Vegetatio Vol. 39–2: 97–114, 1979

TRANSFORMATION OF COVER-ABUNDANCE VALUES IN PHYTOSOCIOLOGY AND ITS EFFECTS ON COMMUNITY SIMILARITY*, **

E. van der MAAREL***

Division of Geobotany, Toernooiveld, 6525 ED Nijmegen, The Netherlands.

Keywords:
Arrhenatheretum, Classification, Combined estimation, Cover-abundance scale, Ordination, Phytosociology, Salt marsh, Similarity, Transformation.

Introduction

The numerical treatment of phytosociological data is often based on estimates of cover and/or abundance according to the Braun-Blanquet and Domin scales. Since Schwickerath (1931, 1938, 1940) and Tüxen & Ellenberg (1937) published their transformations there has been discussion on the way the scale values should be used in calculations. Qualitative approaches, i.e. based on presence and absence have also been favoured (e.g. Williams & Lambert 1959, van der Maarel 1966) Dagnelie (1960) proposed a pseudoqualitative basis for various calculations by means of a 'coupure'. A coupure includes the deletion of lower values, usually according to a fixed criterion, e.g. the number of occurrences in a phytosociological table to be remained should be as close as possible to 50%. Dagnelie's approach remained largely unknown and apparently it has never been tested.

Transformation of cover-abundance values may involve the differential weighting of species in numerical phytosociological classification, or the standardization of values to zero mean (and unit variance) in the rows or columns (or both) of phytosociological data matrices. Such standardizations are usual in multivariate analysis and their implications for vegetation ecology have been discussed in many Anglo-American studies (e.g. Austin & Greig-Smith 1968, Noy-Meir 1973, Noy-Meir, Walker & Williams 1975, Orlóci 1978).

Since the use of numerical methods in European phytosociology is rapidly growing it may be useful to review the various transformations published so far and to give some proposals for unification.

Some practical examples of the effects of transformations on classification and ordination are then given with data used in various projects of the Working Group for Data-processing in Phytosociology. Such effects will include changes in patterns of (dis-) similarity between the phytosociological units – relevés or community types – involved, hence the title of this contribution. (see also Campbell 1978). Since I consider weighting of species performance as a more urgent transformation problem in phytosociology then standardization, the latter type of transformation will not be treated here.

During the preparation of this paper I became involved in two similar studies which have been published in Vegetatio (Jensén 1978, Campbell 1978) and which serve as additional sources for my paper.

* Contribution from the Working Group for Data-Processing in Phytosociology, based on an earlier report for that group (Van der Maarel 1972).
** Nomenclature of salt marsh species follows Lausi, Kortekaas, & Beeftink (1979), for names of *Arrhenatheretum* species see E. Oberdorfer, 1970, Pflanzensoziologische Exkursionsflora für Süddeutschland, 3. Aufl. Ulmer, Stuttgart.
*** This paper was partly prepared during my stays at the Växtekologiska Institutionen at Lund under NFR grant B 252605. I thank Prof. Nils Malmer, Head of this institute for his interest in my numerical approaches in phytosociology and Dr. Sven Jensén of the same institute for valuable discussions on data transformation. Of my own department I thank Sophie Hochstenbach for preparation of the numerical results and Jo Louppen for technical help and discussions concerning the computer programs involved. Finally I thank Drs. László Orlóci and Mike Austin for useful comments on the manuscript, and Dr. Dicky Clymo for discussions on transformation formulae and his permission to mention an unpublished formula.

On transformation

Angular transformation of cover data

In most cover-abundance scales cover is considered of major importance and in calculations the lower values of the scale, though defined as abundance categories, are often interpreted as cover values. (Tüxen & Ellenberg 1937). Dagnelie (1960) stated that the classes obtained in such a way are not equidistant. Dagnelie, following Goodall (1953–1954) suggested the angular transformation. This transformation takes a cover % value c as a proportion $p = c/100$, and converts it to y according to

$$y = 2 \arcsin \sqrt{p} \text{ for } p \leqq 0.5 \quad (1a)$$

$$y = 3{,}1416 - 2 \arcsin \sqrt{1-p}, \text{ for } p > 0.5 \quad (1b)$$

Dagnelie showed that the transformed values of the Braun-Blanquet scale (as converted to cover values by Tüxen & Ellenberg 1937 in the form adopted by Braun-Blanquet 1964, 1965) form a series which runs roughly parallel to the original series (Table 1). This may be considered an additional argument in the controversy on the transformations suggested by Tüxen & Ellenberg (1937) and Schwickerath (1931) in favour of the latter one. Van der Maarel (1966) developed a transformation which can be approximated with integers from 1–9. This transformation has been used by Fresco (1969) and van der Maarel & Fresco (1975).

The transformed scale is presented in Table 2 (col. 6) together with rounded values from angular transformations of the scales of Braun-Blanquet, Daubenmire (1968, modified form according to Bailey & Poulton 1968, see also Mueller-Dombois & Ellenberg 1974), Hult-Sernander, Domin (cf Shimwell 1971 for scales and references and Bannister 1966 for an angular transformation of the Domin scale), Doing (1954), and Barkman, Doing & Segal (1964, see also Londo 1976).

Table 1. Braun-Blanquet cover-abundance values, corresponding cover % values according to Braun-Blanquet (1964), angular transformation values (after Dagnelie 1960) and values multiplied by 2.07 to arrive at values within the original range of the Braun-Blanquet scale.

Br. Bl. scale	corresponding cover % value	arc sin transf.	ibid. adapted to Br. Bl. scale
r	( )	( )	( )
+	0.1	0.06	0.12
1	5.0	0.45	0.93
2	17.5	0.86	1.78
3	37.5	1.31	2.73
4	62.5	1.82	3.77
5	87.5	2.42	5.00

As may be seen from Table 2 it is difficult to transform low and often roughly estimated cover values corresponding with the abundance classes '*r*' and '+'. It is possible to treat the associated class values either as unity or to ignore them. Angular transformation has been regularly applied to cover % estimations (e.g. Bannister 1966, Smartt, Meacock & Lambert 1976) but it has never become a standard procedure.

Transformations of the Braun-Blanquet scale

As has been already remarked the angular transformation of the Braun-Blanquet cover values resembles the approach of Schwickerath (1931 a.f.) developed for the measurement of what he called 'Artmächtigkeit' or Gruppenmächtigkeit. This is a species weight, or 'species magnitude' (Braun-Blanquet 1965), or less appropriately 'species significance' (Krajina 1960). As a sort of species importance value (cf Curtis & MacIntosh 1951) it can be used in fidelity determination and calculation of spectra of syntaxonomical species groups (Segal & Westhoff 1959) etc.

Schwickerath used the Braun-Blanquet values 1–5 directly and replaced + by 0.25 (The value *r* was neglected). Tüxen & Ellenberg (1937) suggested a transformation for exactly the same procedures, i.e. to arrive at what they called a 'Gruppenwert'. Their transformation was based on the average cover % values in the classes 2–5, while 1 and + were arbitrarily replaced by 2.5 % and 0.1 % respectively.

Braun-Blanquet (1946, 1964, 1965) while adopting a somewhat different transformation seems to prefer the Tüxen-Ellenberg approach. He used (in his 1946 paper) a surprising motive. He disregarded Schwickerath's approach and the warning by Tüxen & Ellenberg (1937) to use the group value only for the comparison of facies and not to overemphasize ecologically important species occurring with low abundance values. Braun-Blanquet (1946) stated (in translation): 'until now the sociological significance of species in a plant community was estimated according to their constancy and their average abundance . . . . it has now become clear that the cover value of species presents a much better expression of their sociological significance'. Braun-Blanquet then defined cover value of a species as 100 times the sum of the average cover value of that species in a phytosociological table, divided by the number of relevés. Note that this is in fact a new index, which gives a measure for the performance of a species in a plant

Table 2. Angular transformation values for some currently used cover-abundance scales. Combined transformation values (see text) are added.

cover %	arcsin transf.	Hult-Sernander arcs tr.	orig scale	comb tr.	Braun-Blanquet arcs tr.	orig scale	comb tr.	Daubenmire Baily-Pouton arcs tr.	orig. scale	comb tr.	Domin arcs tr.	orig scale	comb tr.	Doing arcs tr.	orig scale	comb tr.	Barkman et al. arcs tr.	orig scale	comb tr.	Braun-Blanquet diff. symbol 2 arcs tr.	orig. scale	comb. tr.	cover %
																	1	r	1				
					1	r	1	1	1	1	1	+	1	1	r	1	1	+r	1	1	r	1	
					(0)												1	+p	1				
1					1	+	2				1	1	2	1	p	2	1	1p	2	1	+	2	1
					(0)												1	+a	2				
2	1										1	2	3				1	1a	3				2
		1	1	3										1	a	3				1	1	3-	
3					1	1	3	1	2	3	1	3	4							(2)			3
					(2)												1	1b	4				
4														1	m	4	(2)						4
																	1	2m	5	1	2m	4	
																	(2)			(2)			
5	2										2	4	5										5
		2	2	5										2	01	5	2	2a	5	2	2a	5	
10					3	2	5	3	3	5													10
20	3	3	3	6							3	5	6	3	02	6	3	2b	6	3	2b	6	20
30	4										4	6	7	4	03	7	4	3a	7				30
40	5	5	4	7	5	3	7	5	4	7										5	3	7	40
											5	7	7	5	04	7	5	3b	7				
50	6													6	05	7							50
60														6	06	8	6	4a	8				60
	7				7	4	8	7	5	8	7	8	8							7	4	8	
70														7	07	8	7	4b	9				70
		8	5	8																			
80	8							8	6	9	8	9	9	8	08	9	8	5a	9				80
90	9				9	5	9							9	09	9				9	5	9	90
								9	7	9	9	10	9				9	5b	9				
100														9	10	9							100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

community, which is not identical to the group values of Tüxen & Ellenberg (1937).

The Braun-Blanquet transformation and a similar one by Etter (1949, also mentioned by Becking 1957) has been used frequently in classical phytosociology (see Ellenberg 1956, Mueller-Dombois & Ellenberg 1974). Schwickerath's scale has nevertheless been preferred by Westhoff (1947), Meyer Drees (1949), Sissingh (1950), Londo (1971) and others.

In later approaches (e.g. Dagnelie 1960, Barkman et al 1964, van der Maarel 1966, Londo 1971) transformed scales similar to Schwickerath's were suggested, while in recent numerical treatments (e.g. Moore 1966, Schmid & Kuhn 1970) extra weight was given to the low abundance values of the scale. Coetzee & Werger (1973) proposed an intermediate transformation. A logarithmic transformation of the Braun-Blanquet (1964, 1965) average cover values is suggested by Jensén (1978) in the form of (1 + log cover %) and in some other forms. Logarithmic transformation was also applied by Hogeweg (1976) for reasons similar to that of Jensén, i.e. to find a balance between preponderance of very abundant versus rare species.

Table 3 presents the various transformations mentioned so far, as well as a scale suggested by Barkman (col. 11, pers. comm.) resembling that of Schmid & Kuhn (col. 12). The angular transformation as suggested earlier is added in col. 16.

A new numerical cover-abundance scale

At our department a differentiated Braun-Blanquet scale has been introduced for use at courses (Westhoff & van der

Table 3. Transformations of the Braun-Blanquet cover-abundance scale.

Braun-Blanquet orig. scale	Tüxen-Ellenberg 1937	Braun-Blanquet transf. 1964	Etter 1949	Londo 1971	van der Maarel 1966	Dagnelie 1960	Schwickerath 1931	Coetzee & Werger 1973	Barkman et al 1964	Barkman ms	Schmid-Kuhn 1970	Moore 1966	Jensén 1978	Combined transf.	angular transf. van der Maarel 1966	Braun-Blanquet
r	()	()	0	0	0	()	()	1	0	0.5	2	10	1,00	1	0(1)	r
+	0.1	0.1	1.0	0	0	0.2	0.25	5	2	1	4	10	1,00	2	1	+
1	2.5	5.0	10.0	0	0.5	1	1	10	3	2	6	11	1,69	3	2	1
2	15	17.5	20.0	1	1	2	2	20	6	4	7	12	2,25	5	3	2
3	37.5	37.5	37.5	3	2	3	3	30	8	8	8	13	2,58	7	5	3
4	62.5	62.5	62.5	5	4	4	4	40	9	10	9	14	2,79	8	7	4
5	87.5	87.5	87.5	7	5	5	5	50	10	10	9	15	2,94	9	9	5
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Maarel 1978). In this scale a differentiation of the original Braun-Blanquet category 2 is adopted from Barkman et al. (1964): *2m* = cover 5%, abundance high, *2a* = cover 5–12%, *2b* = cover 12–25% Table 2, col. 21–23. This scale is an effective compromise between the original Braun-Blanquet scale, which is relatively insensitive in the range covered by category 2, and elaborate but laborious scales like the one of Barkman et al (1964).

This differentiated alpha-numerical Braun-Blanquet scale (a) may be replaced by the fully numerical 1–9 scale (b) as follows:

(a)	*r*	+	1	*2m*	*2a*	*2b*	3	4	5
(b)	1	2	3	4	5	6	7	8	9

This transformation is added to Table 2, col. 23. In comparison with the angular transformation, col. 21, this new scale can be considered a combination of a cover scale in angular transformation, with a weighting based on abundance. This weighting is maximal in the Braun-Blanquet interval 2 where high abundance values are supposed to be of relatively high importance. We may call this new scale a combined transformation, since the original idea in Braun-Blanquet's combined estimation is maintained.

The points on this scale are by no means 'equidistant'. Still, it expresses differences in the performance of species in an efficient way while keeping close to the original and ingenious idea of Braun-Blanquet. In many classification and ordination treatments at our department (cf. van der Maarel 1969, Westhoff & van der Maarel 1978, Kortekaas, van der Maarel & Beeftink 1976, van der Maarel, Janssen & Louppen 1978) this 'ordinal transform' scale, proved to be satisfactory.

Obviously the scale is not only applicable in transformations of existing data collected along other scales, it can also be used directly in the field. For many students without experience with the original Braun-Blanquet symbols the new scale appears easy to learn and moreover easy to use in the field. An additional advantage of the scale is that the raw data can be easily entered into the data-processing system in use. Therefore this scale may be recommended for further use.

Comparison of transformations.

The most important aspect in which the transformations listed in table 3 differ, is no doubt the ratio between the transformed values the Braun-Blanquet symbols + and 5 (symbol *r* is difficultly to include in the comparison because this category is often converted to zero cover, or it is not distinguished from category +). This ratio varies as follows: 0 (Londo 1971), 0,01 (Braun-Blanquet 1964 average cover values), 0,05 (Schwickerath 1931), 0,10 (Coetzee & Werger 1973, see also Campbell 1978), 0,22 (combined transformation), 0,52 (log transform), 0,67 (Moore 1966) and 1,00 in the presence-absence approach. Clearly the possible influence of species with low abundance or cover values against species with high cover values in any numerical comparison of relevés or species groups increases from very little to equal influence.

The shortening or lengthening of the range of the numerical values obtained in the various transformations may now be simulated by applying an exponential transformation of the general form

$$y = x^w \qquad (2)$$

where x = the original value and y its transform, for different values of w. It appeared that when taking the ordinal transform values from 1–9 as original values many of the existing transformations could be approached rather well with values for w varying from 0 to 4. See Table 4. (Of course, for each other series of starting values e.g. cover % values, a similar series of w-values can be found).

The deviations occurring within the range *2m–2a–2b* are acceptable. The Jensén and Coetzee & Werger scales are somewhat overestimated in the lower range, but this is consistent with the implied emphasis of these scales. With the exponential transformation an easy comparison can be made of the effects of various transformations on com-

Table 4. Approximation of the transformation scales from Schwickerath, Tüxen & Ellenberg, based on Braun-Blanquet (1964), Moore, Coetzee & Werger and Jensén, by exponential transformation of the 1–9 combined transformation scale. For easy comparison the exponential transforms are multiplied by a factor as to make the highest values corresponding to the Braun-Blanquet value 5 equal. The transformation function used here is of the form $y = ax^w$, which is explained in the Discussion. Average cover % values for *2a*, and *2b* are taken 8 % and 18 % and values for 1 and *2m* are arbitrarily chosen with regard to Tüxen & Ellenberg (1937) and Braun-Blanquet (1964). Schwickerath -and Moore- values for *2m*, *2a* and *2b*, and Coetzee & Werger values for *2m* are newly suggested.

Braun-Blanquet scale diff. symbol 2	Presence-absence transform.	$y = x^0$	Moore transform.	approx. $y = 8.67\ x^{0.25}$	Jensén transform. 1 + log. cover %	approx. $y = 0.98 . x^{0.50}$	combined transformation	$y = x^{1.00}$	Coetzee & Werger transform.	approx. $y = 1,852\ x^{1.50}$	Schwickerath transform.	approx. $y = 0.62\ x^{2.00}$	Tüxen & Ellenberg average cover %-values	approx. $y = 0.01333 . x^{4.00}$
r	1	1	10	8.7	1.00	0.98	1	1	1	2	( )	0.06	0.02	0.01
+	1	1	10	10.3	1.00	1.39	2	2	5	5	0.25	0.25	0.1	0.2
1	1	1	11	11.4	1.39	1.70	3	3	10	10	1	0.56	2.5	1.1
2m	1	1	11.5	12.2	1.69	1.96	4	4	13	15	1.5	1.0	5.0	3.4
2a	1	1	12	13.0	1.90	2.24	5	5	17	21	2	1.6	8.75	8.3
2b	1	1	12.5	13.6	2.25	2.32	6	6	24	27	2.5	2.2	18.75	17.3
3	1	1	13	14.1	2.58	2.60	7	7	30	34	3	3.0	37.5	32.0
4	1	1	14	14.6	2.70	2.77	8	8	40	42	4	4.0	62.5	54.6
5	1	1	15	15.0	2.94	2.94	9	9	50	50	5	5.0	87.5	87.5

munity similarity: either patterns of relevé similarity or of homotoneity levels of clusters (cf Westhoff & van der Maarel 1978). The quantitative data on species need only to be stored in ordinal transform values and on applying the appropriate value of the exponent w the required transformation is obtained. Incidentally, this may be considered an additional motive for choosing the 1–9 ordinal transform directly as a field scale. If the original Braun-Blanquet values are available, it is advised (table 2) to take ordinal transform 5 for Br Bl symbol 2. Other field scales, notably those of Hult – Sernander and Domin can be transformed to the 1–9 scale without loss of much accuracy. (Table 2).

It is then possible to apply a series of transformations in the sequence $w = 0$ (presence – absence), $w = 0{,}25$ or $0{,}50$ (emphasis on presence), $w = 1$ (intermediate, presence and dominance balanced) $w = 1{,}50$ or $2{,}00$ (emphasis on dominance) and $w = 4{,}00$ (strong emphasis on dominance). Indeed, we have programmed in our department such a serious of transformations which can be performed before applying one of the standard numerical analyses.

Dr. R.S. Clymo (Westfield College, London) devised a similar transformation function. It was primarily meant for cover % values, but it can used for all other values. Dr. Clymo agreed in presenting his formula in this paper for further comparisons. It reads:

$$y = \frac{1-e^{-ax}}{1-e^{-a}} \qquad (3)$$

where e is the base of natural logarithms, a is the transformation exponent and x the species score, which is supposed to range from 0 to 1. With this formula values for y are always between 0 and 1. When using cover values as proportions of unity a value of a near to 0 will result in a nearly linear relation between y and x, i.e. the x values remain largely untransformed; for large values of a a presence – absence transformation is approached, for $a = 4$ the transformed values are approximately Hult-Sernander values.*

* While completing another manuscript in which transformation of cover-abundance values is discussed (van der Maarel 1979) I came across exactly the same exponential transformation as I devised, viz. in an attempt by Baum (1977) to reduce the dimensionality of a dissimilarity matrix of taxonomically compared individuals. (This effect is also discussed in the present paper). Moreover Baum suggested an alternative reminding Clymo's function: $y = e^{-ax} - 1$!

Effects of transformation of cover – abundance values on the numerical relations between relevés

Multivariate methods used

As in the studies by Jensén (1978) and Campbell (1978) the effects of data transformations were investigated by applying some multivariate methods to concrete phytosociological datasets, viz. the *Arrhenatheretum* material provided by Mueller-Dombois & Ellenberg (1974), and the *Glauco-Puccinellietalia* and *Spartinetea* selections of the Working Group for Data – Processing, which were also used for the elucidation of the table rearrangement program TABORD (van der Maarel, Janssen & Louppen 1978). In all cases both a classification and ordination technique were used. The classification technique was Ward's clustering technique, and agglomerative clustering provided in the CLUSTAN package (Wishart 1975) which was used with Euclidean distance as a dissimilarity coefficient. The ordination technique was ORDINA (cf Roskam 1971, van der Maarel 1972a, van der Maarel, Janssen & Louppen 1978) a principal components analysis on a Euclidean distance matrix. The transformations used are based on the ordinal transform running from 1–9 and include values of the exponent $w = 0; 0{,}25; 1{,}00; 1{,}50; 2{,}00$ and $4{,}00$. These transformations will be indicated as a, b, c, d, e and f respectively.

Any interpretation of the results obtained with various transformations should lead to the ranking of the transformations as to the effectiveness of the classification and ordination results they produce. Effectiveness can be evaluated in terms of the structure of the cluster dendrogram, discrimination between clusters at one particular level, separation of clusters of relevé points in an ordination space, the phytosociological and environmental interpretability of the results, and the agreement of the results with already established knowledge about the plant communities involved. The present study will concentrate on the latter.

Example Arrhenatheretum

This example involves 25 relevés of *Arrhenatheretum* grasslands in Southern Germany which has been used by Ellenberg (1956) to demonstrate the manual technique of constructing a phytosociological table and by Mueller-Dombois & Ellenberg (1974) to demonstrate various numerical treatments. We have also used this material to demonstrate our table rearrangement program TABORD (van der Maarel, Janssen & Louppen 1978). The table and ordination diagram presented in the latter paper is used as a reference for the following discussion.

The *Arrhenatheretum* material contains relevés of three types (subassociations), one with *Bromus erectus* and other xerophilous species (rel. 1, 3, 4, 9, 10, 15, 24), one with *Cirsium oleraceum*, *Deschampsia caespitosa* and other wetland species (rel. 6, 7, 8, 11, 14, 17, 19, 21), and one intermediate type in which *Helictotrichon pubescens* with *Trisetum flavescens* and other mesophilous species find an optimum (rel. 2, 5, 12, 13, 16, 18, 20, 22, 23). There is one deviating relevé joining the *Cirsium oleraceum* group but having five species of its own (ref. 19). These three types will be named *Bromus* –, *Cirsium* – and *Geum* type according to the indication by Mueller – Dombois & Ellenberg (1974). Fig. 1 shows the dendrogram resulting from Ward's clustering method with data transformation c, $w = 1$, i.e. the 1–9 ordinal transform. Fig. 2 presents the results of and ORDINA – ordination, for dimension 1 and 2, applied to each of the six transformations of the data matrix. For the interpretation of the results we make use of Table 5

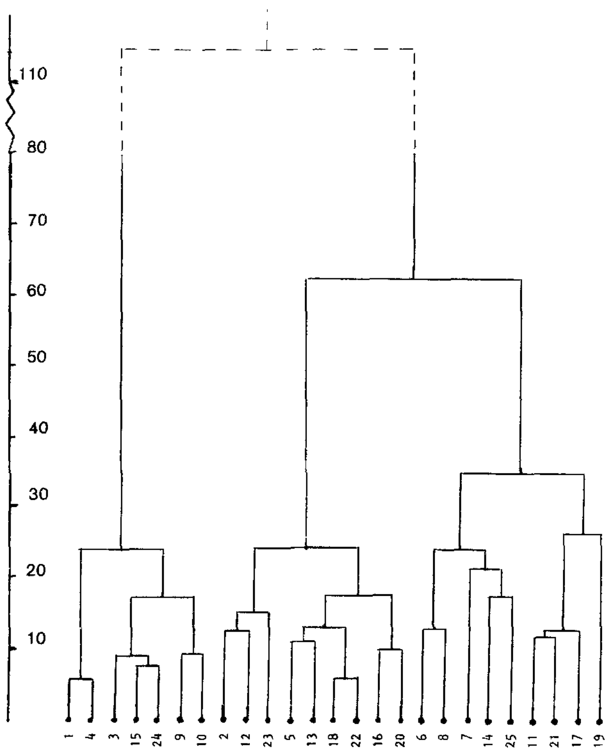


Fig. 1. Dendrogram of 25 *Arrhenatheretum* relevés clustered with Ward's method, with transformation c ($w = 1.00$) applied to the species scores.

which summarizes some relevant information on the relevés, and Table 6 which presents some characteristics of the clusters arrived at.

Classification

The dendrograms for the six transformations are similar in overall structure. Fusions occur at regular intervals showing no obvious discontinuity where clusters could be isolated, except for the final step: In all cases two main groups result, one with the *Bromus erectus* relevés and one including all the others. This confirms the conclusion on the main structure of the data set reached by van der Maarel, Janssen & Louppen (1978). It is still interesting to compare the cluster sets obtained on the basis of different transformations. Two levels were arbitrarily chosen – one with 8 clusters and one with 3.

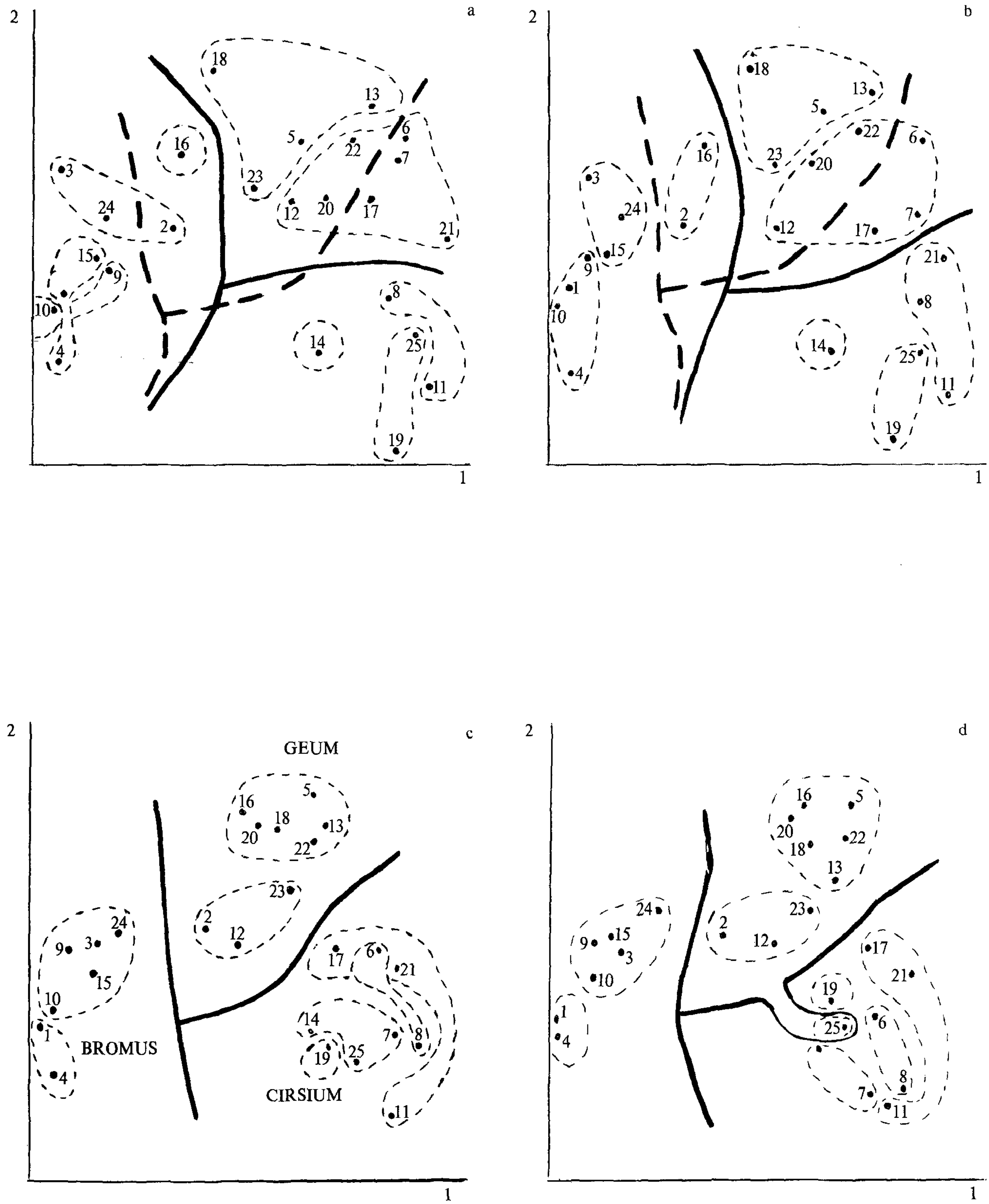
On the 8-cluster level (and the 9-cluster level with transformation a, because comparatively rapid fusions occur here, from 9 down to 3 clusters) the ordinal transformation c shows the best result in terms of the phytosociological interpretations of the resulting clusters: 7 out of 8 clusters have 'exclusive constants', i.e. species with a constancy > 75 % in that cluster and a constancy of < 75 % in all other clusters. The total number of such species is 20, only one less than in the b situation. Transformations b and d produce slightly less and the remaining three much less satisfactory results than c. Furthermore the c-transformation is the only one at which the deviating relevé 19 and no other relevés occur as a single – relevé cluster.

On the 3-cluster level the resulting grouping may be compared with the main division into three types by Ellenberg. Again the c- result is in complete accordance: all 25 relevés placed in the group they were originally assigned to. Now a reasonable second position is taken in by transformations d and e.

The two extreme transformations, i.e. 'presence-absence' and 'Tüxen – Ellenberg dominance weighting' produce unsatisfactory classifications.

Ordination

Fig. 2a–f shows how the configuration of points changes from widely spaced at transformations a and b to more concentrated at f. This concentration in the central part of the diagram is accentuated by the extreme position of relevé 2. The wide scattering of points in the first two diagrams should not be interpreted as an expression of the effectiveness of the corresponding ordinations. On the


a
b
c
d
GEUM
BROMUS
CIRSIUM
1
2

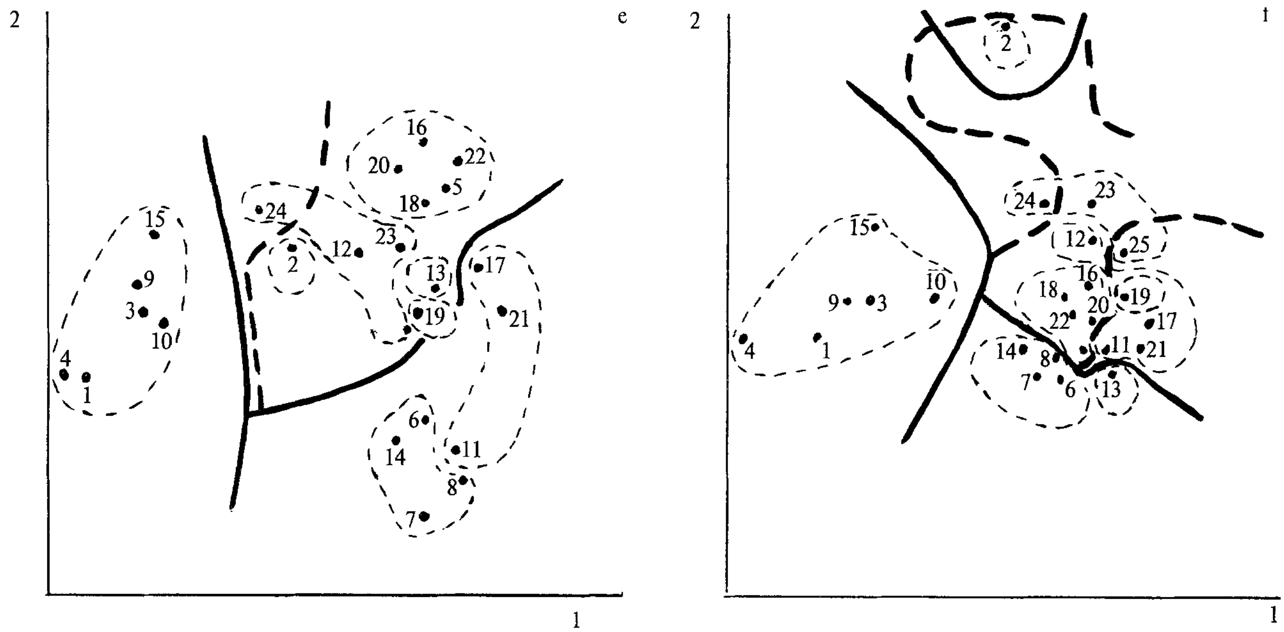


Fig. 2. a/f. Position along dimensions 1 and 2 of an ORDINA-ordination of 25 *Arrhenatheretum* relevés (positive and negative loadings reversed if necessary to obtain comparable structures.a: after exponential data transformation with $w = 0$, b: ibid. $w = 0.25$; c: ibid. $w = 1.00$, d: ibid. $w = 1.50$; e: ibid. $w = 2.00$; f: ibid. $w = 4.00$. Clusters are obtained with Ward's method and presented at the 8 cluster level (case *a* at the 9-cluster lvel) with boundaries in thin interrupted lines, at the 3-cluster level with thick lines. Correct cluster structure as to main division into three types by Ellenberg is indicated with thick interrupted lines (if deviating from 3-cluster system); the transformation *c* gave the correct situation.

contrary: the extracted variance per dimension is very low at lower values of *w* and increases with increasing weight on dominance. In the first case, when only presence and absence are concerned we can imagine that with a total species number of 94 many more dimensions are needed to explain most of the variation involved. The same trend towards lower dimensionality at high dominance levels has been reported by Jensén 1978 for species-poor lake vegetation, be it on a much higher level of extracted variance.* On the other hand by the heavy weighting of dominant species the total variation in the transformed data matrix is mainly contributed by the 12 species occurring at least once with ordinal transform values 6, 7 or 8. 46 % extracted variance is reached with the first two dimensions. However, the variation due to the species with lower cover – abundance values is obscured. (Austin & Greig-Smith 1968 observed a similar trend with species occurring at high density levels).

The presence – absence ordination diagram shows a clear horse shoe configuration, along which the environmental transition occurs from the relatively very dry sites with the *Bromus* type (e.g. relevés 4 and 10) and the mesic sites with the *Geum* type (e.g. rel. 5, 13 and 18) to the moist sites with the *Cirsium* type (e.g. rel. 8 and 25) and the wet site of rel. 19 with *Glyceria fluitans* and *Phalaris arundinacea*. The most dissimilar pair of relevés in this case is 10 and 19.

If the results of the clustering are combined with that of the ordination, the transformations *b* and *c* can be considered the most effective ones, in the sense that in the middle range of the transformations the two different multivariate methods using the same dissimilarity matrix produce coherent structures.

Example Spartinetea

This example is concerned with 22 relevés taken from the selection *f* of 50 relevés used by the the Working Group for Data – Processing. The full selection is treated by van der Maarel, Janssen & Louppen (1978, tables 2 and 3). This selection was treated in the same way as the previous *Arrhenatheretum* material. Table 7 and Fig. 4 present

* (See Baum 1977!)

Table 5. Information on species composition of 25 Arrhenatheretum relevés which is relevant for the interpretation of Fig. 2 and Table 6. Transformations compared are as in Fig. 2.

Relevé nr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Number of species	31	25	32	28	32	32	26	34	32	31	28	34	39	32	33	37	35	29	29	30	35	27	29	30	28
Nr. of species with value 7x8 or 9	1x7	1x8	1x7	1x8					1x7		1x7	1x7	1x7		1x7		1x7		1x7	1x7			1x7		1x7
Nr. of species with value exceeding other values of the species with 2 or more scale values	1	2					2	1			1		2	1				1	3					1	2
Nr. of species occurring 1x or 2x		1		1			2		1		2	3	2	2		3	2	2	7		2		1	3	2
Occurrence as single relevé cluster in 8-cluster-structure at transf. a-f		e f									f		e f	a b		a			c f						
Extreme position along ordination axis 1, 2 or 3		f:2		f:1										a:3					a:2 d:3 e:3						
Strong move in successive ordin.		x		x		x	x			x									x						
Nr. of misclassif. in 3-cluster syst.		3				2	2				1		1			1	2		1		2			2	3

Table 6. Characteristics of the clusters arrived at on the 8-cluster and 3-cluster levels with Ward's clustering method applied to 25 *Arrhenatheretum* relevés (Ellenberg 1956, Mueller-Dombois & Ellenberg 1974) and figures for extracted variance per dimension in ORDINA-ordinations, for six data transformations.

Transformation	a	b	c	d	e	f
Value of w	0	0.25	1.00	1.50	2.00	4.00
Nr. of clusters compared at 8 cluster level	9	8	8	8	8	8
Nr. of clusters with at least one constant and exclusive species	5	6	7	7	5	5
Total nr. of constant-exclusive species	9	21	20	17	12	12
Nr. of clusters compared at 3 cluster level	3	3	3	3	3	4
Nr. of relevés classified correctly according to Ellenberg's classification	19	20	25	24	24	19
Extracted variance dimension 1%	19,5	21,5	25,3	26,0	26,8	31,0
2	9,0	10,0	13,1	13,5	13,0	14,9
3	6,6	6,7	9,2	10,2	10,4	10,7
1+2+3	35,1	38,2	47,6	49,7	50,2	56,6
Most dissimilar pair of relevés	10-19	10-19	1-19	1-19	1-19	2-4

information on the relevés. The comparison of ordination and classification results is based on the results obtained from the total selection by applying the program TABORD. In this treatment 11 clusters were derived. Two of these could be subdivided in view of the quantitative differences in the occurrence of some species. The result is a system of 13 elementary clusters.

On a higher level 6 main clusters may be distinguished, four of which being characterized by the dominance of one *Spartina* species. The clusters dominated by *Spartina alterniflora* (rel. 5, 6) and *S. patens* (rel. 7, 8) are clear cut and so is the cluster with the three *S. townsendii* dominated relevés (rel. 9, 10 and 11), but two of the *S. maritima* relevés (rel. 3 and 4) are only slightly less similar to the remaining group of *S. townsendii* relevés than to the 'pure' *S. maritima* relevés (rel. 1 and 2) The structures with 13 clusters and 6 clusters are described in table 7. (On the 13-cluster level the number of clusters involved in the comparison is 12 in four cases, and at the 6-cluster level it is seven in three cases, see Fig. 3).

Table 8 presents information on the clusters in a similar way as Table 6. Since the clusters on the 13–cluster level are small no characteristics of the clusters are given. At the 6-cluster level a relevé is considered correctly 'placed' if

Table 7. Information on 22 *Spartinetea* relevés. *M* = *Spartina maritima* cluster, *Mp* = *Spartina maritima-Puccinellia maritima* cluster, *A* = *Spartina alterniflora* cluster, *P* = *Spartina patens* cluster *T* = *Spartina townsendii* cluster, *Ts* = *Spartina townsendii- Suaeda maritima* cluster; *Spm* = *Spartina maritima; Pum* = *Puccinellia maritima; Sap* = *Salicornia perennis: Spa*= *Spartina alterniflora; Spp* = *Spartina patens; Spt* = *Spartina townsendii; Sae* = *Salicornia europaea; Sum* = *Suaeda maritima; Ath* = *Atriplex hastata.*

Relevé nr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Nr. in selection f	2	4	6	9	12	15	16	17	21	23	24	27	29	32	33	34	39	40	44	45	47	50
13-cluster level TABORD	1	1	8	2	3	3	4	4	5	5	5	9	10	7b	7b	10	11	11	6a	6b	7a	7a
6-cluster level	M	M	M_p	M_p	A	A	P	P	T	T	T	T_s	T_s	T_s	T_s	T_s	T_s	T_s	T_s	T_s	T_s	T_s
Prevailing species	Spm	Spm	Pum Sap Spm	Sap Pum Spm	Spa	Spa	Spp	Spp	Spt	Spt	Spt	Pum Sae Spt	Pum Sae Spt	Sae Spt	Sae Spt	Sae Pum Spt	Sum Spt	Sum Spt	Ath Pum Spt	Ath Spt	Spt Sum	Spt Sum
Nr. of species	1	4	6	6	1	4	3	6	3	2	1	6	5	4	5	7	6	4	8	3	5	4
Species with value 7, 8 or 9	9	8	8,7	8	8	9	9	9	7	9	9	8	7	8	7	7	8	9	7	9		
Nr. of species occurring 1x						11		2											2	1		
Occurrence as single-relevé cluster at transf. a-f in 13 cluster structure		a				a	a,b	a,b											a f	a f		
Extreme position along ordination axis 1, 2 or 3						a:3 b:3	f:1 2	f:1 2		f:1	f:1											
Strong move in successive ordinations			x	x	x	x	x	x		x	x									x		
Nr. of misclassifications in 6 cluster system			3	3					3	1	1									1		

the cluster to which it is assigned is either identical with one of the six clusters as determined by the dominant *Spartina* species, or included in such a cluster.

If we consider the similarity between the classification at the two levels with the respective classifications considered best on the basis of earlier phytosociological interpretations, the optimum transformations for the 13-cluster level are *d* and *e*, while for the 6 cluster level *c*, *d* and *e* are acceptable, but *c* is better.

Table 8. Characteristics of the clusters arrived at with Ward's method applied to 22 *Spartinetea* relevés and figures for ordination results. (See Table 6).

Transformation	a	b	c	d	e	f
Value of w	0	0.25	1.00	1.50	2.00	4.00
Nr. of clusters compared at 13 cluster level	13	12	13	12	12	12
Nr. of identical clusters	2	3	8	10	10	8
Nr. of relevés placed correctly according to 13 cluster structure	3	4	13	17	17	12
Nr. of clusters compared at 6 cluster level	7	6	7	6	7	6
Nr. of identical clusters.	1	4	4	3	4	3
Nr. of relevés placed correctly according to 4 cluster structure	8	8	17	15	15	11
Nr. of clusters with at least one constant-exclusive species	3	5	6	6	7	5
Extracted variance dimension 1 %	33,7	33,2	24,3	20,4	18,9	20,2
2	15,8	17,6	20,0	19,5	18,3	18,0
3	11,7	11,5	11,9	12,8	13,6	13,8
1+2+3	61,2	62,3	56,2	52,7	50,8	52,0
Most dissimilar pair of relevés	8-19	8-19	3-8	3-8	8-20	8-20

The best agreement between the classification and ordination structures is found at transformation *d*, although not as good as in the best case of the *Arrhenatheretum* example. As could be expected in this example transformations with an emphasis on dominance, and also the ordinal transformation produce acceptable results while, as in the *Arrhenetheretum* example, those with an emphasis on presence, fail. However, the transformation with the strongest emphasis on dominance, i.e. transformation *f*, is also less effective.

This pattern can be explained as follows: In some clusters the dominant *Spartina* species occurs with others species, in some clusters it does not (Table 7). In a presence – absence transformation the companion species change the position of the corresponding relevé, as is the case with for example relevé 4 as compared with rel. 2 and rel. 6 as compared with rel. 5. On the other hand clusters with the same prevailing species which varies in cover – abundance value, will become more heterogeneous with higher

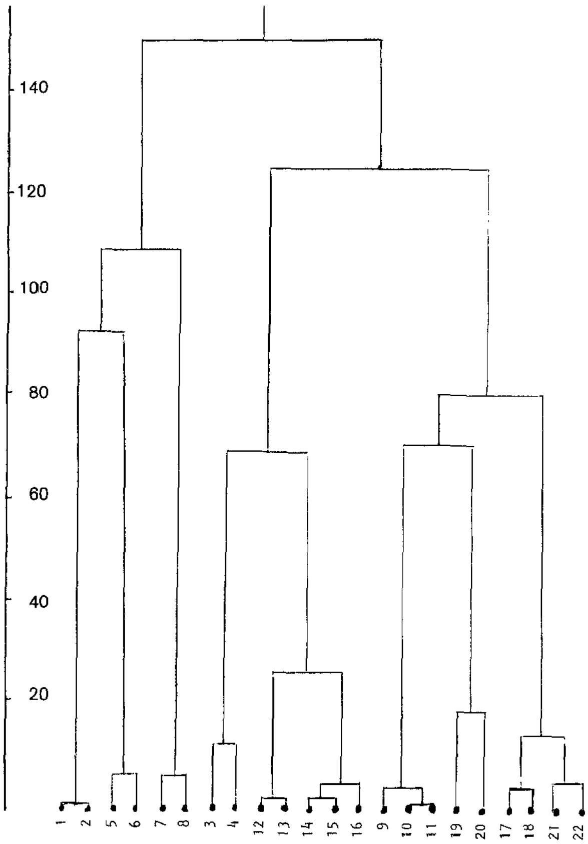


Fig. 3. Dendrogram of 22 *Spartinetea* relevés clustered with Ward's method, with transformation *d* (w = 1.50) applied to species scores.

transformation values. This can be observed in cluster *T*, '*pure Spartina townsendii*', where with transformation *f*, rel. 9 having *Spartina townsendii* with value 7 is no longer fused with rel. 10 and 11, having *Spartina* with value 9. Note that at lower transformation values rel. 9 is not fused with rel. 10 and 11 either, because it has two extra species.

The effect of the transformations on the general structure of the ordination diagram is different from that obtained with the *Arrhenatheretum* selection. The percentage of extracted variance increases only from transformation *a* to *b* and then decreases again. This could be explained by the interesting fact that the most dissimilar pair of relevés at lower transformation values is 18 and 19 and at higher values 8 and 20, while relevés 19 and 20 are both characterized by *Atriplex hastata*, which species does not occur in any other relevé involved. Relevés 8 and 20 each have one species (*Juncus maritimus* and *Scirpus maritimus* respectively) with cover – abundance value 5, lacking in all other relevés. Weighting these species more heavily as the total variation in the data-set increases, provides an explanation for why more axes are needed.

Example Glauco – Puccinellietalia

This example includes 23 relevés taken from selection *e* of 58 relevés used by the Working Group for Data – Processing (see van der Maarel et al 1978, tables 7 and 8). The same treatments were applied as in the other examples. Information on the relevés and the treatments is presented in Tables 9 and 10. Only one classification was used as a reference. This is an 8-cluster classification which is based on (1) the results of a TABORD version used in the TABORD treatment of selection *e* (van der Maarel, Janssen & Louppen 1978), (2) Feoli's (1977) results and (3) the original phytosociological classification applied by the authors of the tables from which selection *e* was taken (see Feoli 1977 for details)). Six of these clusters can be named according to the original syntaxonomical units, two deviating relevés, 22 and 23, have been named clusters X and Y (see Table 9). The overall similarity between the 8-cluster classification and the series of classifications with Ward's analysis is less than in the two previous examples, mainly because of the deviating position of relevés 21, 22 and 23 which are obviously misclassified in the 8-cluster

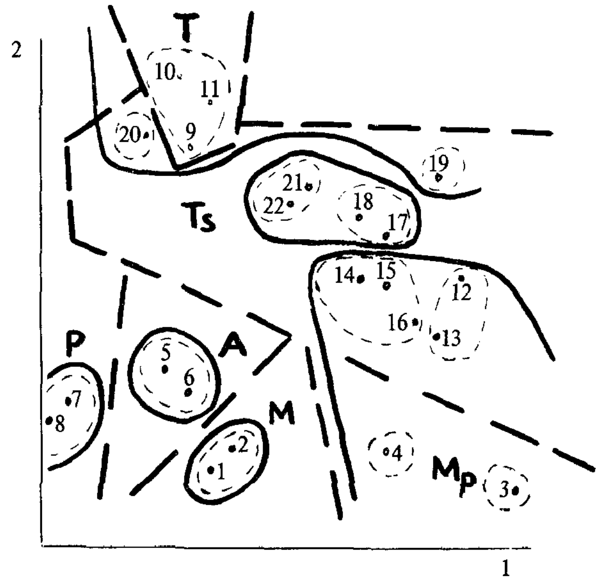


Fig. 4. Position along dimensions 1 and 2 of an ORDINA-ordination of 22 *Spartinetea* relevés with transformation *d*. See for the selection and abbreviations Table 7. The lines refer to the 12-cluster-and 6-cluster configuration with transformation *d* (thin interrupted and thick lines) and to the 6-cluster structure as obtained with TABORD (thick interrupted lines).

Table 9. Information on 23 *Glauco-Puccinellietalia* relevés.

Relevé nr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Nr. in selection e	2	3	11	17	18	19	20	20	27	28	30	31	35	38	41	42	45	47	49	50	53	54	55
Prevailing species	Pum	Pum Liv	Jug	Scr	Scr	Pum Ast	Pum	Jug Glm	Fer	Fer	Fer Atm	Fer Atm	Pum	Jug	Jum	Jum	Pum	Jug	Cae Gem	Scm	Jug Gem	Jug	Pas Arm
8 cluster level	P	P	J	S	S	P	P	J	F	F	F	F	P	J	M	M	P	C	C	C	J	X	Y
Nr. of species	8	9	6	14	14	3	5	9	10	9	12	15	3	19	16	9	4	15	11	10	9	12	13
Species with value 7, 8 en 9	9	8,7	9	7	-	9,7	9	9,7	8	8	2x7	2x7	9,7	9	8	8	9	8	2x7	8	3x8 2x7	8,7	8,7
Nr. of species occurring 1x			1	4	2		1		1		4	4			2	1		1		1			2
Occurrence as single relevé cluster at transf. a-f in 8 cluster structure											a									f	c d e		e f
Extreme position along ordination axis, 1, 2 or 3											a:3 b:2												e:3
Strong move in successive ordinations																						x	x
Nr. of misclassifications in 8 cluster system			2	2	2	1	1	2	1	1			1	2	2	2	1	2	1	1	6	6	4

system. Transformation *e* is slightly superior to the others, but transformation *d* is not far behind. The agreement between the classification and ordination results is very good at transformation *d*, less at *e* and *f*, and much less at *a*, *b* and *c*. Apparently the structure of this data-set, with the total number of high cover-abundance scores high, is most optimally approached with a moderate emphasis on dominance, similarly as in the *Spartinetea* example.

Table 10. Characteristics of the clusters arrived at with Ward's method applied to 23 *Glauco-Puccinellietalia* relevés and figures for ordination results. (See Table 6).

Transformation	a	b	c	d	e	f
Value of w	0	0.25	1.00	1.50	2.00	4.00
Nr. of clusters compared at 8 cluster level.		8	8	8	8	8
Nr. of identical clusters.	0	1	3	5	5	4
Nr. of relevés placed correctly according to 8 cluster structure						
Nr. of clusters with at least one constant-exclusive species	4	4	7	7	7	7
Nr. of clusters compared at 4 cluster level.	4	5	4	4	5	5
Nr. of relevés placed correctly	6	17	22	23	19	19
Extracted variance dimension 1,%	20,4	21,1	23,3	26,1	29,4	40,7
" 2	14,1	14,3	15,2	16,8	18,1	22,6
" 3	10,4	11,1	12,4	11,1	10,6	8,6
" 1+2+3	44,9	46,5	50,9	54,0	58,1	71,9
Most dissimilar pair of relevés	11-15	11-23	11-23	11-21	11-21	8-17

Since no elaborated phytosociological classification of the *Glauco – Puccinellietalia* selection on a higher level of abstraction is available, only a superficial comparison can be made at the 4-cluster level. On this level cluster *P*, *Puccinellion maritimae* remains on its own. Of the other clusters, which could all be assigned to the *Armerion maritimae*. cluster *F*, *Armerio – Festucetum* of dry places, is also a cluster of its own, clusters *S*, *J*, *C* and *M*, representing related communities of wetter places, fuse, while the deviating clusters *X* and *Y* form a new cluster in which all three former groups are represented (See also Van der Maarel et al. 1978: table 8 and fig. 3). Because of the more complicated structure of this material the criterion for correct placing of a relevé was extended: (1) respective clusters are identical; (2) cluster forms part of a standard cluster to which it is compared (1 and 2 as in previous examples); (3) cluster overlap with standard cluster for more than 50% of the relevés. The results (Table 10) show that the optimal transformation is *d* and transformation *c* is second. Thus as compared with the 8-cluster level we see a shift towards the lower transformation values.

Discussion

Weighting and standardization

Transformation of species performance data through weighting of cover – abundance figures is an important issue in numerical phytosociological treatments. This paper confirms in a general way earlier findings and statements about the dependence of both classification and ordination results on the transformation to which the data are subjected.

In view of the similarity between combined cover – abundance scales and the angular transforms of the cover % scales, and the possibility to approach various transformations with the exponential function, one might consider any cover – abundance scale as a transformation of some theoretical scale for species performance in phytocoenoses. This applies also to the still commonly used traditional field scales of Braun-Blanquet and Domin.

Standardization is a particular, but in our view a secondary form of data transformation. It is equally considered as a central problem in multivariate analyses (Dagnelie 1960, Austin & Greig-Smith 1968, Noy-Meir 1973, Noy-Meir & Whittaker 1978). Some effects of standardization resemble those of weigthing, as has become especially clear from the general studies on the ecological meaning of transformation by Noy-Meir, Walker & Williams (1975). From their description of the features of standardization the following may be summarized (see also Van der Maarel 1979):

– Standardization by species, e.g. by the sum of the performance values for each species in all relevés, implies the underweighting of differences in frequency of a species in a data – set and hence the overweighting of the rarer species.

– Standardization by site (we would say by relevé), e.g. by the sum of the performance values of all species for each relevé, implies the underweighting of differences in total cover (or cover and abundance) in the relevés. It 'weights' the relevés with a low cover (cover-abundance) total and consequently the species with high cover – abundance values are overweighted relative to other values in the relevé.

– No standardization implies a weighting (by nature of the multivariate methods used) of common species, especially when occuring together in group of relevés.

To these general features we may add that through standardization by species the influence of the dominant species is diminished. Thus the similarity between the effects of standardization and weighting is clear: standardization by species has effects similar to that of weighting with a low value of the transformation exponent w, and standardization by relevé resembles weighting with a high value of w. In this connection the use of an intermediate transformation has a similar effect as non – standardization.

Interestingly in all our examples and in those discussed by Jensén (1978) and Campbell (1978) the intermediate transformations lead to ecologically satisfactory results. Noy – Meir et al (1975) conclude that non – standardization, having a similar effect,' may seem appropriate for many phytosociological studies.' Indeed, when the general structure of a phytosociological data set is our main concern and we wish to include both relationships between sites and between species in our approach, as is essential in phytosociology, non-standardization or, similarly, intermediate weighting seems effective.

Obviously standardization and weighting are two different types of transformation, although some similarities in effect exist. The main difference is that with weighting the amplitude of the scale is changed and hence, in terms of standardization, the variance. On the other hand, standardization makes the data- set more uniform. Standardization by species may wipe out the influence of differences in species frequency, irrespective of the amplitude in cover – abundance value. As Noy-Meir et al (op. cit.) demonstrate this may be effective in a phytosociological approach where groups of faithful and differential species are sought (cf Goodall 1953, 1969). Standardization by relevé diminishes the influence of differences in total cover and abundance in a site and this may be ineffective where (Noy-Meir et al., op. cit.) 'the study is concerned primarily neither with species nor with sites but rather with the bulk of vegetation, the total plant cover or biomass, and the patterns of its distribution between species and stands'. Clearly, in such cases no standardization would be appropriate. It may be worthwhile studying the effects of standardization, in a phytosociological context first by sites and then by species, after an optimal weighting has been found, or in combination with different weightings. (cf Gauch, Whittaker & Wentworth 1977).

Finally weighting and standardization should be considered in relation to the type of resemblance function used in further multivariate analyses (cf Orlóci 1978). To mention one example: as van der Maarel (1979) pointed out the Euclidean distance is a very attractive resemblance measure, but it has the disadvantage that strong differences in the performance value of one or a few species may outweigh the similarity between relevés as to the joint occurrence of many species with equal but low performance values. In this case standardization by relevé, i.e. by performance value total, would cope with this problem. The disadvantage of this standardization as such (see above) could be overcome by a prior intermediate weighting. An additional advantage of this standardization is that the Euclidean distance becomes fixed in range, i.e. between 0 and 1.

In order to manipulate with weighting and standardization in relation to each other we may extend the exponential function by making use of a transformation function suggested by Orlóci (1978). Orlóci's function is of the form

$$y_{ij} = a_i x_{ij} \qquad (4)$$

where y_{ij} is the transformed score x_{ij} of species i in relevé j and a_i is a standardization factor specific to species i. (Orlóci used other symbols and spoke of weighting here, but the examples he gave for the substitution of a, such as $a_i = 1/x_i$ refer to standardization in the sense used in the present paper).
The combined transformation function then becomes:

$$y_{ij} = a_i x_{ij}^w \qquad (5)$$

(As was shown in Table 4 the factor a can also be used for adapting ranges of scales!)

Effects of transformation on different levels of hierarchic classification

It has been suggested (Smartt, Meacock & Lambert 1976, M.B. Dale and E. van der Maarel in pers. comm.) that in an hierarchical classification the weighting may be changed along with the level of abstraction. Broad groupings of relevés, the higher syntaxonomical units such as orders and classes, are characterized by combinations of species on a presence-absence basis. In the lower groupings, the lower syntaxonomical units such as associations and alliances, the quantitative differences between species become important. The finest subdivisions, the variants and facies (see Westhoff & van der Maarel 1978), are characterized mainly by dominance or prominence of one species: they may come out through strong weighting of cover-abundance values.

The results of the present study provide some evidence for differences in efficiency of the transformation used and the level of abstraction in the hierarchical classification, but there is no general tendency. In the *Arrhenatheretum* case the higher level in the hierarchy is optimally approached by a range of transformation values which are slightly higher than in the lower level situation. In the *Spartinetea* example there is hardly any difference. At both levels of classification a comparatively strong weighting gives optimal results. In the *Glauco-Puccinellietalia* example higher transformation values are slightly more efficient on the lower level of classification.

These results may still fit into the general picture if we take into account that the three examples represent different levels of syntaxonomical complexity of their own. The *Glauco-Puccinellietalia* example, as the name indicates, shows variation on the syntaxonomical order level and here we may expect what was actually found. The *Arrhenatheretum* example represents a data-set which is syntaxonomically already homogeneous enough to be approached with a moderate dominance weighting. Since the subassociations put together in this material are mainly characterized by groups of differential species and hardly by quantitative differences between species, the shift towards lower transformations is understandable. The *Spartinetea*- example represents an extreme situation: grosso modo each facies of a *Spartina* species or one other halophyte represents almost a separate syntaxonomical class.

Since the chosen examples are small in number and small in size we cannot derive more than just indicative results, but they justify the general suggestion that in hierarchical classifications, either divisive or agglomerative ones, various transformations should be tried on various levels of abstraction.

Transformation and intrinsic features of species performance

In his discussion of coupures Dagnelie (1960, see Introduction) used three arguments in favour of deleting certain performance values in a phytosociological data matrix. One of the arguments is biological. According to it low cover-abundance values are biologically less meaningful, at least in relation to higher values occurring elsewhere in the matrix. In view of the newer results obtained with transformations it is by no means certain that low quantities of a species occurring with high values elsewhere in a table do not have an indicator value. In many cases, e.g. in the *Spartinetea* treatment by Kortekaas, van der Maarel & Beeftink 1976, separate community types can be based on species occurrences with low values.

This brings us back to the pros and cons of the various scales mentioned in this contribution. Unless standardizations would be applied, full cover scales or scales transforming low values to zero cover, are ecologically ineffective because we would loose information on species which never attain high cover-abundance values by the nature of their intrinsic features, but are often good character-species, such as many tiny *Orchidaceae*, *Cyperaceae*, *Brassicaceae* and *Scrophulariaceae* (see van der Maarel 1966). Therefore I would suggest to retain all information carried in the combined scales such as those of Braun-Blanquet and Domin. Transformations with a strong weight on the mere presence, such as Moore's scale and in extremis, the presence-absence transformation appear to perform badly in most phytosociological cases known so far. Transformation with a heavy weight on high cover values, notably the original and still used group value transformation of Tüxen & Ellenberg, perform equally bad.

Finally we may interpret the relative success of intermediate transformations as an indication for a general, ecologically significant species performance. If we seek a parallel with other biological processes, a logarithmic transformation seems obvious, although the exact type of transformation is not yet clear (see Hogeweg 1976, Smartt et al. 1976, Jensén 1978). However, abundance and cover may not be ruled by the same biological processes.

From the exponential formula presented here, we could also deduct a parallel with exponentially developing processes and conclude that species performance may be expressed as an exponential phenomenon within a limited range for the value of the exponent. Maybe, this range is dependent on both an abundance-type and a dominance – type of species performance.

Summary

Various cover and cover-abundance scales are compared, together with some current transformations, including the angular transformation and logarithmic transformations. A new cover-abundance scale, being a fully numerical, extended Braun-Blanquet scale is introduced under the name ordinal scale. The transformation of cover-abundance data is discussed in terms of a general transformation function $y = x^w$ and it is shown that by applying different values of w to the ordinal scale all other scales can be approached, ranging from the presence-absence transformation for $w = 0$ to to the Tüxen & Ellenberg cover scale for $w = 4$.

The effect of the transformation of cover-abundance values on community similarity is shown in three examples: (1) 25 relevés of *Arrhenatheretum* grassland, being the exampletable used by Mueller-Dombois & Ellenberg; (2) 22 relevés of *Spartinetea* communities; and (3) 23 relevés of *Glauco-Puccinellietalia* communities, the latter two sets being taken from selections devised by the Working Group for Data-Processing. In all examples classification and ordination results obtained with intermediate transformations were superior to those obtained with either a strong weighting on mere presence, or an emphasis on dominance. This comparison was based on previous phytosociological experience.

Weighting and standardization are compared with each other. It is concluded (1) that standardization by species has effects similar to those of weighting of rare species with low cover-abundance values; (2) that standardization by relevé is similar to weighting the dominant species; and (3) that no standardization and intermediate weighting are hence similar in effect.

It is stated that the relations between weighting and standardization are insufficiently studied and need more attention. A general formula for applying both forms of transformation is presented: $y = a\,x^w$.

It is supposed that the effect of the amount of weighting will depend on the heterogeneity level of the data-set under study. Indeed some indications were found that weighting the dominant species may help distinguishing lower syntaxonomical units, especially facies, and also higher units, even up to the class level if the communities are characterized by one or a few dominant species.

Some remarks are made on the possible ecological background of the effects of weighting. It is argued that biological (reproduction) processes responsible for the performance of a species are of an exponential nature. Two performance types may be distinguished, viz. the abundance type and the dominance type. Both types may be approached with logarithmic scales.

References

Austin, M.P. & P. Greig-Smith, 1968. The application of quantitative methods to vegetation survey. II. Some methodological problems of data from rain forest. J. Ecol. 56: 827–844.

Bailey, A.W. & C.E. Poulton, 1968. Plant communities and environmental relationship in a portion of the Tillamook burn, Northwestern Oregon. Ecology: 49: 1–13.

Bannister, P. 1966. The use of subjective estimates of cover – abundance as the basis for ordination. J. Ecol. 54: 665–674.

Baum, B.R. 1977. Reduction of dimensionality for heuristic purposes. Taxon 26: 791–795.

Becking, R.W. (1957). The Zürich-Montpellier school of phytosociology. Bot. Rev. 23: 411–488.

Braun-Blanquet, J. 1946. Über den Deckungswert der Arten in den Pflanzengesellschaften der Ordnung Vaccinio-Piceetalia. Jahresber. Naturforsch. Ges. Graubündens 130: 115–119.

Braun-Blanquet, J. 1964. Pflanzensoziologie, Grundzüge der Vegetationskunde. 3. Aufl. Springer, Wien, New York. XIV + 865 pp.

Braun-Blanquet, J. 1965. Plant sociology: the study of plant communities. Transl. rev. and ed. by C.D. Fuller & H.S. Conard. Hafner, London, 439 pp.

Campbell, B.M.: 1978. Similarity coefficients for classifying relevés. Vegetatio 37: 101–109.

Coetzee, B.J. & M.J.A. Werger, 1973. On hierarchical syndrome analysis and the Zürich-Montpellier table method. Bothalia 11: 159–164.

Curtis, J.T. & R.P. McIntosh. 1951. An upland forest continuum in the prairie – forest border region of Wisconsin. Ecology 32: 476–496.

Dagnelie, P. 1960. Contribution à l'étude des communautés végétales par l'analyse factorielle. Bull. Service Carte Phytogéogr. CNRS B-5: 7–71, 93–195.

Daubenmire, R. 1968. Plant communities. A textbook of plant synecology. Harper & Row, New York. XI + 300 pp.

Doing Kraft, H. 1954. l'Analyse des carrés permanents. Acta Bot. Neerl. 3: 421–425.

Ellenberg, H. 1956. Aufgaben und Methoden der Vegetationskunde. Ulmer, Stuttgart. 136 pp.

Etter, H. 1949. De l'analyse statistique des tableaux de végétation. Vegetatio 1: 147–154.

Feoli, E. 1977. A criterion for monothetic classification of phytosociological entities on the basis of species ordination. Vegetatio 33: 147–152.

Fresco, L.F.M. 1969. Q-type factor analysis as a method in synecological research. Acta Bot. Neerl. 18: 477–482.

Goodall, D.W. 1953–1954. Objective methods for the classification of vegetation. I, II and III. Austr. J. Bot. 1: 39–63, 1: 434–456, 2: 304–324.

Goodall, D.W. 1969. A procedure for recognition of uncommon species combinations in sets of vegetation samples. Vegetatio 18: 19–35.

Hogeweg, P. 1976. Topics in biological pattern analysis. Thesis Utrecht, 208 pp.

Jensén, S. 1978. Influences of transformation of cover values on classification and ordination of lake vegetation. Vegetatio 37: 19–31.

Kortekaas, W.M., E. van der Maarel & W.G. Beeftink. 1976. A numerical classification of European Spartina communities. Vegetatio 33: 51–60.

Krajina, V.J. 1960. Can we find a common platform for the different schoolt of forest – type classification? Silva Fenn. 105: 50–59.

Lausi, D., W.G. Beeftink & W.M. Kortekaas, 1979. Survey of salt marsh relevés, selected for the Working – Group for Data – Processing in Phytosociology. In prep.

Londo, G. 1971. Patroon en proces in duinvalleivegetaties langs een gegraven meer in de Kennemerduinen. (With summary). Thesis Nijmegen. 279 pp.

Londo, G. 1976. The decimal scale for relevés of permanent quadrats. Vegetatio 33: 61–64.

Maarel, E. van der 1966. Over vegetatiestructuren, – relaties en – systemen, in het bijzonder in de duingraslanden van Voorne. (With summary). Thesis Utrecht, 170 pp.

Maarel, E. van der 1969. On the use of ordination models in phytosociology. Vegetatio 19: 21–46.

Maarel, E. van der 1972. On the transformation of cover – abundance values in phytosociology. Report Botanical Laboratory, Nijmegen, 12 pp.

Maarel, E. van der 1972a. Ordination of plant communities on the basis of their plant genus, family and order relationships. In E. van der Maarel & R. Tüxen (ed) Grundfragen und Methoden der Pflanzensoziologie. Ber. Int. Symp. Rinteln 1970, p. 183–192. Junk, Den Haag.

Maarel, E. van der 1979. Multivariate methods in phytosociology with reference to the Netherlands. In M.J.A. Werger (ed.) The science of vegetation, p. 161–225. Junk, The Hague.

Maarel, E. van der & L.F.M. Fresco. 1975. Zusammenhänge zwischen Vegetation und Substrat erläutert an Ordinationsmodellen. In: Vegetation und Substrat. Ber. Int. Symp. Rinteln 1969, p. 233–253. Cramer, Vaduz.

Maarel, E. van der, J.G.M. Janssen & J.M.W. Louppen. 1978. TABORD, a program for structuring phytosociological tables. Vegetatio 38: 143–156.

Maarel, E. van der, L. Orlóci & S. Pignatti. 1976. Data – processing in phytosociology, retrospeet and anticipation. Vegetatio 32: 65–72.

Meyer Drees, E. 1949. Combined taxation and presence in analysing and comparing association tables. Vegetatio 2: 43–46.

Moore, J.J. 1966. PHYTO. Re-arranging a phytosociological array according to the principles of Braun-Blanquet. Programs in Fortran II. Mimeogr. Paper Dublin. 4 pp.

Mueller-Dombois, D. & H. Ellenberg. 1974. Aims and methods of vegetation ecology. Wiley, New York, XXX + 547 pp.

Noy-Meir, I. 1973. Data transformation in ecological ordination. I. Some advantages of non – centering. J. Ecol. 61: 329–341.

Noy-Meir, I.D. Walker & W.T. Williams. 1975. Data transformations in ecological ordination. II. On the meaning of data standardization. J. Ecol. 63: 779–800.

Orlóci, L. 1978. Multivariate analysis in vegetation research. 2nd ed. Junk, The Hague. IX + 451 pp.

Noy-Meir, I. & R.H. Whittaker. 1978. Recent developments in continuous multivariate techniques. In R.H. Whittaker (ed), Ordination of plant communities, p. 337–378, Junk, The Hague.

Roskam, E. 1971. Programme ORDINA: Multidimensional

ordination of observation vectors. Programme Bull. 16, Psychology Lab. Nijmegen, 8 pp.
Schmid, P. & N. Kuhn. 1970. Automatische Ordination von Vegetationsaufnahmen in pflanzensoziologischen Tabellen. Naturwissenschaften 57: 462.
Schwickerath, M. 1931. Die Gruppenabundanz (Gruppenmächtigkeit); ein Beitrag zur Begriffsbildung in der Pflanzensoziologie. Englers Bot. Jahrb. 64: 1–16.
Schwickerath, M. 1938. Neue Beiträge zur Kenntnis der Gruppenmächtigkeit der Assoziation. Englers Bot. Jahrb. 68: 497–514.
Schwickerath, M. 1940. Die Artmächtigkeit. Fedde Rep. Beih. 121: 48–52.
Segal, S. & V. Westhoff. 1959. Die vegetationskundliche Stellung von Carex buxbaumii in Europa, besonders in den Niederlanden. Acta Bot. Neerl. 8: 304–329.
Shimwell, D.W. 1971. The description and classification of vegetation. Sidgwick & Jackson, London, XIV + 322 pp.
Sissingh, G. 1950. Onkruid-associaties in Nederland (With French summary). Thesis Wageningen, 224 pp. + bijl.
Smart, P.F.M., S.E. Meacock & J. M. Lambert. 1976. Investigations into the properties of quantitative vegetational data. II. Further data type comparisons. J. Ecol. 64: 47–78.
Tüxen, R. & H. Ellenberg. 1937. Der systematische und ökologische Gruppenwert. Ein Beitrag zur Begriffsbildung und Methodik der Pflanzensoziologie. Mitt. Flor.-Soz. Arbeitsgem. 3: 171–184.
Westhoff, V. 1947. The vegetation of dunes and salt marshes on the Dutch islands of Terschelling, Vlieland and Texel Thesis Utrecht, 131 pp.
Westhoff, V. & E. van der Maarel. 1978. The Braun-Blanquet approach. 2nd ed. In: R.H. Whittaker (ed). Classification of plant communities, p. 287–399. Junk, The Hague.
Williams, W.T. & J.M. Lambert. 1959. Multivariate methods in plant ecology. I. Association analysis in plant communities. J. Ecol. 47: 83–101.
Wishart, D. 1975. CLUSTAN 1c user manual. Computer Centre University College London, 124 pp.

Accepted 20 November 1978