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Towards a structural-functional classification of fynbos: a comparison of methods

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ABSTRACT

The need for a classification of the vegetation of the fynbos region is stressed. In the present work we have evaluated some structural-functional approaches that could be used to classify and describe fynbos. *A priori* and *a posteriori* approaches to classification are reviewed. The *a posteriori* approach appears to be superior.

Test data derived from 21 plots from a range of fynbos types were used to test some methods of collecting and analysing structural-functional information for an *a posteriori* classification. With respect to data collection, no single method was superior. However, a major improvement on our methodology would be possible if the growth-form system used were to be extended. The classifications that were erected were produced by means of computer-based numerical methods. These methods are essential if large data sets are to be analysed. However, the structural-functional classifications produced by numerical methods should only be regarded as working hypotheses; refinement of the classifications should proceed by intuitive methods. We feel that the *a posteriori* approach, even though it has its problems, will provide a suitable methodology for an ecologically meaningful classification of fynbos vegetation.

RÉSUMÉ

VERS UNE CLASSIFICATION STRUCTURO-FONCTIONNELLE DU MAQUIS: COMPARAISON DE MÉTHODES

On souligne le besoin d'une classification de la végétation dans la zone à maquis. Dans le présent travail nous avons évalué quelques approches structuro-fonctionnelles que l'on pourrait employer pour classifier et décrire le maquis. Des approches a priori *et* a posteriori *sont passées en revue: la dernière méthode paraît la meilleure.*

Des données expérimentales tirées de 21 endroits appartenant à un registre de types de maquis ont été employées pour tester quelques méthodes de récolte et d'analyse d'information structuro-fonctionnelle en vue d'une classification a posteriori. *En ce qui concerne la récolte des données, il n'y a pas de méthode meilleure qu'une autre. Il serait cependant possible d'améliorer grandement notre méthodologie en élargissant le système de croissance-forme qui a été utilisé. Les classifications construites ont été produites au moyen de méthodes numériques appliquées avec l'aide d'un ordinateur. Ces méthodes sont essentielles si l'on doit analyser de vastes ensembles de données. Toutefois les classifications structuro-fonctionnelles produites par des méthodes numériques ne devraient être considérées que comme des hypothèses de travail: le raffinement de ces classifications est à poursuivre par des méthodes intuitives. Nous estimons que l'approche* a posteriori, *malgré les problèmes qu'elle pose, fournira une méthodologie adéquate pour une classification écologiquement sensée de la végétation du maquis.*

INTRODUCTION

A classification of the vegetation of the Southern Cape Province, South Africa, referred to as fynbos (Kruger, 1978; Taylor, 1978), is urgently required for the solution of problems in conservation, and in resource management (e.g. Taylor, 1978) and as a reference classification for more detailed research work. Despite the uniqueness of the fynbos, it has received no detailed classification as yet (Kruger, 1978; Taylor, 1978). A floristic approach to the classification of the fynbos region is largely precluded because the fynbos is floristically diverse (Taylor, 1978) and because a substantial proportion of the flora has had little or no recent taxonomic treatment.

The present work is part of a project designed to test the feasibility of using simple plant-community structure and function parameters for classifying fynbos. Structure is defined as the spatial arrangement of the plant biomass, and function refers to those features of the plant that are apparent adjustments to the environment, e.g. leaf size (Fosberg, 1967).

A priori *or* a posteriori *approaches?*

There are essentially two ways of using structural-functional information to classify vegetation. One approach is to classify vegetation by reference to fixed vegetation classes defined *a priori*. This is the approach used in most general systems (e.g. UNESCO, 1973; Fosberg, 1967). Such *a priori* systems have classes that are defined by a few subjectively selected criteria (however, the criteria are selected on their proven 'value' in other classifications). The classifications are highly artificial in that the items of the classes show a likeness in only a small number of characteristics. Classifications defined *a priori* tend to have rigid criteria separating different types. Such systems are prone to a high degree of misclassification (Goodall, 1973; see Werger's, 1973, discussion of Fosberg's 1967 system). This approach depends on the analysis of a preconceived range of structural forms into *a priori* defined classes (operationally similar to keys in taxonomy).

The other approach to using structional-functional information in a classification is the *a posteriori* approach. In this approach the classification is erected on the basis of a large number of attributes. As many attributes as possible should be used, but attributes that do not vary between the items are clearly of no importance. Items are grouped on the basis of their overall similarities. As the resultant groups (or classes, if placed into a taxonomic hierarchy) are thus synthesized out of empirical data, this approach is termed the *a posteriori* approach. The *a posteriori* approach appreciates that vegetation types are variable and therefore numerous samples from each vegetation type ought to be collected to account for this variability. An additional advantageous effect of this approach is that the resultant clusters of items can be treated either as discrete vegetation classes (by the generation of a dendrogram) or as noda with ranges of intermediates (by multi-dimensional ordination). As the *a posteriori* approach does not depend on *a priori* formulation of the structural-functional

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range of the vegetation studied, peculiar types discovered later can always be added to the classification. The absence of *a priori* classes allows for recognition of intermediate groups, new groups and sub-groups. Basing the eventual vegetation classification on a large number of attributes results in a general-purpose classification which is information-rich, and which has high predictive power (Sneath & Sokal, 1973).

Because the polythetic *a posteriori* approach requires much data, computer-based numerical techniques are essential. Modern computers can rapidly group large numbers of samples on the basis of numerous attributes. The relative success of Webb *et al.* (1970, 1976) with their computer-based structural approach in tropical rain forest, where floristic problems are similar to those in fynbos, logically suggests an enquiry into the value of such an approach in fynbos studies.

Vertical structure

Data collection ought to be as objective and as simple as possible. Properties must be such that they can be repeatedly identified in various vegetation types, but not be too general, as that would result in a loss of information.

Vertical structure is an important aspect of vegetation structure. How should it be quantified? There are three possible approaches to record vertical structure as outlined below.

(1) *Method* 1

A completely objective, operationally defined method of quantifying vertical structure is by arbitrarily defining height classes, and recording structural-functional data for each height class (Moll *et al.*, 1976; Kuchler, 1967, p. 188; De Moor *et al.*, 1977). However, strata in vegetation have functional significance. For example, the species of the canopy stratum, whatever their height, are probably adapted to higher light and lower moisture conditions than the species of the ground layer, whatever their height. If predetermined height classes are employed, any functional similarity of the canopy stratum of two plots may not be recognized in the analysis if the canopy strata fall in different height classes. An additional problem with pre-selected height classes is that a natural stratum could fit into more than one height class. This would result in one characteristic being represented by two attributes. In a numerical analysis a stratum falling into two height classes will be given a different weight than a stratum that fits into a single height class (cf. Hall, 1969).

(2) *Method* 2

To more accurately reflect stratification, 'natural' strata can be identified and structural-functional data for each stratum can be recorded. This method does not have the disadvantages mentioned above. However, strata cannot always be described operationally, and different workers might recognize different strata. To compound problems, strata can be missing or not clearly developed. As a result 'non-analogous' (*sensu* Jardine, 1967) strata could be compared in the analysis.

(3) *Method* 3

Instead of recording stratification direct, vertical structure could be represented by the total cover and height of each growth form. This approach results in the loss of much potentially valuable information on stratification, but avoids distortion due to the comparison of characteristics that are non-analogous.

In this study, structural data were collected throughout the range of the mountain fynbos region using the three methods outlined above. These data were analysed by various numerical methods. We aimed to determine which, if any, of the possible methods would be suitable for an extensive survey of fynbos.

METHODS

Data collection

Data were collected in February 1978 at 21 stations scattered throughout the geographical range of the main body of fynbos. A wide range of structural types was sampled (Table 1). Where possible, at least

TABLE 1.—Location and brief vegetation description of samples

Sample number	Area	Vegetation type	References to the vegetation types
16 14 15 12	Witteberg Witteberg Witteberg Swartberg	Short dry open montane vegetation with high graminoid, ericoid and restioid component on shallow stony soil	Taylor (1978): ericoid-restioid zone; Kruger (1978): low narrow-sclerophyllous heath and graminoid heath
4	Langeberg...	Short, wet, closed montane vegetation with high graminoid, ericoid and restioid component on moist deep soils	—
2 3 4 10	Swellendam Langeberg Outeniquas Swartberg	Tall dense *Berzelia–Widdringtonia* Scrub with a low cover of the proteoid component and a high cover of the restioid–ericoid components	Muir (1929, p. 56); Taylor (1978); Kruger (1978): mixed sclerophyllous scrub
17	Koue bokkeveld	Mountain renosterbosveld..........................	Acocks (1975)
18	S.-Cedarberg.	*Chondropetalum* restioid vegetation..................	—
13	Swartberg....	*Merxmuellera* tussock marsh.......................	Kruger (1978): herblands with seasonal waterlogging
19 6	Cedarberg Cloetes Pass	Waboomveld....................................	Taylor (1978): Waboomveld; Kruger (1978): tall broad-sclerophyllous shrubland
20	Cedarberg...	Restioid marsh..	Kruger (1978): herblands with seasonal waterlogging
21	Cedarberg...	*Widdringtonia cedarbergensis* Woodland.............	Taylor (1978)
1 5 8 11	Hex River Langeberg Outeniquas Swartberg	Proteoid scrub (2–4 m) with restioid–ericoid lower stratum	Taylor (1978): proteoid zone of mountain fynbos; Kruger (1978): broad-sclerophyllous scrub
9	Outeniquas...	*Leucadendron* scrub with restioid–ericoid lower stratum	—

two samples were taken from the same structural type, and recently burnt vegetation was not sampled (Sample 3 is an exception). The 10 × 10 m samples were subjectively placed in stands that appeared to be structurally homogeneous.

As broad a range as possible of objectively-definable growth-form attributes was selected: an obvious necessity for a valid polythetic approach (Sneath & Sokal, 1973). Growth-form attributes that could be open to different interpretations were avoided (e.g. canopy shape and density, degree of branching, chamaephyte *vs.* phanerophyte, tree *vs.* shrub). Properties such as spinescence and succulence were not considered as they occurred rarely in our study. The growth forms selected are shown in Table 2. We feel that they are the minimum requirement to represent the range of structural variation that occurs in fynbos. This range of structural variation has been discussed by Kruger (1978).

TABLE 2.—Growth forms used in the present study

Growth form	*Description*
1. Ferns..................	—
2. Stem-photosynthetic graminoids	Restionaceae, and rarely Cyperaceae and Poaceae
3. Narrow-leaved graminoids	Mainly Poaceae, and Cyperaceae (*Tetraria*) with linear leaves
4. Broad-leaved graminoids..	As for (3) but with leaves more than 1 cm broad
5. Non-graminoid 'monocots'	Non-graminoid plants with leaves that have parallel veins—mostly Liliaceae and Iridaceae
6. Perennial herbaceous 'dicots'	'Dicots'=plants with leaves that have netted veins
7. Annual herbaceous 'dicots'	—
8. Woody plants—subdivided according to Raunkiaer's (1934) leaf sizes: mesophyll, microphyll, nanophyll, and leptophyll. We further subdivided leptophyll according to leaf shape, namely narrow (ericoid, cupressoid and terete) *vs.* broad	

The details of the three methods that were used in the field to quantify vertical structure, and which have been discussed in the introduction, are as follows:

(1) *Method* 1 (*pre-determined height classes*)

The following height classes were selected: 0–0,25 m; 0,25–0,5 m; 0,5–1 m; 1–1,5 m; 1,5–2 m; 2–3 m and 3–5 m. The cover of each growth form in each height class was estimated. Thus a total of 52 different attributes was recorded.

(2) *Method* 2 (*strata*)

Kruger (1978) recognizes and describes three strata in fynbos: a ground, middle and upper shrub stratum. These are the strata recognized in this study. A fourth stratum consisting of small trees is also recognized. This stratum occurs very rarely: only *Widdringtonia cedarbergensis* was recorded in this stratum in our sample. The ground stratum consists of "low hemicryptophytes, chamaephytes, forbs, and geophytes" (Kruger, 1978). The dense middle stratum comprises a great variety of species and growth forms except where suppressed by taller plants of the upper shrub stratum (Kruger, 1978). Major components are ericoid shrubs and stem-graminoids. The upper stratum is usually 2–4 m tall, and often consists of broad-sclerophyllous shrubs of the Proteaceae.

In each of the four strata the cover of the different growth forms was estimated. The heights of the strata were recorded and used as attributes in the analysis. A total of 28 different attributes was used.

(3) *Method* 3 (*non-stratified method*)

In this method, strata are not recognized. The growth-form system was much simplified. Only stem-graminoids, leaf-graminoids and woody plants were recorded. Woody plants were only divided into (1) plants with cupressoid, ericoid or terete leptophylls, (2) small-leaved plants (smaller than microphylls) and (3) large-leaved plants (larger than nanophylls). The half-height and cover of each growth form was estimated, and to give an indication of the vertical structure of the taller (i.e. woody) growth forms, the maximum height was estimated. Half-height is here defined as the height above which 50% of the projected canopy cover occurs. Method 3 was designed to be the simplest method: a total of only 13 different attributes was recorded.

Data analysis

The polythetic agglomerative method of group-average sorting (Campbell, 1978) was used to construct the numerical classifications, which are represented as dendrograms. Two similarity coefficients were investigated, viz. (1) the Czekanowski coefficient in its unrelativized form and (2) the Canberra measure. The formulae for these coefficients are given in Campbell (1978). The Czekanowski coefficient is an abundance-weighted (i.e. cover-weighted) coefficient, therefore attributes with a high abundance value contribute more to the similarity assessment than attributes with low abundance. The Canberra measure is not abundance-weighted (see Campbell, 1978).

The success of similarity coefficients usually depends on the nature of the data. In this study, percentage-cover values and percentage-cover values converted to the Braun-Blanquet scale were used in different analyses. The Braun-Blanquet scale is an alpha-numerical scale; for numerical purposes it was converted to an ordinal scale with 1=less than 1% cover (BB+); 2=1–5% (BB1); 3=5–25% (BB2); 4=25–50% (BB3); 5=50–75% (BB4); 6=75–100% (BB5). In methods 2 and 3 where height and cover attributes are being used, each height attribute was standardized so that the range of standardized height values was the same as the maximum possible range of cover values. The need for standardization is discussed by, among others, Walker (1974).

A visual comparison of the dendrograms can be very confusing; a method of objectively rating dendrograms is preferred. We developed an index which indicates the degree to which 'correct' groups are formed by the dendrogram. Our 'correct' classification was erected on the basis of our field experience. The classes of this classification are shown in Table 1 and are felt to represent the ecologically most meaningful grouping of samples. The index is determined as follows. Each numerically defined group of the dendrogram is scored by the number of correct items (1 point each) in the group, minus ½ point for each incorrect item in the group, and minus ½ point for each item that should be in the group. Dendrogram groups are defined by the drawing of a phenon-line (Sneath & Sokal, 1973). The phenon-line was drawn at the similarity level which gave the dendrogram the highest rating on the index. By calculating the index value for each class of the 'correct' classification it was possible to quantify the performance of the methods for each class.

RESULTS AND DISCUSSION

The various combinations of methods used in data collection and analysis are shown in Table 3, together with the over-all rating of each analysis. Table 4 indicates the rating obtained for each class of the 'correct' classification for each analysis.

TABLE 3.—The various analyses and their values on the index Each analysis is a combination of a data-collection method (Methods 1, 2 or 3—see text), a type of data (%=percentage-cover; BB=Braun-Blanquet values; Tot.=total cover for each growth form, irrespective of height class, added to the data matrix), and a similarity coefficient (Cz=Czekanowski, Can=Canberra)

Analysis number	Data collection	Data type	Similarity coefficient	Index values
1	1	%	Can	10,5
2	1	%	Cz	7,5
3	1	BB	Can	14,5
4	1	BB	Cz	9,5
5	2	BB	Can	12
6	2	BB	Cz	13
7	3	%	Can	13
8	3	%	Cz	12
9	1	%, Tot.	Can	6,5
10	1	%, Tot.	Cz	13

A priori *versus* a posteriori *approaches*

We briefly compared the *a priori* and *a posteriori* approaches. The *a priori* method that we used was that used at present by the Department of Forestry for resource surveys of mountain fynbos. Of the 12 classifications that were erected with our test data, a 12-group *a priori* classification gave the worst results (Table 4, Analysis 12). The other *a priori* classification, a 7-group classification (Table 4, Analysis 11) gave results that were better than only 2 of the 10 *a posteriori* classifications.

Method 1: *pre-determined height classes* (*Analyses* 1–4)

The best classification was given by Analysis 3. This involved the Canberra measure, percentage cover transformed to the Braun-Blanquet scale and data collection Method 1. However, the success of Method 1 is strongly dependent on the particular numerical method. Thus, for example, when percentage data from Method 1 are used with the Czekanowski coefficient (Analysis 2) the classification is completely unacceptable. The major factor affecting the results of the analyses is probably the weighting-deweighting property inherent in some numerical methods (Campbell, 1978). The heavy abundance-weighting built into the Czekanowski coefficient probably accounts for the failure of Analysis 2. Where the weighting effect of this coefficient is modified by transforming percentage-cover values to Braun-Blanquet values (Analysis 4) (see Campbell, 1978) the performance of the Czekanowski coefficient improves. On the other hand, the relative failure of the Canberra measure with percentage data (Analysis 1) is probably a result of the equal weight given to low-cover and high-cover attributes, i.e. the lack of abundance weighting of the Canberra measure. This lack of abundance weighting can be overcome, however, by using the Braun-Blanquet scale instead of percentage values (Analysis 3). Cover values between 25% and 100% now contribute equally to the similarity assessment while values below 25% are being progressively deweighted. This deweighting characteristic of the Braun-Blanquet scale when it is used with the Canberra measure occurs as a result of the unequal class intervals in the scale (Campbell & Linder, in prep.). Above 25% cover the scale values have large equal intervals, while below 25% cover the intervals are progressively decreased.

A comparison of the results of the Canberra measure (Analysis 3) and Czekanowski coefficient (Analysis 4), used in conjunction with the Braun-Blanquet scale, shows that the Czekanowski analysis is more abundance-weighted than the Canberra analysis even though the Braun-Blanquet scale is reducing the abundance-weighting property of the Czekanowski coefficient. For example, the renosterbosveld samples link very closely with the ericoid-leaved samples (Items 8, 9, 7, 2) in the Czekanowski analysis. This false linkage is probably due to the similar high cover values of a few attributes (2 or 3 narrow-leptophyll attributes). In the Canberra analysis low-cover attributes are also included in the assessment of similarity and the renosterbosveld now links (correctly) at a very low similarity level to the proteoid group.

To some extent, the leaf of renosterbos is not analogous to that of a middle-layer ericoid shrub, to which it is being compared. These non-analogous comparisons can probably be overcome if the data matrix is large enough (Moss, 1968; Fisher & Rohlf, 1969). This is in effect what happened in the Canberra analysis, where a few attributes do not dominate in the assessment of similarity.

TABLE 4.—Ratings (index values) obtained for each analysis for each class of the 'correct' classification and the over-all value for each analysis. Analyses 11 and 12 are for the *a priori* classification (7-group classification and 12-group classification respectively, see discussion). The last column shows the maximum possible values

Vegetation types (Sample numbers)	Analyses												Maximum rating
	1	2	3	4	5	6	7	8	9	10	11	12	
Short dry montane (16,14,15,12)	3,5	1	3,5	3	4	4	0,5	0,5	0,5	4	0	0	4
Short moist montane (4)......	1	0	0,5	0	1	1	0	0	0,5	0,5	1	1	1
Berzelia–Widdringtonia (2,3,7)..	3	0	3	2	1,5	0	1,5	1,5	1,5	1,5	0	0,5	3
Renosterbosveld (10,17)	1	1,5	2	2	1,5	1	2	2	1	1,5	1,5	0	2
Chondropetalum (18)..........	0	0,5	0	0	0	0	1	1	1	1	0	0	1
Merxmuellera marsh (13).....	0	1	0	0	0	0	1	1	0	1	1	1	1
Waboomveld (19,6)..........	0	1	0	0	0	1	0	0	0	1	0,5	0	2
Restioid marsh (20)...........	1	1	1	1	1	1	1	1	1	1	0	0	1
Cedar woodland (21).........	0	1	0,5	1	0	1	1	1	0	0,5	1	0,5	1
Proteoid scrub (1,5,8,11)......	1	0,5	3,5	0,5	3	4	4	4	0	0,5	3,5	1,5	5
Leucadendron scrub (9).......	0	0	0	0	0	0	1	0	0,5	0,5	1	0	1
Over-all rating...............	10,5	7,5	14,5	9,5	12	13	13	12	6	13	9,5	4,5	22

A detailed analysis of the placement of Items 8 and 9 empirically illustrates the effect of excessive weighting. It is ecologically more meaningful if 8 and 9 are linked to Items 1, 11 and 19 than to Items 7 and 2. Five of the 15 attributes that are common to (8,9) and (7,2) involve Braun-Blanquet values above 1, while only three of the 21 attributes common to (8,9) and (1,11,19) involve Braun-Blanquet values above 1. Thus the Czekanowski coefficient falsely places (8,9) with (7,2) as similarity is largely assessed on the high cover attributes. In the Canberra analysis the more appropriate linkage occurs as similarity is assessed not only on the high cover values.

In short, it appears as if some weighting of high cover values (or, conversely, deweighting of low cover values) is necessary, as in the case of Analysis 3 (Canberra and Braun-Blanquet scale), but that excessive weighting is likely to occur with an abundance-weighted coefficient especially if used with percentage-cover values (Analysis 2).

Method 1 *with total cover values for growth forms* (*Analyses* 9 *and* 10)

Method 1 suffers from the inherent problem that certain attributes are very similar to each other and yet the method of analysis does not take this into account. For example vegetation type A, which only has 0–0,25 m stem-graminoids, should be much more similar to vegetation type B, which only has 0,25–0,5 m stem-graminoids, than to vegetation type C which only has 0,25–0,5 m ferns. In our analyses these vegetation types are regarded as equally dissimilar because the characteristics mentioned above are regarded as being equally different. We attempted to overcome this problem by calculating total values for each growth form and including these with the 'growth form by height classes' data. Thus vegetation types A and B are now more similar to each other than they are to C as they have an attribute (total cover of stem-graminoids) in common.

The results with totals included show once again the different results that are likely when different numerical methods are used. It is difficult to explain why the Canberra measure does so poorly (Analysis 9), and why the Czekanowski coefficient with percentage-cover data does relatively well (Analysis 10). The exact opposite results were shown when totals were not used.

Method 2: *strata* (*Analyses* 5 *and* 6)

Although this method did not give the best results, the results are not highly sensitive to the methods of analyses used. This is also the case with Method 3.

Method 2 suffers from the problem of identifying the analogous strata. For example, in the "short dry montane" vegetation, the decision to place the single layer of low bushes and restios into the middle stratum is, at this stage, arbitrary. Placing it in the ground stratum does, of course, have an effect on the resultant groups.

The present approach also fails to take into account the extreme variability in the middle stratum (Kruger, 1978). Field collection of the data is beset with problems as the various growth forms have to be consistently treated when they are placed into 'natural' strata. This problem largely arises because of the lack of clear stratification in fynbos (Kruger, 1978, and personal observation).

The weak treatment in Analyses 5 and 6 of the Langeberg *Berzelia–Widdringtonia* scrub (Table 4), which shows little stratification (Kruger, 1978), is an indication of the type of problems that will arise with Method 2. Attempts to place data into strata lead to misclassification. The strata are designed to cope with 'typical' proteoid fynbos; as a result data collected in strata-format are not sufficiently flexible to deal with vegetation with a different vertical organization.

Method 3: *non-stratified method* (*Analyses* 7 *and* 8)

Method 3 was not very sensitive to the similarity coefficient that was used. The Canberra measure (Analysis 7) was slightly more successful; this would be expected as it is not appropriate to abundance-weight height values (two vegetation-types are not more similar because they are higher).

Unsatisfactory group formation with Method 3 occurred only with the "short dry montane" vegetation. This points to a major problem in this method. Are two vegetation types dissimilar if the one type has very low cover of a particular growth form whereas the other lacks the growth form? In this method, these vegetation types are incorrectly regarded as being dissimilar as they differ not only in the presence or absence of cover of the growth form but also in the presence or absence of heights of the growth forms. Item 12 lacks two woody growth forms which the other items of the "short dry montane" vegetation possess in small amounts. Item 12 thus lacks 6 attributes (2 cover, 2 maximum height, and 2 half-height attributes) out of a total of 13 attributes. Thus Item 12 is incorrectly placed with Item 13 which also lacks these attributes. This problem is largely a result of the small number of attributes in the analysis; thus any one attribute has a marked effect on the grouping.

Method 1 (with totals), when used with the Czekanowski coefficient (Analysis 10), gives a similar type of information about the various growth forms as Method 3. Both give the total cover of each growth form, as well as information on the vertical distribution of that growth form. In Method 3, the non-woody growth forms constitute $\frac{1}{3}$ of the total number of attributes, whereas in Method 1 (totals) they only constitute approximately $\frac{1}{5}$. From the results it would appear that the inequality in the distribution of attributes over the available theoretical range of attributes has an effect on the resultant groupings. This partial lack of congruence between classifications based on different data sets has also been noted by numerical plant taxonomists (Sneath & Sokal, 1973, p. 97). Careful distribution of attributes widely and evenly over the whole structural range of the vegetation is, therefore, of prime importance. It is difficult to say what the "correct" distribution of attributes is. This will either have to be determined empirically, or we shall have to advance our knowledge of the structural-functional relationships in fynbos.

CONCLUSIONS

The three data-collecting methods appear to have both advantages and disadvantages. Even though Method 1 gave the best result (Analysis 3), its success was highly dependent on the type of analysis. This method appears to generate a data matrix which is very sensitive to different numerical analyses. This is a disadvantage, as the empirical/theoretical basis for preferring one analysis above another is not yet sufficiently well developed to allow uncritical use of any method. Methods 2 and 3 at least gave consistently good results in the two analyses that were performed on the data matrices generated by each method.

A direct comparison between the methods is complicated by the disparity in the number of attributes over which the analyses were carried out: Method 1 employed 52 attributes, Method 2 employed 28, and Method 3 yielded only 13 attributes. It is generally recommended that numerical studies employ at least 60 attributes (Sneath & Sokal, 1973, p. 106).

In the field, Method 3 was the most efficient. It only required the estimation of height and cover of a few growth forms. The resultant data set of only 13 attributes produced relatively successful classifications. However, the problem that was indicated by the poor grouping of the "short dry montane" vegetation must be overcome if this method is to be of value.

Method 2 also produced relatively successful classifications. However, it has the disadvantage of being more difficult to gather data as it requires a large degree of subjectivity in the allocation of growth forms to so-called 'natural strata'. Strata are not always easily recognized in fynbos.

Method 1 has a disadvantage in the field-work stage. It is time-consuming as it is difficult to estimate the cover of each growth form for each height class. Moreover, this method requires the selection of appropriate numerical methods as it appears to be very dependent cn the type of numerical analysis. However, this method did produce the best classification. Our study suggests that the most suitable numerical analysis for data in the format of Method 1 would be the Canberra measure with Braun-Blanquet values. However, this suggestion must be regarded as preliminary.

Each of the methods has problems with regard to the recording of the vertical structure of the vegetation. This can be partially overcome by the use of a more detailed growth-form system (e.g. by separating out cupressoid plants from non-cupressoid plants, one will no longer need height information to separate *Widdringtonia* spp. from Ericaceae).

In general, the *a posteriori* approach is able to produce relatively successful classifications. The best classification in this study was very similar to the grouping of samples that we regarded as being the 'most ecologically meaningful'. On theoretical grounds the *a posteriori* approach is superior to the *a priori* approach and the brief testing of the *a priori* approach showed that the classifications it produced were ecologically unacceptable.

Nevertheless, it has been indicated that the *a posteriori* approach is not without its problems. Each numerical method stresses a different facet of the data, thus a range of different classifications can be obtained, some of which are ecologically meaningless. At the best, the classification obtained from numerical methods must be used as a working hypothesis and analysis of the groupings must proceed by intuitive methods. We suggest the use of two-way sorting tables (e.g. Moll *et al.*, 1976) for analysing the numerically defined groups and for indicating alternate, perhaps more meaningful, classifications. The tables can be sorted in a similar fashion to the sorting of phytosociological tables (e.g. see Werger, 1973).

As the ranges of variation 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 will have to accompany attempts at basing a classification on these data.

In summary, we feel that an *a posteriori* structural approach, even though it has its problems, should provide a methodology which will be suitable for erecting an ecologically meaningful classification of fynbos.

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UITTREKSEL

Die behoefte aan 'n klassifikasie van die plantegroei van die fynbos streek word beklemtoon. Die waarde van 'n paar struktureel-funksionele benaderings, wat gebruik kan word om fynbos te klassifiseer en te beskryf, word in hierdie artikel waardeer. A priori *en* a posteriori *benaderings tot klassifikasie word in oënskou geneem. Die* a posteriori *benadering blyk beter te wees.*

Gegewens wat ontstaan uit 21 *toetspersele vanuit 'n verskeidenheid van fynbostipes is gebruik om etlike metodes van insameling en ontleding van struktureel-funksionele gegewens te toets vir 'n a posteriori klassifikasie. Met betrekking tot die insameling van gegewens, is die metodes ewe goed. 'n Groot verbetering in metodiek sou, etger, moontlik wees, indien die groeivormindeling wat gebruik is, verbreed sou kon word. Die klassifikasie wat opgestel is, ontstaan uit numeriese metodes met behulp van 'n rekenaar. Hierdie metodes is onontbeerlik as groot datastelle gebruik word. Die struktureel-funksionele klassifikasie wat ontstaan deur middel van numeriese metodes behoort, egter, net as werkende hipoteses beskou te word; verfyning van die indelings behoort intuïtief te geskied. Die aanduidings is dat, ten spyte van probleme, die* a posteriori *benadering 'n geskikte metodiek sal verskaf vir 'n ekologies betekenisvolle klassifikasie van fynbos plantegroei.*

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