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GROUPS OF ASSOCIATED SPECIES IN THE PHYTOPLANKTON OF THE CARIBBEAN SEA (NE OF VENEZUELA)

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INTRODUCTION

This work results from the confluence of two programs of investigation and, naturally, from a common interest in ecological problems. The Institute of Forrestry and Plant Biology had utilized, besides other methods, the analysis of principle components of correlation matrices for the study of vegetation and have at their disposal adequate programs for the treatment of a great volume of data. For its part, the Institute of Fishery Investigations is interested in very similar problems of classification, standardization and calculation, and has collected a large quantity of data on the cell density of different species in the plankton and environmental factors. Among these, a series relating to the sea near the Antillies appeared very adequate for trying a test, for the great quantity of samples which it includes and the extensive range of localities, dates and depths from which said samples come.

Aside from the interest that it represented in elaborating some concrete data for obtaining information of obvious value and perhaps usable for practical ends, the application of the techniques presently used for higher vegetation to the samples of phytoplankton had a methodological and experimental interest. In addition to the possible differences owing to the nature of the data, the wide margin of environmental conditions in which these were obtained made interesting the application of methods that up to now has only been tried for much more restricted samples.

MATERIALS AND METHODS

The results of counting, in an inverted microscope, the phytoplankton cells contained in 1144 samples of water, obtained in an area NE of Venezuela have been utilized. The area studied is presented in figure 1, in which in addition, sketches a subdivision of the same in subregions, fundamentally attending to the hydrographical characteristics. This material was obtained as part of a program of investigation of the Station for Marine Investigations of Margarita (Venezuela). The tables with the composition of the phytoplankton, accompanied by other information of interest, were delivered to that center for its publication in the Reports of the La Salle Society of Natural Sciences, of Caracas. The samples represented plankton from the diverse depths which could be encountered in the zone of study and were obtained in all the seasons of the year.

The distributions of the cell densities of a like species in the different samples, are not normal. Nevertheless, they approach normality after its logarithmic transformation, which is normal and ordinary in all the enumerations of data of phytoplankton. For all the calculations transformed data was used, by means of the expression $\ln(1 + x)$, in which x is the number of cells (not colonies) for 100 ml of water. Starting from these transformed data the correlation matrix between species was calculated, utilizing the IBM 7070 calculator of the Center for Calculus of the Higher Council of Scientific Investigations. The total number of species was about

300, but for limitations of the capacity of the calculator only 81 species were taken into consideration. This reduction is less than a third of the original total of species was made eliminating the very rare, whose presence might be most fortuitious or those in which there were confusions or foreseeable errors of identification, just as others probably not tainted by any of these faults. Nevertheless, *Nitzschia* <<*delicatissima*>> might contain different forms, whose identification had required the use of the electron microscope, and *Peridinium* <<*trochoideum*>>possibly is not a homogenous entity either. Naturally, this selection of species assumed a series of subjective decisions which, aside from this, are not the only ones in the treatment of the problem. It is considered, nevertheless, that the elimination of rare species can have a benificial effect on the results, as it will be seen further on in treating the null values or << zeros >> and their foreseeable effects in the interpretation.

The matrix of the 3240 correlation coefficients, which we did not reproduce for its length and for its relative interests, was examined by different procedures which are described later and the analysis of its prinvipal components (Ralston and Wilf, 1960) was accomplished utilizing the same calculator.

Due to the high number of degrees of freedom, it does not make sense to speak of the levels of significance of the correlation coefficients encountered. Employing the usual approximation, the valuesoof r higher than 0.082 corresponds to $p < 0.01$, those higher than 0.104 to $p < 0.001$ and those higher than 0.182 to $p < 0.00005$.

OBJECTIVES PURSUED AND THEIR LIMITATIONS

Although the first statement of the study referred to the classification or arrangement of the samples and to search for the relations between groups of samples of similar composition and the corresponding conditions of the medium, the great quantity of samples examined overwhelmed our means. It was not possible to apply the programs available or utilized on other occasions for representing the different samples in a Cartesian square.

On the other hand, to obtain a classification of the samples was not too desirable. It was preferable to develop critera for the << future >> arrangement of samples while these were being analyzed.

Inevitably, we finally get to a study of the association between species and the definition of groups of associated species. These species can be called characteristic species or, if one wants, indicators. In their function it is imaginable to propose a method for automatically classifying new samples while these were being analyzed. The same groups of species, in their sense of << indicators >>, can offer great interest from the hydrographical point of view, by detecting or verifying movements of the water. For this reason, the elaboration of the data was centered on the study of the association between species.

The application of automatic methods, facilitated by the employment of computers, to the study of communities is up to date and obviously is of interest. Probably it is indespensible when one works with very extensive material and can signify a certain purpose, especially necessary, when different persons collaborate in a common project. But perhaps the major advantage that the machines represent in the progress of ecology, is that it compels one to fragment and to expose with clarity the reasoning followed in the course of any process of classification or typification. Nevertheless we hold certain reservations with regard to the fitness to the reality of the mathmatical models proposed heretofore, which occurs to us as an exceedingly unpolished notion. Its utilization can be considered as an interesting experiment which has the significance of a preliminary step in a process of elimination and approximation. Two criticisms of a very general type can be formulated to the methods in use and, naturally, are quite applicable to the present work.

1. The study of the association between species is normally made by correlation or regression, extracting them from its spacial-temporal frame and examining nothing more than the densities of some species in function with others. But the density of a species is also a function of its density (or of that of the other species) in neighboring regions and in the same place and in times passed, not becoming possible to deal with it independently of the general motive or << pattern >> of distribution.

In the analysis of the correlations, the statisticians consider as undesirable that the observations nearest in space and time tend to present similarities by leading to spurious or disoriented correlations; but in our problems said circumstance is inevitable.

The reticulated relations between species and the lack of resolvability of the correlation matrices could be attributed, in good part, to the historical nature and to the spacial continuence of the ecosystems. The same circumstance is extraordinarily important in the study of affinity between inventories or samples - not directly undertaken presently - to the point where the spacial-temporal proximity between the same ones is almost equivalent to what the correlations indicate, and, where upon, are more easy to establish and to make public. It is possible that the problem be stated in distinct boundaries when it deals with classifying samples of terrestrial vegetation, very remote from these in the center of a mosaic environment, as is in the case of comparing samples taken from a more continuous environment, as is the plankton. In this case, the necessity appears obvious to think of some form of analysis in sequence, based on obtained data with a great density along gradients. Lamentably, the data just as it is obtained by the present oceanographic techniques are not commensurate with said necessity.

2. Using groups of species very closely associated among themselves (crowds or constellations) for classifying and arranging inventories constitutes a simplification of the procedure which might separately employ all of the species. The justification lies in the fact that the presence of perfectly associated species is redundant, as is that of the totally correlated characters in numerical taxonomy. At substance, the same approach is utilized by the classical phytosociological methods, by those that operate on the basis << certain species tend to present themselves as groups >>.

Nevertheless, in natural groups, perfectly associated species do not exist, or rarly exist (some parasites or simbionts). One can have legitimate doubts in regard to the adequacy to reality of the treatments that take the simultaneously frequent appearance of species as a criterion for analysis of the samples of natural communities. Apart from the influence of the size of the sample in the type of resulting association, the experience demonstrates that the grade of << association >> between the same species varies according to the amplitude of the margin of environmental conditions which might be examined.

At any rate, it is not very hard to demonstrate that it is possible to obtain an acceptable classification of a great number of inventories using arbitrary groups of species, as it is possible to classify adequately series of photographs using their level of superposition with a series of transparencies with motives at random. This means that the success in the classification of inventories obtained by means of the use of certain allied groups of characteristic or associated species, is not, in the least, a guarantee that the groups of associated species that have been used be the best ones that can be formed, and, nor only, that they be best fit. It is natural that if they are << less bad >> (that is to say if it includes species that effectively tend to present themselves together and have a parallel distribution) it shall be possible to obtain a very rapid discrimination consistent with a smaller number of groups.

This conclusion is not totally pessimestic, because it can make us look with a certain amount of indifference the fact that by means of different procedures applied to some similar data, depending on the details of the process or the type of discussion which we must introduce, one arrives at classifications or constellations of species which are not totally equal or superposable.

INSPECTION OF THE CORRELATION MATRIX

The rudimentary procedure of noticing high values of correlation in order to disturb or rearrange the initial correlation matrix in such a way that groups of species strongly associated among themselves stand out, is very coarse: soon it is noticed that there exists numerous species which establish connections between diverse groups, otherwise fairly well defined, leading to a system of complicated reticulations. At some moment one must draw the line at some point. On the other hand it is convenient to substitute the procedure of using colored pencils and to repeat the matrices by another more automatic and elegant procedure, sensitive to programming, if the need arises.

The procedure followed, as arbitrary as and maybe better than another, is the following: The species have been arranged in a sequence, attending to the value that reaches affunction equal to the sum of the squares of the correlation coefficients between the species that we considered and every one of the remaining 80. By this procedure the negative correlation coefficients << weigh >> also in the evaluation of the intensity of the relations - positive or negative - with other species. In our matrix, the negative correlation coefficients are of lower values. It can be considered that the species in which the sum mentioned is large (always a predominence of positive coefficients) occupy the center of constellations or crowds of species, within an ideal ecological space.

The specie that occupies the first place in said series (*Rhizosolenia stolterfothi* in our case) is considered the center or nucleus of the first association group and all the species were examined whose correlation coefficient with it surpasses the determined value. All these form the first group. Next the first free specie that follows in the series is sought and is used as the center of the second group, and so on successively in this manner. A few species (the nine that do not carry any indication in the column << groups >> of Table I) remain isolated and, in so much as they are infrequent, were not considered as unique representatives of any one group.

Some small << pitfalls >> have entered in the preparation of the square. In the separation of the first groups I to III, the correlation of 0.200 was made the limit and, starting at IV, this value was lowered to 0.100. Nevertheless, a certain specie was assigned to I in spite of having a correlation less than 0.200 with *Rh. stolterfothi*, although higher than 0.20 with the majority of the species associated with it. This measure was not followed with *Skeletonema costatum*, head of the second group, which also shows strong correlation with the majority of the species of the first. A procedure probably more adequate (principably because it is programable) although it carries with it a large volume of calculations, would consist of obtaining a new correlation matrix among the remaining species, after the extraction of each group. In this manner we would not be obliged to diminish the value of the correlation coefficient starting from a determined stage.

Furthermore, the strategy employed is irreversible, that is these have not been included in a group, a specie that shows strong correlation with the head specie or with others associated when said specie was already gathered or retained in a previously separated group. These decisions are a bit arbitrary, but no worse than the others. To us, any procedure creates twisted conflicts. Nevertheless, species of mixed character are useful for determining the relations between the different groups. Groups IV and VII have notable affinities with III, X with V, etc.

Table I indicates the groups encountered, which are repeated, in perhaps a more legible form, in Table II (a and b). The examination of the original tables, taking into consideration the data on the characteristics of the environment, leads to the belief that the groups distinguished have a real ecological base. In another stage of the study of the ecology of each group could be quantitatively determined. Generally the following vision of unity, undoubtably a little impressionistic, can be presented. It is worthwhile to take notice that the order consistent to which the groups are appearing does not imply affinities or links between these and does not result in the most fit for its exposition.

Group II (*Skeletonema, Ditylum, Coscinodiscus*) is extremely characteristic of coastal waters of the Paria region that, although not necessarily of very low salinity, are always influenced by mixing of the continental contributions.

Group VIII consists of diatoms of small cellular volume and rapid multiplication, producers of abundant slime, which form dense populations next to the coast, in ascending waters to the east of Margarita Island.

Group IV (*Lauderia, Encampia, Stepanopyxis*) turns out less well defined, with diatoms of rather large cells and some dinoflagellates, were principally distributed around Margarita.

Group III and I contain a majority of diatoms and characterize the fertile waters of upwelling. In group III *Chaetoceros* predominate and in group I the genera *Rhizosolenia* and *Nitzschia*. This second one has a slightly less neritic tint.

Group VII and IX are of transition between very coastal waters and others more removed from the coast, or less form part of the (somewhat more advanced) stages of the succession in coastal waters.

Group V includes numerous dinoflagellates and is found in advanced stages of the coastal succession or in very oceanic waters. Typical of these are groups X and XI, with cyanophytes, dinoflagellates and the few existing oceanic diatoms.

In the study in press on the phytoplankton of the NE of Venezuela which was mentioned before there is proposed the division of the area into various subareas, established on environmental and biotic characteristics (Fig. 1). The map of Figure 2 superposes to each subarea a spectrum of the relative representation of the various groups distinguished by the described procedure. The aspect of coherence of the map is excellent for one familiarized with the characteristics of the region. The dominance of group II in the zone of the Paria Gulf, influenced by contributions of continental water, has been confirmed by a series of very recent independent observations.

SOME DIFFICULTIES ENCOUNTERED

One must call attention to the fact that the sum of the squares of the correlations (column A of Table I) keeps relation with the characteristic/mean deviation quotient (on transformed data) in the sense that the aforementioned sum is greater in the more abundant species and of a more uniform distribution, as was expected. The verification of such an interchange suggest the possibility of finding another more appropriate indice than the sum of the squares of the correlations as a help in the process of the extraction of groups. It is a thesis which merits greater attention, although possibly the different procedures would effect only the order with which the species group head appear.

In addition to the procedure indicated for extracting groups of associated species, another was tried, consistent in seeking, not only the species with the greatest positive correlation with the group head, but also the one which showed with it the maximum negative correlation within the general aggregate, in order to consider it as center of another opposite group. This procedure led, in part, to the same groups (for example, the species of the less coastal groups - VI and X at least - stood out rapidly from the first groups), but resulted in some confusion, probably on account of the low absolute value of the negative correlation coefficients. The shortage of negative correlation coefficients of large absolute value is a characteristic of this study, in comparison with the examples of terrestrial vegetation examined up to now by means of correlation matrices. This trend less accused to the mutual exclusion of the species can be owed as much to the large number of samples (which encompasses very varied environmental and spacial-temporal conditions) as to the relatively uniform character of the planktonic communities.

The problem of the less abundant species and which have values of zero in many samples, presents difficulties related also with the aforementioned. In the same way as in the analysis of presence and absence by means of the X^2, the square of double absences is influenced by the size of the area sampled (which may encompass zones in which the admittance or the life of various species is impossible), the correlation coefficient can be high between species which only have in common then variety (and the presence of numerous zeros in the table). The characteristic extreme of this situation would be that of two species not present in the area studied and which would have a correlation coefficient = 1.

The recent methods of classification based on this information theory (Lance and Williams, 1966; Nacnaughton-Smith, 1965) are sensitive also to this factor, being able to group as very related inventories which only have in common the lack of many species abundantly represented in the others.

These inconveniences appear inherent to the necessity of deliminating in some manner the zone studied as much as the samples collected within it. There seems to be the necessity of establishing classifications or affinities between species, of a flexible type, which would vary according to the size of the areas considered to include factors of historical-temporal type. On the other hand, these approaches would have the advantage of gathering the fact, frequently observed, that the affinities between species are changed as the observations are extended to new areas. The affinities of distribution between species which are very useful for detecting, for example, the environmental conditions in a relatively reduced zone, can disappear on extending the area of study, losing valuable information of a more local character.

To this respect it can be instructive to compare the groups which were arrived at in the present study with a classification previously intended for the eastern med. (Margalef, 1966). It must be taken into account that, as much for the more cosmopolitan character of the species of phytoplankton, as for certain accentuated similarities between the European Med. and American, there exists a very high number of common species which makes such a comparison ideal.

The truth is that, in detail, there exists a very great number of discrepancies and it is not possible to identify entirely groups of the two areas. It may have contributed to the disparity the fact that the procedures used are not exactly the same, because for the Med. a correlation matrix between cell densities was not calculated, but instead a matrix of affinities based simply on presence or absence, without taking into consideration the real abundance. Nevertheless, it is unquestionable that in general lines and, expecially when groups of groups of groups are considered, there exists, it could not be less, a basis for comparison: on the one hand the less neretic species (groups VI, VII, X of the Med.; V VII and X of the Caribbean) and later different clusters in which it is possible to recognize many affinities. Nevertheless, the ecological conditions of the respective regions establish differences: In the Med. continental contributions like those which lead to conditions appropriate to the life of the group *Skeletonema-Ditylum-Coscinodiscus* do not exist; on the other hand the nutritive waters may be limited to a certain depth establishing there groups of species which, in the region of Margarita, with a greater vertical equalization of the nutrients, are selected and grouped otherwise.

ANALYSIS OF THE PRINCIPLE COMPONENTS OF THE CORRELATION MATRIX

The analysis of the principle components of the correlation matrix (Harman, 1960) resulted in relatively limited efficiency, owing to the poor quality of the matrix. The relatively hyper-spheroidal situation and the absence of directions of favored variation, contrasts with the examples relating to terrestrial vegetation heretofore examined by us. The utilization of the variance-covariance matrix instead of the correlation had perhaps led to a more efficient summary of the information, but the more abundant species would have perhaps dominated the analysis. Our interest for the interspecific relations and the character << indicator >> of relatively less abundant species made us opt for the correlations. At any rate, of the principle objective of the study is to describe similarities of behavior between different species, more than the total or almost total reduction of the original information to a few some few manageable factors, now useful data may be obtained without the exploration of the matrix being exhaustive.

The species most connected to the different components detected (characterized by possessing the highest coefficients of charge) can serve as << indicators >> or potential centers for groups of indicator species. Naturally, and in spite of the possibility of increasing the discriminatory character of the species by means of rotations of the principle axis considered. The separation of these species in groups continues to depend on subjective decisions, for example, the selection of the standard of the coefficients of charge.

Owing to the difficulties of disarrangeability cited, only four components were obtained in the analysis:

Eigenvector	Eigenvalve
1	5.43962
2	2.95128
3	2.27514
4	2.18604
Σ of Eigenvalves	12.85208

The components cited represent only some 15.86% (= 12.852/81) of the variation contained in the original data. Its low value and the small change in the last components which is observed is reflexive of the absence of especially important or useful directions of variations. These results are perhaps foreseeable in cases in which the samples embrace very extensive environmental and temporal combinations, in which the interspecific relations lose clarity and the number of components approximated the species. As is natural, we encounter the same difficulties present in the examination of the correlation matrix, and which lead to accepting very complicated and reticulated relations between the species.

The use of correlations or other indices of affinity can be inadequate for the analysis of the ecosystems in regard to the distribution of species, but once chosen the system of correlations for the examination of species abundance, the analysis of components is surely the most potent system of those known. In our case, even having renounced the extraction of more than four components these can serve as basis for a reasonable classification of the species in groups. The coefficients of charge with relation to the four components for the different species are represented in Table III.

The graphic procedure of tracing the position of every specie in a space whose coordinates are the components 1 to 4, in order to later inspect constellations, can have usefullness. In figure 3 in this way there is presented and under the pretext of an example, the position of the species in function with the components 3 and 4, which serves also for looking at the relations with the defined groups according to the previous procedure.

It has been found practical to utilize the principle components in a very simple way, classifying the species according to the component for which they possess the greatest coefficient of charge. A similar procedure has been used by Cassie (1967) for classifying in groups the components of the zooplankton of Lake Maggiore. If four components are considered, the four resulting groups can be subdivided according to the relative importance of the specie in the other components. In summary, every specie can be characterized by some premutation of the numbers 1 to 4, which express the decreasing order of values of the respective components (Table I and II). This classification leads to a total of 15 groups,pplus some small groups infrequently represented of the total of 24 premutations possible (Table II).

The interchange between these groups and the groups I to X of the first classification remains evident in Table II. There exists notable interchanges: in particular the three large units, neritic, coastal with influence of continental contributions, and with characteristics most accentuated of the high sea is reflected in all parts. Major descrepancies, probably interesting, but not yet totally interpretable are observed in the groups, such as they come, or that is, without regrouping more extensive groups.

In this context the problem of the significance of the principle components of analysis is stated. One thing is clear, the pelegie or less neritic species, have high values in component 4, the neretic in component 1 and, with regard to those influenced by substances of continental origin, the greatest coefficient of charge is given for component 3. In regard to 2, it is difficult for now to assign it a precise significance. Everyone of these components reflects then combinations of factors not easily separable; the coast/high sea opposition is reflected, at least in two components.

CONCLUSIONS OF GENERAL ECOLOGICAL INTEREST

At the end of this study we come to two classifications, only superposable in part, of the aggregate of species in a series of constellations or groups of associated species. They are so little coherent that they permit one to question the existence of groups of characteristic species and certain premises traditionally accepted in phytosocialogy. But in part, this can be a consequence of the nature of planktonic communities and instigates a comparative study between these and terrestrial communities, which in fact, act in a little different way in the face of the analysis, as has already been indicated.

A next step should be to examine the significance of every one of the groups in relation with the ecological factors which define the distribution of the respective species and, further on and in the measurement of the possibilities, to examine the efficiency of the groups distinguished in a rapid analysis of a new gathering of plankton in the same area and in different areas.

Although if the critical discussion of the same is deepened, the concept of << nich >> can become unnecessary, it will not be useless to remember the pertinence of this type of investigations in relation with the most quantifiable idea that we can formulate of what is an ecological nich. We could consider it as a space of probability defined, for each specie, within a space of many dimensions, every one of which represents one of the factors which can be distinguished as forming part of the environment in which that specie lives. It is obvious that in this case the specie will be represented by a cloud of probability, most dense in the volume defined by the coordinates which correspond to the optimal combination of environmental factors. This form of representation has been utilized, although very simplified, in the diagrams designated as T-S-Plankton (Fig. 4). In introducing the factorial analysis new possibilities are opened to us. Like coordinates we can use principal components in place of defined factors. Then the species remain represented by a single point and the irresolution translates to the interpretation of the components in terms of the different environmental factors.

In closing we wish to point out that, whatever is the procedure suggested for defining them, each one of the groups include numerous congeneric species. Different *Peridinium*, different *Ceratium*, *Chaetoceros*, *Rhizosolenia*, *Nitzschia*, are distributed closely. This fact seems to contradict the hypothesis, frequently admitted, according to which the competition is particularly intense between species which belong to a same genus. There must be sought, therefore, an explanation of the particular situation which is observed in the plankton. On the one hand it is possible that under certain circumstances, the competition passes to the generic level there existing mechanisms which permit a high differentiation within the same genus, which is perfectly natural that it occur when specified ectocrine substances common to the species of a genus act as agents of competition. On the other hand, the phenomena of succession and turbulence can abnormally increase the diversity of phytoplanktonic populations and one of its manifestations would be the frequent association of species of a same genus, which succeeds or overtakes it maximum rate of multiplication in << packets >> of water separated, but adjacent and mixable.

Fig. 1. Types of phytoplankton in the five subareas distinguished around Margarita Island, NE of Venezuela. For each area the density of the most frequent species in the 50 meters closest to the surface is indicated. The scale is logarithmic and the numbers indicate the number of cells per ml.

Fig. 2. Characteristics of the phytoplankton in the same subareas of figure 1, defined by the participation in the plankton of each subsrea of the different groups of association I to X. The surface area of the circles is proportional to the density of the phytoplankton in the respective subarea. Groups II (and III) predominate in the eastern region, group I in the majority of the subareas and there exists a greater participation of the groups of most oceanic characteristics (VI, X) on the high sea (subarea V). The geographical position of Margarita Island (M) is 64°W 11°N.

Fig. 3. Position of the species studied in relation with the principle components 3 and 4. Data from table III. It indicates entirely the numbers of some species, in order to make public a possible ecological interpretation of the components considered.

Fig. 4. Illustration of the two forms considering the nich defined by coordinates in an ecological space. To the left, the coordinates represent factors of the environment and the nich of a species is represented by a cloud of probability

around a nucleus of optimal conditions (the figure sums up observations accomplished in the eastern Med.). To the right, the coordinates represent principle components and the nich remains represented by a simple point (data from the present study). In this second case, the uncertainty which before was represented by a cloud of probability, remains transferred to the definition of the principal components in terms of factors of the environment.

Table I. (A) The sums of squares of the 80 correlation coefficients of the other species. (B) Mean population densities, after the transformation ln (1 + x) where x is the number of cells per 100 ml. (C) Dispersion standard of the transformed population densities. (D) C/B quotient, dispersion standard/mean. (E) References number of the species associated with each group head. (F) Order of the coefficients of charge, by its magnitude, of the four primary components, in the factorial analysis.

Table IIa. Relation between the two classifications. In the column on the left, groups extracted from the matrix, by association. In the heading, groups defined by the order of values (positive) of the four primary principal components. In the intersection of both classifications the corresponding species are enumerated, serialized by decreasing mean abundances.

Table IIb. Relation between the two classifications. In the column on the left, groups extracted from the matrix, by association. In the row of the heading, groups defined by the order of values, from most positive to most negative, or the four primary principal components. In the intersection of both classifications the corresponding species are enumerated, serialized by decreasing man abundances.

Table III. List of the species whose relations have been analyzed, with indication of its respective coefficient of charge for each one of the four primary principal components. The species bear a number of correlative order and behind it, between parenthesis, the group to which it pertains, from those distinguished on the correlation matrix.

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