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# A NUMERICAL CLASSIFICATION OF EUROPEAN SPARTINA COMMUNITIES*

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## Introduction

This contribution is based on two earlier internal reports (Kortekaas & Van der Maarel 1972, 1973): the first one presented at the Colloquium during the Symposium of the International Society for Vegetation Science, at Todenmann near Rinteln, March, 1972; the second at the conference of the Working Group for Data-Processing, Prague, September 1973.

The project described here is aimed at comparing a classical syntaxonomy of *Spartina* communities with the results of numerical treatments. Concurrently with the numerical analyses by W. M. Kortekaas and E. van der Maarel at Nijmegen, W. G. Beeftink at Yerseke, demonstrated and discussed the outcome of the classical approach which he published (Beeftink & Géhu 1973) as the first volume of the new Prodrome series for the European plant communities 'Prodromus der europäischen Pflanzengesellschaften' (Prodrome des Groupements végétaux d'Europe). About 500 relevés were analysed and four associations with sixteen subassociations in one alliance, one order and one class, *Spartinetea maritimae*, were distinguished.

The idea of our approach was to produce a numerical classification on the basis of a set of relevés overlapping as much as possible with the set used for the Prodrome study.

## Material and methods

The Nijmegen material used in the analysis consists of 576 relevés with at least one *Spartina* species with a Braun-Blanquet combined estimation value of at least 1 in each. This material has been selected from about 2200 relevés, stored on punched cards and computer tapes; 1300 forming selection a (see Van der Maarel, Orlóci & Pignatti 1976) and 900 stored at Nijmegen from additional, mostly unpublished *Spartina* relevé tables. It should be noted that it was obvious from the beginning that many relevés thus chosen may not normally be considered as a '*Spartinetum*'. Nevertheless, the sample facilitates establishment of boundaries between the *Spartina* communities towards other communities. The lower Braun-Blanquet value 1 was effective to reduce the total size of the selection.

The relevés were treated with various methods of the CLUSTAN program developed and described by Wishart (1969). This program is accessible on disc via the IBM 370-158 computer of the University of Nijmegen. The method RELOC appeared most promising and will be briefly described here.

The objective of RELOC is a relocation of misclassified relevés within the initial clusters, which have to be specified by the user before the relocation process. These clusters may be the result of a random grouping of the original relevés or a preliminary classification. Each relevé is considered in turn and its similarities with all clusters are computed. A relevé removed from the initial cluster is attached to the one with which it has the highest similarity. A threshold minimum similarity value is chosen at which a relevé is fused with a cluster. The program achieves optimum clustering depending on the homogeneity of the basic material, the number of clusters demanded, and the

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threshold value. In combination with the relocation process, hierarchical fusions may be performed.

The similarity measure used by us is the similarity ratio (Wishart 1969),

$$S = \frac{\sum x_i y_i}{\sum x_i^2 + \sum y_i^2 - \sum x_i y_i}$$

where $x_i$ is a score of species $i$ in relevé $x$ and $y_i$ a score of species $i$ in relevé $y$.

This measure is rather similar to the Jaccard index and could be considered as a quantitative analogue of the qualitative Jaccard formula,

$$S_J = \frac{c}{a+b+c}$$

In the Jaccard formula, $c$ is the sum of the lesser values for each species. According to our experience values of $S$ are about 20% higher than the quantitative values of $S_J$, and about 10% higher than the equally similar Sørensen values.

$$S_s = \frac{2c}{a+b}$$

We started RELOC with 34 clusters, obtained from preliminary CLUSTAN analyses, viz. HIERAR and Group analysis. A threshold value of 0.70 seemed reasonable considering that average similarity of not more than 0.80 may be found between samples of one and the same stand (cf. Curtis 1959). After the first relocation cycle 62 relevés could not be assigned to any cluster because of the threshold value adopted. They were placed in a remainder group. These remainder relevés were then considered as potential noda for additional clusters. From this set 49 clusters were obtained after fusion on the threshold level, i.e. 0.70. Together with the 34 initial clusters they formed a set of 83 clusters for the next relocation cycle. During this cycle some relocation took place, whilst no relevés were placed in a remainder group.

Then a series of fusions and subsequent relocations were performed. At the 81 cluster phase one relevé was placed in the remainder group. Since we wished each relevé to be classified in a cluster that is homogeneous at the chosen level, i.e. 0.70, the procedure was stopped at that phase and the result was thus a system of 82 clusters.

To obtain an idea of the hierarchical structure of the clusters, an agglomerative clustering was performed. In the CLUSTAN set, program HIERAR is available for this purpose. Since this program would take too much computer time, a complete linkage analysis (cf. Sokal & Sneath 1963) was performed long-hand. This clustering was terminated at the 0.30 similarity level where only
clusters were left.

## Interpretation of the clusters

### *Selection of Spartineta clusters*

From an inspection of the clusters it appeared that nea
all clusters showed a constant occurrence of one or mc
species and were thus easily to characterise. Then so
provisional rules were set up in order to select the *Spartin*
clusters. (These rules are entirely arbitrary and they ha
no relation to the numerical procedure. They do rel
though to the problem of delimitating species-poor pla
communities with dominance or sometimes codominar
of species).

1. At least one *Spartina* species should constantly occur
   the relevés with a minimum Braun-Blanquet value o
2. If one constant companion species occurs, the Bra
   Blanquet value of *Spartina* should exceed the value
   this species with at least 2 scale values.
3. If two or more constant companions occur, the Brau
   Blanquet value of *Spartina* should exceed the value of th
   species with at least 2 scale values.

Based on the use of these rules 20 clusters were rec
nised. A new dendrogram of these 20 clusters has be
constructed (Fig. 1). The other clusters were removed fr
consideration. Within the selected groups two categor
of clusters may be distinguished:

1. Clusters in which all relevés conform to one of the abo
   mentioned rules.
2. Clusters in which one of the rules can be applied t
   portion of the relevés.

In the synoptic Tables as presented in Tables 1–3, t
relevés which do not satisfy the rules were omitted. T
three *Spartina patens* clusters have also been left out of t
general dendogram and the synoptic tables, because t
of them represent transitional types and the remaini
typical cluster would contain only three relevés.

### *Syntaxonomical ranking*

The 20 clusters were syntaxonomically ranked accord
to the following considerations: It is reasonable to ex
a certain relation between the homogeneity level withi
cluster and the syntaxonomical rank that cluster sho
obtain. Ellenberg (1956) stated that the average simila
of relevés within an association is between 0.25 and
and that subunits should be distinguished on levels
0.50. These are Jaccard values. According to our exp

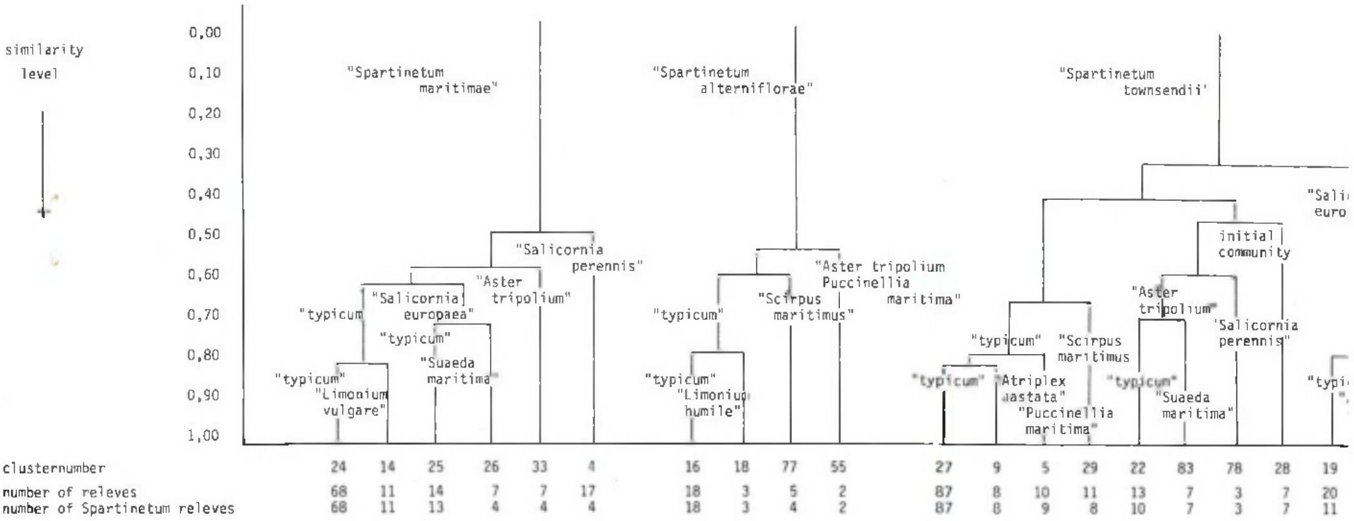

Fig. 1. Agglomerative clustering of *Spartina* communities. Resulting clusters are interpreted in terms of the existing syntaxonomical hierarchy. See text.

ence the Sørensen values are 10% higher, in which case the interval would be 0.30–060. Sørensen (1948) found that his grassland groups on a similarity level between 40 and 50 (Sørensen values) corresponded with the alliance level. Looman & Campbell (1960) calculated Sørensen values of > 0.70 within subunits belonging to one grassland association, whereas values between subunits were all <0.50. Hofmann & Passarge (1964) presented group affinity values between various woodland associations and subassociations. Within associations values were mostly > 0.60, between typical subassociations of related associations values tended to be between 0.30 and 0.50. Raabe (1952) obtained affinity values (Kulcziński coefficient) between associations and alliances of weed, salt marsh and alpine communities. Within-alliance values were between 0.40 and 0.50, between-alliance values were 0.20 to 0.40. Within salt marsh associations values varied more widely, from 0.30 to 0.80, and here the influence of geographical distance between local representatives of associations was evident. These and other similarity level indications have been discussed by Westhoff & Van der Maarel (1973).

For our purpose we take values between 0.40 and 0.60 as association level, values between 0.61 and 0.70 as subassociation level and values from 0.71–0.80 as variant level. Of course, these values are again arbitrary; the main purpose of the ranking is to facilitate a direct comparison with the units of the Prodrome. We shall therefore speak of associations, subassociations and variants, but use quotation-marks to indicate that they were derived by our scheme based on the given similarity levels.

Fig. 1 shows three groups of clusters, characterised by respectively *Spartina maritima*, *Spartina alterniflora* and *Spartina townsendii*. They have been considered as representatives of three associations, '*Spartinetum maritimae*', '*Spartinetum alterniflorae*' and *Spartinetum townsendii*'. The three groups will be discussed. One should realise that:

1. At present no algae have been recorded on punched cards. Thus in our study algae could not be used as differential taxa.
2. At present no subspecies have been recorded on punched cards and thus used in characterizing the units.

'*Spartinetum maritimae*'

General structure of the dendogram:

Cluster 24 represents the central cluster here; clusters 24 and 14 are fused at a similarity level of 0.81, 25 and 26 at 0.69; clusters 24, 14, 25 and 26 are fused at 0.61 while cluster 33 and 4 remain separated down to below the 0.61 level.

Syntaxonomical interpretation:

The following interpretations are based upon the rules presented above for the clusters identified by numbers:

24 'subassociation *typicum*', 'variant *typicum*'*

14 'subassociation *typicum*', 'variant with *Limonium vulgare*'

* We use the indication typicum here, although we realise that we usually deal with 'a-typical' species-poor forms, which should rather we called 'inops' (cf. Westhoff & Van der Maarel 1973).

Table 1. Synoptic table of *Spartina maritima* communities on 'variant' and 'subassociation' level. See Fig. I for interpretation of clusters. For each species % presence and range of Braun-Blanquet values in each cluster is indicat

| | "variant" level | | | | | "subassociation" level | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cluster | 24 | 14 | 25 | 26 | 33 | 4 | 24-14 | 25 | 26 | 33 | 4 | Total |
| *Spartina maritima* | $100^{2-5}$ | $100^{2-5}$ | $100^{3-5}$ | $100^{3-4}$ | $100^{4-5}$ | $100^{4}$ | $100^{2-5}$ | $100^{3-5}$ | $100^{3-4}$ | $100^{4-5}$ | $100^{4}$ | $100^{2-5}$ |
| *Limonium vulgare* | $24^{+}$ | $100^{1-2}$ | $15^{+}$ | | | | $34^{+-2}$ | $15^{+}$ | | | | $28^{+-2}$ |
| *Salicornia fruticosa* | $7^{+-1}$ | $56^{r-2}$ | | | | | $14^{r-2}$ | | | | | $11^{r-2}$ |
| *Salicornia europaea* | $19^{+}$ | $9^{+}$ | $100^{1-2}$ | $50^{+-1}$ | $50^{+-1}$ | $50^{+}$ | $18^{+}$ | $100^{1-2}$ | $50^{+-1}$ | $50^{+-1}$ | $50^{+}$ | $32^{+-2}$ |
| *Spartina townsendii* | $15^{r-+}$ | | $8^{+}$ | $100^{1-2}$ | | | $13^{r-+}$ | $8^{+}$ | $100^{1-2}$ | | | $14^{r-2}$ |
| *Aster tripolium* | $9^{+}$ | $18^{+}$ | $8^{1}$ | | $100^{1-2}$ | $25^{+}$ | $10^{+}$ | $8^{1}$ | | $100^{1-2}$ | $25^{+}$ | $13^{+-2}$ |
| *Salicornia perennis* | | | | | | $100^{3}$ | | | | | $100^{3}$ | $4^{3}$ |
| *Puccinellia maritima* | $4^{+}$ | | $38^{+}$ | | $25^{+}$ | | $4^{+}$ | $38^{+}$ | | $25^{+}$ | | $9^{+}$ |
| *Halimione portulacoides* | $1^{+}$ | | $8^{+}$ | | | $50^{+}$ | $1^{+}$ | $8^{+}$ | | | $50^{+}$ | $5^{+}$ |
| *Suaeda maritima* | $6^{+-2}$ | | $15^{+}$ | | | | $5^{+-2}$ | $15^{+}$ | | | | $7^{+-2}$ |
| *Puccinellia palustris* | $7^{+-1}$ | $27^{+-1}$ | | | | | $16^{+-1}$ | | | | | $8^{+-1}$ |
| *Triglochin maritima* | | | $8^{+}$ | | | | | $8^{+}$ | | | | $1^{+}$ |
| *Juncus maritimus* | | $9^{1}$ | | | | | $9^{1}$ | | | | | $1^{1}$ |
| Number of relevés | 68 | 11 | 13 | 4 | 4 | 4 | 79 | 13 | 4 | 4 | 4 | 104 |

25 'subassociation with *Salicornia europaea*'
26 'subassociation with *Spartina townsendii*'
33 'subassociation with *Aster tripolium*'
4 'subassociation with *Salicornia perennis*'

Table 1 presents the synthetic data on the various subassociations and variants. It follows from this table that each of the syntaxonomic subunits is characterised by exactly one differential species. The subassociation with *Spartina townsendii* almost reaches the variant level. Should a lower similarity level such as 0.50 be used for the distinction sub-associations, two subunits would remain, the first including clusters 24, 14, 25, 26, 33 and the second including cluster 4. The first of these two units cannot be characterised, however, by a constant differential species and would then be called '*typicum*'. When a still lower level would be accepted, the whole dendrogram would represent one single subassociation with five variants.

'*Spartinetum alterniflorae*'

General structure of the dendrogram:

Cluster 16 is the central cluster; clusters 16 and 18 are fused at a level of 0.75; both cluster 77 and 55 remain separated below 0.61.

Syntaxonomical interpretation:

Based on the rules presented above, the following interpretations can be made for the clusters:

16 'subassociation *typicum*', 'variant *typicum*'
18 'subassociation *typicum*', 'variant with *Limonium humile*'
77 'subassociation with *Scirpus maritimus*'
55 'subassociation with *Aster tripolium* and *Puccinellia maritima*'

Table 2 presents the synthetic data for the four subunits; the subassociations are clearly characterised, the third o even by two constant differential species: *Aster tripoli* and *Puccinellia maritima*. Should the 0.50 similarity le be accepted for the subassociation level only one su association '*typicum*' would remain.

'*Spartinetum townsendii*'

General structure of the dendrogram:

Cluster 27 is the general cluster; clusters 27, 9 and 5 a fused at a similarity level of 0.82; clusters 27, 9, 5 and form one cluster at 0.69; clusters 22 and 83 are fused 0.70 and fused with 78 at 0.61; 28 is fused with clusters 83, 78 at 0.48; clusters 27, 9, 5, 29 form one group with 83, 78, 28 at 0.42; 12, 19 form an own group at 0.78 (clus 19 is close to 27, 9, 5); 12, 19 are fused with the large clus of 27, 9, 5, 29, 22, 83, 78, 28 at 0.34.

Syntaxonomical interpretation:

According to the established rules, we can make the follo ing interpretations:

27 'subassociation *typicum*', 'variant *typicum*'
9 'subassociation *typicum*', 'variant with *Atriplex hasta*
5 'subassociation *typicum*', 'variant with *Puccinellia maritima*'

Table 2. Synoptic table of *Spartina alterniflora* communities. See Fig. 1 and Table for further explanation.

| | "variant" level | | | | "subassociation" level | | | |
|---|---|---|---|---|---|---|---|---|
| Cluster | 16 | 18 | 77 | 55 | 16-18 | 77 | 55 | To |
| *Spartina alterniflora* | $100^{4-5}$ | $100^{3-4}$ | $100^{4-5}$ | $100^{4-5}$ | $100^{3-5}$ | $100^{4-5}$ | $100^{4-5}$ | 100 |
| *Limonium humile* | $6^{+}$ | $100^{1-2}$ | | | $19^{+-1}$ | | | 15 |
| *Scirpus maritimus* | | | $100^{2}$ | | | $100^{2}$ | | 15 |
| *Aster tripolium* | $28^{+-1}$ | $33^{+}$ | | $100^{1-2}$ | $29^{+-1}$ | | $100^{1-2}$ | 30 |
| *Puccinellia maritima* | $6^{+}$ | | | $100^{1-2}$ | $5^{+}$ | | $100^{1-2}$ | 11 |
| *Agrostis stolonifera* | | | | $50^{+}$ | | | $50^{+}$ | 4 |
| *Spergularia media* | | | | $50^{1}$ | | | $50^{1}$ | 4 |
| *Juncus maritimus* | | $33^{+}$ | | | $5^{+}$ | | | 4 |
| *Atriplex hastata* | | | | $50^{+}$ | | | $50^{+}$ | 4 |
| *Suaeda maritima* | | | | $50^{+}$ | | | $50^{+}$ | 4 |
| *Salicornia europaea* | | $33^{2}$ | | | $5^{2}$ | | | 4 |
| Number of relevés | 18 | 3 | 4 | 2 | 21 | 4 | 2 | 27 |

Table 3. Synoptic table of *Spartina townsendii* communities. See Fig. 1 and Table 1 for further explanation

| | "variant" level | | | | | | | | | "sutassociation" level | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cluster | 27 | 9 | 5 | 19 | 12 | 22 | 83 | 29 | 78 | 27-9-5 | 12-19 | 22-83 | 29 | 78 | Total | (28) |
| *Spartina townsendii* | $100^{2-5}$ | $100^{5}$ | $100^{4-5}$ | $100^{3-5}$ | $100^{4-5}$ | $100^{3-5}$ | $100^{2-5}$ | $100^{4-5}$ | $100^{4-5}$ | $100^{2-5}$ | $100^{3-5}$ | $100^{3-5}$ | $100^{4-5}$ | $100^{4-5}$ | $100^{2-5}$ | $100^{1-5}$ |
| *Atriplex hastata* | $14^{r-+}$ | $100^{1-3}$ | $56^{+-1}$ | | | $50^{+}$ | $14^{+}$ | $75^{+-2}$ | | $23^{r-3}$ | | $35^{+}$ | $75^{+-2}$ | | $24^{r-3}$ | |
| *Puccinellia maritima* | $9^{r-+}$ | | $100^{1-2}$ | | $20^{+}$ | $20^{r-+}$ | $43^{+}$ | $25^{+-1}$ | | $17^{r-2}$ | $6^{+}$ | $29^{r-+}$ | $25^{+-1}$ | | $18^{r-2}$ | |
| *Salicornia europaea* | $16^{+}$ | | $11^{+}$ | $100^{1-2}$ | $100^{1-2}$ | $30^{r-+}$ | $86^{+-1}$ | | | $15^{+}$ | $100^{1-2}$ | $53^{r-+}$ | | | $27^{r-2}$ | $29^{+}$ |
| *Aster tripolium* | $13^{r-+}$ | $43^{+}$ | $33^{+-1}$ | $56^{r-+}$ | $100^{1-2}$ | $100^{1-2}$ | $76^{+-1}$ | $37^{r-+}$ | | $17^{+-1}$ | $69^{r-2}$ | $76^{+-2}$ | $37^{r-+}$ | | $32^{r-2}$ | $29^{+}$ |
| *Suaeda maritima* | $7^{+}$ | $14^{+}$ | $22^{+}$ | $56^{+}$ | $60^{+}$ | $10^{+}$ | $100^{1-2}$ | | | $9^{+}$ | $56^{+}$ | $47^{+-2}$ | | | $18^{+-2}$ | $14^{+}$ |
| *Scirpus maritimus* | $2^{r-+}$ | $14^{+}$ | $11^{1}$ | | | $20^{+}$ | | $100^{1-3}$ | | $4^{r-1}$ | | $12^{+}$ | $100^{1-3}$ | | $9^{r-+}$ | |
| *Salicornia perennis* | $1^{+}$ | | | | | | | | $100^{2}$ | $1^{+}$ | | | | $100^{2}$ | $3^{+-2}$ | |
| *Halimione portulacoides* | $7^{+-1}$ | | $11^{+}$ | $9^{1}$ | | $10^{1}$ | $71^{+-1}$ | | $33^{2}$ | $7^{+-1}$ | $6^{1}$ | $35^{+-1}$ | | $33^{2}$ | $10^{+-1}$ | |
| *Limonium vulgare* | $2^{+}$ | $29^{+}$ | | $9^{+}$ | | $10^{+}$ | $29^{+}$ | | | $4^{+}$ | $6^{+}$ | $18^{+}$ | | | $5^{+}$ | |
| *Triglochin maritima* | $2^{r-+}$ | $14^{+}$ | | | | $20^{r-+}$ | $14^{1}$ | | | $3^{r-+}$ | | $18^{r-+}$ | | | $4^{r-+}$ | |
| *Plantago maritima* | $1^{+}$ | | $11^{+}$ | | | $20^{+}$ | | | | $1^{+}$ | | $12^{+}$ | | | $2^{+}$ | |
| *Spergularia media* | | | | | | $10^{+}$ | | | | $1^{+}$ | | $6^{+}$ | | | $1^{+}$ | |
| *Glaux maritima* | $1^{+}$ | | | | | | | | | $1^{+}$ | | | | | $1^{+}$ | |
| *Spartina maritima* | $1^{r}$ | | | | | | | | | $1^{r}$ | | | | | $1^{r}$ | |
| *Agrostis stolonifera* | | | | | | $20^{+-1}$ | | | | | | $12^{+-1}$ | | | $2^{+-1}$ | |
| *Phragmites communis* | | | | | | | | $12^{r}$ | | | | | $12^{r}$ | | $1^{r}$ | |
| Number of relevés | 87 | 7 | 9 | 11 | 5 | 10 | 7 | 8 | 3 | 103 | 16 | 17 | 8 | 3 | 147 | 7 |

22 'subassociation with *Aster tripolium*', 'variant *typicum*'
83 'subassociation with *Aster tripolium*', 'variant with *Suaeda maritima*'
19 'subassociation with *Salicornia europaea*', 'variant *typicum*'
12 'subassociation with *Salicornia europaea*', 'variant with *Aster tripolium*'
29 'subassociation with *Scirpus maritimus*'
78 'subassociation with *Salicornia perennis*'
28 initial community of *Spartina townsendii*

The last cluster does not satisfy item 1 of the rules presented and cannot therefore be referred to as a '*Spartinetum*'. It nevertheless is still retained for comparison as initial cluster.

Table 3 presents the synthetic data for the ten subunits. Three out of four subassociations are well characterized, but the subassociation *asteretosum tripolii* is not entirely satisfying. Now the two clusters forming this subunit, 22 and 83, are fused at 0.61, almost the lower limit of subassociations. One should therefore consider these two clusters rather as subassociations, characterised by *Aster tripolium* and *Suaeda maritima* respectively.

At the subassociation level of 0.50 three subassociations would remain, but again the characterisation would then be less satisfactory: 27, 9, 5, 29 would form '*typicum*', and 22, 83, 78 would form a floristically loose grouping with *Aster tripolium* as its (weak) differential species. The group 12, 19 only fuses below 0.40 and would properly fall outside the association category. However, a large number of transitional relevés occur in this cluster, which caused the low fusion level. In its purified form the cluster would certainly qualify as an association.

## Comparison of clusters with syntaxonomical units of Spartinetea maritimae in the Prodrome

### *The Prodrome's system*

The Prodrome treats four associations in one alliance *Spartinion maritimae* (order *Spartinetalia maritimae*, class *Spartinetea maritimae*). The associations are: *Spartinetum maritimae*, *Limonio-Spartinetum maritimae*, *Spartinetum alterniflorae* and *Spartinetum townsendii*. The *Limonio-Spartinetum* is not found in the Nijmegen system. This N. Adriatic association is characterised only by *Limonium vulgare* ssp. *serotinum* as differential taxon. These subspecies occurs in mediterranean *Spartinetum maritimae*, while in the atlantic *Spartinetum maritimae* the ssp. *pseudo-limonium* can be found. Up till now no taxa below the rank of species have been distinguished in the storage files of the Working Group, and for that reason no clusters with the subspecies serotinum could be expected. It should however be doubted, that a cluster would separate on the association level. According to Pignatti (personal communication) the occurrence of this *Limonium* taxon in *Spartina* communities is only marginal. Thus both on numerical and local phytosociological grounds the existense of the association *Limonio-Spartinetum maritimae* could be questioned.

### *Spartinetum maritimae* (Table 4)

In both systems five subassociations are found of which four are similar. The subassociation *salicornietosum fruticosae* is not represented in the Nijmegen system while the '*spartinetosum townsendii*' is not distinguished by the Prodrome. The '*spartinetosum townsendii*' cluster fuses at

Table 4. Comparison of numerical system of *Spartina maritima* communities with syntaxonomical system of *Spartinetum maritimae*

| Nijmegen / Prodrome | "Syn-taxa" | "subassociations" | "typical" | | | *"salicornietosum tripolii"* | *"asteretosum tripolii"* | *"salicornietosum perennis"* | | *"spartinetosum townsendii"* | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | "variant" | "typical" | *"Limonium vulgare"* | | | | | | | |
| Syntaxa | Mean species number | Total species number | | 1,9<br>10 | 2,1<br>11 | 2,7<br>9 | 2,8<br>4 | 3,3<br>5 | | 2,5<br>3 | 2,3<br>13 | Mean species numbe<br>Total species numb |
| typical* | 1,3 | 6 | | 68<br>66 | 11 | | | | | | | |
| *salicornietosum strictae** | 2,7 | 6 | | | | 13<br>18 | | | | | | |
| *asteretosum tripolii* | 3,0 | 6 | | | | | 4<br>16 | | | | | |
| *salicornietosum perennis* | 3,1 | 9 | | | | | | 4<br>16 | | | | Number of relevés |
| *salicornietosum fruticosae* | 2,6 | 3 | | | | | | | 5 | 4 | | |
| Total | 2,5 | 9 | | | | | | | | | 104<br>121 | |

* Division of these subassociations into variants are based on algae species. At present no algae have been recorded on punched cards. Thus in our study algae could not be used as differential taxa.

the 0.61 level with clusters 24, 14, 25 and is almost a variant. The 'variant with *Limonium vulgare*' within the 'subassociation *typicum*' is only present in the Nijmegen system. The relevés of this unit originate from the N. Adriatic and have been assigned to the *Limonio-Spartinetum maritimae maritimae* in the Prodrome.

Comparison of the synthetic table on page 8 of the Prodrome with our Table 1 indicates (see our Table 4) that the mean species numbers in both systems are the same, both in the total association and in the subassociations, except in the subassociation *typicum*, where the Nijmegen value is higher; the total species numbers in the tables are 6 (Prodrome) and 10 (Nijmegen): the total relevé numbers are about equal when we compare our material with the table in the Prodrome manuscript. In the final version of the Prodrome nearly 30 new relevés were taken into account (most of them from the 1972 excursion to Portugal of the International Society for Vegetation Science and most of them assigned to subassociation *typicum*). This makes a direct comparison more difficult. Still one conclusion is permitted: when we compare our cluster 24 with the *typicum* from the Prodrome (our cluster 4 contains most of the relevés with *Limonium vulgare* ssp. *serotinum* and not considered) we find about equal relevé numbers, ( and 66. However, 28 Prodrome relevés were new, i.e. the were added to the Prodrome set later on, whilst the numb of relevés assigned to this syntaxon in the Prodrom manuscript table was only 49. This may be explained l the deletion of relevés during the completion of the Pr drome in order to purify the synthetic table. Interesting enough the results of both attempts are still very simila

### *Spartinetum alterniflorae* (Table 5)

There are three corresponding subassociations, *typicu asteretosum tripolii* and *scirpetosum maritimae*, of whi the subassociation typicum has similar subdivisions both systems. The *scirpetosum maritimae* is only su divided by the Prodrome into the variants *typicum* ai *Atriplex hastata*. The third subassociation is characteris by one differential species in the Prodrome and by two the Nijmegen system – *Aster tripolium* (Prodrome) ai *Aster tripolium* plus *Puccinellia maritima* (Nijmegen) r spectively. In the Prodrome *Puccinellia maritima* is us to characterise a variant within the *asteretosum tripol*

Table 5. Comparison of numerical system of *Spartina alterniflora* communities with syntaxonomical system of *Spartinetum alterniflorae*

| Nijmegen "Syn-taxa" / Prodrome | | | | "typical" | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| "subassociation" | | | | | | "*Aster tripolium* and *Puccinellia maritima*" | "*scirpetosum maritime*" | Total | |
| "variant" | | | | "typical" | "*Limonium humile*" | | | | |
| subassociations | variants | Mean species number | Total species Number | 1,4 | | 5,0 | 2,8 | 1,9 | Mean species number |
| | | | | 6 | | 7 | 2 | 11 | Total species number |
| typical | ( - typical<br>( - with Limonium humile | 1,1 | 3 | 22 / 21 | | | | | |
| *asteretosum tripolii* | ( - typical<br>( - with *Puccinellia maritima* | 3,0 | 7 | | | 8 / 2 | | | Number of relevés |
| *scirpetosum maritimae* | ( - typical<br>( - with *Atriplex hastata* | 3,0 | 5 | | | | 5 / 4 | | |
| Total | | 2,3 | 10 | | | | | 35 / 27 | |

The Nijmegen unit has only two relevés. Comparison of the origin of the relevés shows that a number of relevés in our cluster 16 ('typical subassociation', 'typical variant') must have been classified as subassociation *asteretosum* in the Prodrome. The numerical clusters 16 and 55 seem to be not well-distinguished indeed.

The explanation of discrepancies is easy, but requires some additional information on the method described in part 1 of this contribution. The test set of 576 relevés has been subjected to various clustering techniques. (The results of all the treatments are not relevant for the present study and will not be discussed here). In order to obtain a more realistic comparison between techniques bound to presence-absence data (e.g. association analysis according to Williams & Lambert 1959) and quantitative approaches the combined estimation values *r* and + of all species have been omitted. On the whole this seems reasonable when dominants like the *Spartina* species characterise a plant community. In the case of the *Spartinetum alterniflorae asteretosum* most of the relevés which were differently classified contained *Aster tripolium* with Braun-Blanquet value + only.

The mean species number in the total association is somewhat higher in the Prodrome system (see Table 5). The subassociations have similar species numbers except the second one (Prodrome 3.0, Nijmegen 5.0). Total species numbers are for the association 10 (Prodrome) and 11 (Nijmegen); for the subassociations *typical* 3 (Prodrome) and 6 (Nijmegen), *asteretosum tripolii* 7 (both systems), *scripetosum maritimae* 5 (Prodrome) and 2 (Nijmegen). Again the differences are not too great.

*Spartinetum townsendii* (Table 6)
Both systems distinguish similar subassociations. In the subassociation *typicum* corresponding variants are found. However, the division of the *salicornietosum strictae* and the *asteretosum tripolii* is different in the two systems. The *salicornietosum strictae* from the Prodrome does not have variants, the corresponding cluster of the Nijmegen system has a variant with *Aster tripolium*, while the *asteretosum tripolii* of the Prodrome has a variant with *Salicornia europaea*. In the Nijmegen subassociation *asteretosum Suaeda maritima* is used to characterise a variant.

It is interesting to remark that the subassociation *asteretosum* did not appear in an earlier draft of the Prodrome and was apparently distinguished on the suggestion of the results of the numerical approach. This is thus a first example how a numerical classification can

Table 6. Comparison of numerical system of *Spartina townsendii* communities with syntaxonomical system of *Spartinetum townsendii*

| Prodrome \ Nijmegen | | "Syntaxa" "subassociations" | "variant" | "typical": "typical"<br>"Puccinellia maritima"<br>"Atriplex hastata" | "salicornietosum strictae": "typical"<br>"Aster tripolium" | "asteretosum tripolii": "typical"<br>"Suaeda maritima" | "Salicornietosum perennis" | "scirpetosum maritimae" | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| subassociations | variants | Mean species number | Total species number | 2,0<br>15 | 3,4<br>7 | 4,3<br>13 | 2,7<br>3 | 3,5<br>6 | 2,6<br>17 | Mean species numbe<br>Total species numl |
| typical | ( - typical<br>( - *Puccinellia maritima*<br>( - *Atriplex hastata* | 1,3 | 5 | 89<br>9<br>7<br>100 | | | | | | |
| *salicornietosum strictae* | | 2,2 | 5 | | 11<br>5<br>47 | | | | | |
| *asteretosum tripolii* | ( - typical<br>( - *Salicornia europaea* | 3,4 | 7 | | | 10<br>7<br>74 | | | | Number of relevés |
| *salicornietosum perennis* | | 2,8 | 6 | | | | 3<br>8 | | | |
| *scirpetosum maritimae* | | 3,4 | 5 | | | | | 8<br>17 | | |
| Total | | 2,6 | 9 | | | | | | 147<br>246 | |

indicate syntaxa hitherto not recognised in classical treatments.

The mean species numbers at the association level are equal (see Table 6). At the subassociation level only in the two last subassociations are these values similar; while the first three have higher values in the Nijmegen system, especially the *salicornietosum strictae* and the *asteretosum tripolii*.

The total species number of the typical subassociation is 5 for the Prodrome and 15 for the Nijmegen system. This set contains 51 relevés with 1 species, 25 relevés with 2 species, 15 relevés with 3 species, so that there are 12 relevés with more than three species, leading to the difference in total species number. The relevé number is about equal for both systems. Only few relevés have been added to the original Prodrome manuscript table.

For the *salicornietosum strictae* the total species numbers are 5 (Prodrome) and 7 (Nijmegen). The Prodrome has 31 relevés more than Nijmegen, most of which were already present in the original manuscript table.

In the *asteretosum tripolii* the total species number is 7 (Prodrome) and 13 (Nijmegen), while the Prodrome has 57 relevés more than Nijmegen. Comparison of the two systems is rather difficult. In the original version of the Prodrome table this syntaxon was not distinguished remark above).

The total species number for the *salicornietosum pere* is 6 (Prodrome) and 3 (Nijmegen), for the *scirpeto maritimae* 5 (Prodrome) and 6 (Nijmegen). For t syntaxa the Prodrome used more relevés than Nijme The total relevé number at the association level is ab 100 relevés higher in the Prodrome.

*Remarks on the Spartina patens clusters*

The Prodrome has not taken up *Spartina patens* c munities in the *Spartinetea maritimae*. The reason that is as follows. The *Spartinetea maritimae* were delim by the Prodrome authors so as to have only those *Spar* taxa as character-taxa for the lower syntaxa which bel to Mobberley's (1956) taxonomic group II. *Spartina pa* is not assigned to that group. In our study we only seven *Spartina patens* relevés, spread over three sı clusters:

Cluster 17: '*typicum*', consisting of three relevés. M species number is 5.3 and total species number 11. F *Spartina patens* occur with Braun-Blanquet value 5. *Ph mites communis* is present in all relevés (+ to 2).

Cluster 36 and 35: both have two relevés with m species number 6.5 and 12 respectively. Total species number is 9 and 14. Cluster 36 and 35 fuse at the 0.68 level and they fuse with '*typicum*' at 0.52. In these two groups *Phragmites australis* (+), *Juncus maritimus* (2 to 3) and *lachenalii* (+ to 1) occur in all relevés, whereas the last cluster also contains species of the *Plantaginion crassifolii* as *Linum maritimum*, *Centaurium tenuiflorum* and *Plantago crassifolia*. Note that the Prodrome mentions the penetration of *Spartina patens* in some indigenous communities of the West Mediterranean.

## Discussion

The procedure described in this paper leads to a hierarchical system of vegetation units which can be easily described by constant differential species and compared with each other as to their homogeneity level. The procedure for the recognition of syntaxonomical units, i.e. 'associations', 'subassociations' and 'variants', is admittedly an arbitrary one and it demonstrates the advantages of continuous involvement of the investigator in the classification and it shows a specific and effective use of the computer in automating parts of the job.

The present syntaxonomical system does not include a general rule for the distinction of subassociations and variants. The system has however the advantage that the lower rank units are established in a general and reproducible procedure. The reason for ranking in a syntaxonomical system could have been a variation in the weighting of differential species. This weighting could have synsystematical or synecological reasons, e.g. *Salicornia europaea* is an association character species, therefore a subassociation *salicornietosum* might be considered of more validity than one with *Aster tripolium*. However, we do not recognise any justification for such a different weighting, nor did we find any general motivation for it in textbooks. In fact we think the distinction of lower units proceeds intuitively. At least for the *Spartinetea* the levels chosen here for the subassociation and variant categories seem to be realistic.

We did not consider the difficult problem of higher synsystematical units in *Spartineta*. According to our findings the three associations are floristically discontinuous and should properly be termed classes of their own. However, problems such as the introduction of *Spartina alterniflora* and *townsendii*, which cannot be discussed in the present contribution, should be considered with due weight in a general approach to the syntaxonomy of the *Spartineta*.

The overall similarity between the system of European *Spartina* communities as developed in the Prodrome and the numerical classification system of Nijmegen is obvious. This may be considered encouraging for both approaches. The advantage of the numerical approach is no doubt its easier comprehensibility. Species numbers in the numerical units are slightly higher on the average. This could be understood in such a way that the Prodrome units may have been purified by deleting relevés with additional species. The numerical units are less 'pure', but they reflect the natural variation in the syntaxa in a better way. A disadvantage of the deletion of atypical relevés is that one cannot determine what is considered impure, if the deleted relevés are not presented.

With the help of the numerical approach it is worth trying to fix levels of similarity for the various hierarchically coherent lower units such as the variants and subassociations. It remains to be seen whether such levels should vary in different kinds of plant communities. In conclusion we may state that this study has shown perspectives for a more general use of numerical methods in syntaxonomy, which may be indicated as numerical syntaxonomy (Westhoff & Van der Maarel 1973).

## Summary

The classical syntaxonomical treatment of the European *Spartina* communities as published in the series Prodrome of the the European plant communities, is compared with the results of a numerical treatment, based on largely the same set of relevés. 576 relevés, selected from the total salt marsh data set were subjected to agglomerative clustering with relocation with the similarity ratio as similarity measure. The resulting numerical system was compared with the syntaxonomical hierarchy. The correlation between both systems is close. The numerical units are slightly more heterogeneous because no purification occurred, which implies relevés to be left out of consideration. One new syntaxon, *Spartinetum townsendii asteretosum tripolii*, could be suggested from the results of the numerical treatment. Perspectives for the development of a numerical syntaxonomy are stressed.

## Zusammenfassung

Die klassische syntaxonomische Bearbeitung der europäischen *Spartina* Gesellschaften, wie im Prodromus der

europäischen Pflanzengesellschaften veröffentlicht, wird mit den Ergebnissen einer numerischen Bearbeitung verglichen, und zwar auf Basis eines etwa gleichen Aufnahmematerials. 576 Aufnahmen, aus dem gesammten Salzwiesenmaterial entnommen, wurden mit einem agglomerativen Schwarm-Verfahren auf Basis der similarity ratio bearbeitet. Das resultierende numerische System wurde mit der syntaxonomischen Hierarchie verglichen. Der Zusammenhang zwischen beiden Systemen ist gross. Die numerischen Einheiten sind etwas heterogener, weil keine Tabelle-Bereinigung stattfand und daher Aufnahmen ausser Betracht gelassen wurden. Ein neues Syntaxon, *Spartinetum townsendii asteretosum tripolii* konnte aus den Ergebnissen der numerischen Bearbeitung abgeleitet worden. Die Perspektive für die Entwicklung einer numerischen Syntaxonomie werden betont.

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