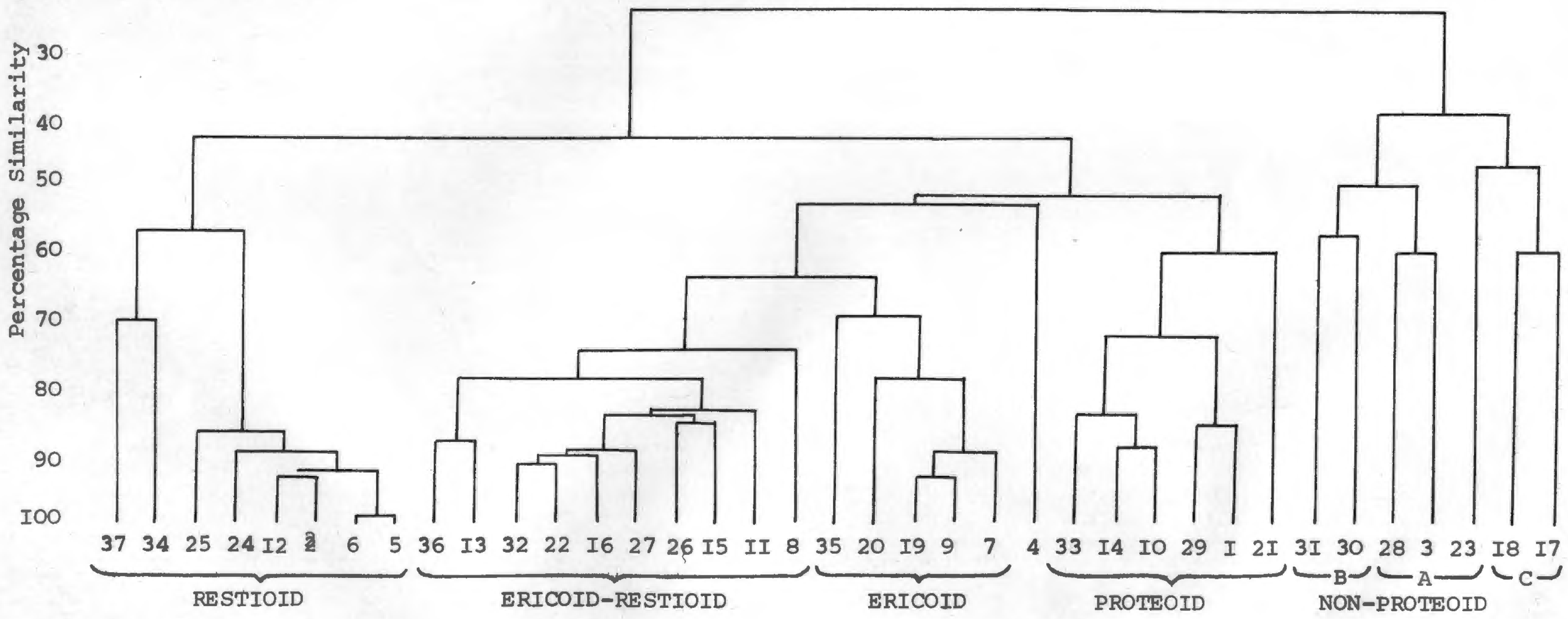

FIG. 3. - Ordination diagrams. 3A: ~~Full ordination;~~ Ordination of all plots using matrix 1; 3B: Outlying plots (rocky outcrop, boulder ridge, riverine) removed. Matrix 3 being used