

## Phytosociology and Biodiversity: an undissociable relationship

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### Abstract

A general review of the ideas and concepts concerning biological diversity is carried out in the first part of this paper. The importance of biodiversity and its role in the ecosystems is considered and the types of biodiversity and some procedures and formulae to assess it are analyzed as well as the factors which influence this parameter in ecosystems. The second part focuses on the relation of vegetation and biodiversity and particularly on the elements of biological diversity contained in the phytosociological information. The advantages of using the relevés data sets and the phytosociological vegetation maps for assessing biodiversity are highlighted: low cost, methodological homogeneity, size and extent of the data set. The attributes of the phytosociological data permit an assessment of the alpha, beta and gamma diversities in the local and habitat scale and the integrated or dynamic-zonal phytosociology can be used to analyze diversity at landscape or regional scale.

Key words: Biodiversity, phytosociology.

### Resumen

En la primera parte de este trabajo se hace una revisión general de las ideas y conceptos relativos a la diversidad biológica. Se reflexiona sobre la importancia de la biodiversidad y su papel en los ecosistemas y se analizan los tipos de biodiversidad que se pueden reconocer así como los procedimientos y fórmulas usadas para su estimación. También se analizan los factores que influyen sobre este parámetro en los ecosistemas. La segunda parte trata sobre la relación entre la vegetación y la biodiversidad y más concretamente sobre los elementos de biodiversidad contenidos en la información fitosociológica. Se ponen de manifiesto las ventajas de usar bases de datos formadas por conjuntos de inventarios así como mapas fitosociológicos para hacer estimaciones de biodiversidad: bajo coste, homogeneidad metodológica, tamaño y extensión del banco de datos. Los atributos de los datos fitosociológicos permiten una estimación de las diversidades alfa, beta y gamma en los niveles locales y de hábitat, al tiempo que la fitosociología integrada o dinámico-catenal se puede usar para analizar la diversidad a nivel del paisaje o a escala regional.

Palabras clave: Biodiversidad, fitosociología.

### Introduction

The idea that the plants and animals which share the world with us constitute a diverse assemblage has always been a question of enormous interest for man; even children are usually strongly attracted by the different living beings of their surroundings, particularly animals. Nevertheless, this diversity has represented a difficult intellectual challenge as man always had problems to define and assess such phenomenon. Till Aristotle appeared in the IV century BC, ancient Greek philosophy had been preferably engaged with unanimous matter phenomena, he (and his pupils, Theophrastus among them) started counting and classifying living beings as a way of studying them in a systematic manner to start to understand our place in the world in relation with the rest of the creatures. In any case, the idea of diversity in living beings seems to be innate to man as a response to the impression caused by the richness and variety of the surrounding nature (Margalef, 1991); certainly we all have at least an intuitive understanding of it (Gaston, 1996). For that reason, the study of that diversity has been one of the

major duties of scientists throughout history and there are particular fields of science, such as Botany, Zoology and some others, which for centuries have been almost entirely devoted to the description of the biological diversity on earth, although this term was formerly not in fashion as it is nowadays. Those historical disciplines did a great work of enormous value during a long time and science is strongly in debt to them, but their approach have been taxonomical and the modern concept of biodiversity, although including it, exceeds the taxonomic level.

Frequently associated with the concept of biodiversity is the idea of the value of the elements we are dealing with. When reflecting upon and talking about biodiversity many of us often instinctively think about the scarcity (rarity) or abundance of the species, if their distribution is narrow (endemic or stenochorous) or wide, if they are relic or belong to vigorous populations, and so on, ideas which are associated with their scarcity and their claim for more conservation attention. Such association is logical due to the conservationist ethic involving all these reflections, but the study of biodiversity in a scientific way should be carefully kept

separated from other considerations than those strictly concerning itself.

### Why is biodiversity good or necessary?

The social awareness in the human society that man's impact on environment causes a high species extinction (Leakey & Lewin, 1996; Primack, 1998) has largely contributed to the rise of the question of biological diversity to a central position in the environmental debate. The loss of the genetic patrimony and the fear of possible malfunctions in the ecological regulation of ecosystems are considered to be major threats for the maintenance of the balances which permit man to survive on the face of earth. The situation is worsening rapidly and effective measures will not be taken until the human society is made aware of the need of it (Pielou, 1991). For that reason, biodiversity conservation constitutes one of the main supports of the ecological and environmental ethic (González Bernáldez, 1991) and has become one of the "most commonly used criterion in conservation evaluation" (Usher, 1991). As a result, now a group of researchers are engaged in this issue.

There are three main groups of arguments for conserving biological diversity:

- **ETHICAL REASONS.** Human species has been able to dominate the planet overwhelmingly but this does not give it the right to extinguish any form of life.
- **UTILITARIAN REASONS.** Biodiversity is regarded as an economic resource: the possibilities of exploiting the huge genetic resources of the existing living organisms on earth.
- **SCIENTIFIC REASONS.** They escape the consideration of most people and are basically discussed within the scientific community.

From the strictly scientific point of view we can pose some basic questions about the role of biodiversity in the ecological systems:

- ◆ Are all organisms necessary to keep the ecosystems functioning or can some of them disappear without their processes suffering?
- ◆ How much diversity is necessary to maintain the basic processes and fluxes of matter and energy?
- ◆ Which are the processes which maintain the biological diversity?

From the ecologic point of view and as a general statement, it is admitted that a high number of species

in an ecosystem guarantees a higher efficiency in the use of the resources (complementary effect) that induces a higher stability of the system against disturbances (buffer effect). There is a positive effect of diversity on the functional aspects of the ecosystems.

There are two main hypothesis about the functional role of biological diversity in ecosystems:

1. The redundancy hypothesis says that several species of one ecosystem play similar roles and thus are at least partially redundant. If one of them is lost no important effects are to be expected as there are others which will replace it, at least in a major part. Thus, most of the species are unnecessary (superfluous), as the passengers of an aircraft are unnecessary for the plane to fly; only a few members of the crew play a decisive role similar to that of some "important" species (keystone species) whose loss would mean a serious disturbance in the ecosystem.
2. The bolt hypothesis says that each species plays a more or less important role in the ecosystem, thus many of them are not indispensable for it to survive, as the bolts of a plane. If we lose a few of them, the plane will be able to continue flying but if we keep losing bolts, the moment will come the moment in which the loss of one bolt will mean the fall of the plane. There is a threshold in the loss of biodiversity above which the ecosystems cannot function. Also, with less species the ecosystem is more vulnerable against any sudden change in the site conditions.

It is known that biodiversity is a result of the historical evolutionary process and that ecosystems can often work with less diversity than they have nowadays, but it is also certain that a minimum of diversity is necessary to ensure the survival of any ecosystem, specially in response to fluctuations or disturbances. In any case most people will agree that, if considering biodiversity as a resource, high levels are good and lower levels should be considered as an impoverishment of our inheritance. This used to be universally accepted and, as mentioned above, biological diversity is considered one of the primordial criterion of naturalistic evaluation for conservation and there is the assumption that high diversity areas deserve harder conservation efforts. Moreover, in terms of conservation policy diversity is a parameter which has to be prudentially combined with other relevant aspects such as the analysis of the significance and value of the different species present in the area: e.g. endemics, relic and rare species should be evaluated at a different level than ruderals or subcosmopolitan weeds.

## Definition and concept

Biodiversity can be understood as the total variety of life on earth; this includes any kind of life (animal, plant, fungi, viruses, bacteria, algae, etc.) as well as the variation existing within the populations and individuals of each species till the genetic level and the variations observed in the communities and ecosystems reaching the functional, landscape and geographical levels. We can say that *it is the total diversity and variability of living things and of the systems of which they are part ... and refers to the quality, range or extent of differences between the biological entities in a given set* (Heywood & Baste, 1995). The breadth of the concept of biodiversity is so wide that in fact it becomes too difficult to comprehend, perhaps it is not a satisfactory concept because it is imprecise and runs the danger of being defined so broadly that it equates to the whole of biology (Gaston, 1996a); in other words it could be considered a non-concept. It is something like an optical illusion: the more it is looked at, the less clearly defined it appears to be and viewing it from different angles can lead to different perceptions of what is involved (Magurran, 1988).

There are plenty of definitions for biodiversity and we are not going to repeat here a couple of them nor give a new one. Perhaps it is enough to adopt a brief official one: *“The variety and variability among living organisms and the ecological complexes in which they occur”* (U.S. Office of Technology Assessment). This conception leads to the acceptance of several levels at which biodiversity takes place (Heywood & Baste, 1995; Gaston, 1996a; Noss, 1997): 1. Genetic level; 2. Organismal level (Population-Species); 3. Ecological level (Community-Ecosystem-Landscape). The first is studied by the Genetics, the second by the Taxonomy and the third is in the scope of the Ecology *sensu lato*. Each of these three main levels have a set of components of a hierarchical nature which overlap:

The ecological or systemic diversity is the most inclusive of all the forms of diversity and hence is more difficult to define and assess than the other two levels (Pielou, 1991). We can accept Pielou’s definition for the biodiversity of an ecosystem, as it *“consists of all the different communities of organisms, of every phylum, that occupy or visit the area, together with all the environmental factors (biotic and abiotic) that affect, or are affected by, these communities. This inclusiveness is the hallmark of an ecosystem. Nothing is left out, and it is this that makes measurement of an ecosystem’s diversity so difficult”*.

## The enormous task

Is it really possible to reach a liable assessment of the biological diversity in the world or at least in some parts of it? For centuries, Botanists, Zoologists and other taxonomists have been intensely working on the description of as many species as possible in their respective fields. Their legacy is enormously valuable as the number of species of any kinds of organisms already described by science is now about 1.5-1.8 million (of them about 750,000 are insects, 250,000 vascular plants, 70,000 fungi and 41,000 vertebrates). However, the estimations for the total number of species really existing in the world are extremely vague and range between 5 to 50 (or even to 100 or more) million; recent estimations consider a working figure of about 13-14 millions (Hawksworth & Kalin-Arroyo, 1995). In any case, it is clear that only a small proportion of the estimated species are really known by man nowadays and that even with the most conservative calculations, to a rate of 1000 newly described species per year, mankind will need about one thousand five hundred years to double the taxonomical knowledge of the species on earth. This makes the assessment efforts on biological diversity an impossible exercise today

### Ecological Diversity

Biomes  
Biorregions (Biogeogr. Units)  
Landscapes  
Ecosystems  
Communities (habitats)  
Synusia  
Populations

### Genetic Diversity

Populations  
Individuals  
Chromosomes  
Genes  
nucleotides

### Organismal Diversity

Kingdoms  
Phyla (divisions)  
Families  
Genera  
Species  
Subspecies  
Populations

**Cultural diversity:** human interactions at all levels

because there are so many undiscovered organisms and it makes it unrealistic to think that we could reach a reasonably accurate knowledge of biodiversity (even at the specific level) in the near future. This has been called the Global Taxonomic Impediment (GTI). In addition, the actual extinction rate of species would bring into disarition many of the undiscovered taxa before they were described for science.

Another question is that, from the operative point of view, when assessing the biodiversity of a particular ecosystem, to reach a reasonably good knowledge of all the taxocoenosis, we would need as many specialists as groups are involved. It would take years of research by a legion of field workers and taxonomists to assess the diversity of all the groups, and even in this case, the result would not be worth the effort and would come much too late to be useful for conservation efforts (Pielou, 1991). For that reason when biodiversity is to be studied, it is done upon a determinate group: vascular plants, vertebrates, fungi, lepidopters, etc. i.e., when studying specific diversity in concrete cases, usually it is related to the diversity of a particular taxocenosis, not the total biodiversity.

### Diversity types

The broad sense of the biodiversity concept, the various scales included and the variety of processes involved, means that inside this concept an enormous quantity of phenomena can be included. Nevertheless, some formalization is needed and some approaches have been made to achieve this.

Originally proposed by Whittaker (1972), and widely accepted nowadays, three basic types of biodiversity can be differentiated in a given area, particularly when we consider the specific level:

“Alpha” ( $\alpha$ ) is the diversity within a particular ecosystem or community (or small sampling unit);

“Beta” ( $\beta$ ) is the diversity between the different ecosystems or communities of a larger area. It was formerly described as the degree of species change along a gradient (Whittaker 1960);

“Gamma” ( $\gamma$ ) is the total diversity of a given area without regard to its structure in communities; it is often related to the total number of species. There is no limit in the considered area for gamma diversity but sometimes for regions including landscape complexes it is spoken of “delta” ( $\delta$ ) diversity and when considering the entire world, then is the “omega” ( $\omega$ ) diversity.

Beta diversity is related to the habitats diversity of an

area, strongly influenced by the land management model and with the ecological heterogeneity. This type of diversity is correlated with the consideration of the value of singular habitats, often under severe stress, in which specialized species live forming particular communities which show low alpha diversity but increase the beta and the gamma diversity of the territory. Those poor habitats with low species richness often represent particular and original solutions under certain site conditions, and such situations increase the inter-habitat diversity increasing the global diversity of an area. At the landscape or the geographical levels, the described types lose their value as units of higher organisation level are required. Ecosystem types, landscape units, etc. are necessary for an assessment and formalization of diversity at spatial large scale.

This biodiversity, as defined till now, is concerning essentially genetic, taxonomic and ecosystem diversity; nevertheless, most organisms show strong differences in size, longevity and other eco-morphological adaptations. In Botany, the description of every species includes the morphological type, usually after Raunkjaer (1916) and all the vegetative features considered relevant. More recently the Plant Functional Types (PFTs) have been developed (Gitay & Noble, 1997) trying to establish an easy typology in order to be used for global assessments. All these approaches represent, to a certain extent, the eco-morphologic diversity in plants. When considering communities, the structure of the vegetation (different strata or layers, presence of epiphytes or lianas, etc.) introduces another element of diversity as well.

### How to assess diversity

We could perfectly work for the protection and improvement of biodiversity with the feeling for it or having an approximate idea of its importance in every particular case we could find in our current work, i.e. without attaching a number to it. Then, why measure diversity? The answer to this question is that it is widely accepted in science, that phenomena have to be measured in numbers as far as is possible if we want to have a satisfactory knowledge of them; no real knowledge exists about a phenomenon if there is not a numerical assessment of it. Certainly, numerically supported discourses have high prestige in our society and this has led many ecologists to carry out numerical assessments on biodiversity. As a result, a huge number of indices and models have been described to measure

biological diversity (Magurran, 1988). However, we have to recognize that giving a bare number to indicate the diversity of a particular ecosystem is meaningless to most people except to some specialists, and it is not very informative even for them (Pielou, 1991).

When studying biodiversity in one ecosystem or in one area, we always find that all the groups are formed by a number of species quite unevenly represented. Some species are frequent or abundant (dominants) and others (often the majority) are scarce or rare and form a long tail in the species list. This reality has led many people (mostly ecologists) to separate two components of diversity, the number of species and their relative abundance (Magurran, 1988), although for some others it is not really necessary to go much further in this distinction as both parameters are manifestations of the same regularity (Margalef, 1991).

As stated by Margalef (1974), diversity is the expression of a structure which is the result of the forms of interaction between the elements of a system. For that reason those elements rarely have the same abundance or frequency in terms of number or quantity in any assemblage they can constitute and this is a relevant circumstance concerning the structural attributes of biodiversity. Therefore, at any level we consider the biological diversity, it always has two components: the number of different elements which are considered (species if we consider the specific level), called *richness* and usually signaled with  $S$ , and the relative abundance of those elements (or species), called *evenness*. It is a general phenomenon that the number of individuals or the biomass of each species is unequal, there are usually few species with many individuals and/or much biomass, and others, usually more, which have less individuals. The distribution species-abundance follows a typical exponential curve in most of the cases. This distribution is quite similar to that of the wealth of the people of a human society (few rich and many poor), to the frequency of the letters of the alphabet in a written text or to the extent of the countries in the world (few large and many little). In many cases, however, richness in species (or in other units) is usually positively correlated with measurements of ecological biodiversity (Gaston, 1996b).

Thus, in assessing biological diversity this question is usually taken into consideration and it is widely accepted that diversity is composed not only by the species richness (number of species) but also by the relative quantity of each of them in the considered unit (evenness). Diversity is enhanced by the number of species as well as by the even distribution of the

individuals among them. When dominance occurs, many individuals belong to one or few species while the many other species will have few individuals, leading to a decrease of diversity.

Most of the formulae extensively used to assess (alpha) diversity reflect this principle.

A quite simple and practical one was proposed by Margalef (1962):

$$D = (S-1)/\ln N$$

where  $D$  is diversity,  $S$  is the species richness and  $N$  is the total number of individuals of all the species.

Other formulae are measurements of the concentration of the dominance, as in the case of the Simpson index (1949):

$$D = \sum (y/N)^2$$

where  $D$  is diversity,  $y$  is the number of individuals of the  $i$  species ( $=N_i$ ) in a total of  $s$  species and  $N$  is the total number of individuals.

More popular has been the equation of Shannon and Weaver (1963)

$$H = \sum p_i \log_2 p_i,$$

Where  $H$  is diversity,  $p_i = N_i/N$  and thus  $\sum p_i = 1$

The last formula, extensively used, is really an information theory index which pretends to be an expression of the information contained in the system in a similar way as measuring the information contained in a code or message (Magurran, 1988). As far as biodiversity can be considered as the information of the ecosystem (another attribute to be added to the energy and matter fluxes), it can be appropriate to measure it applying this formula and the unit is the byte. The higher the uncertainty about to which species the neighbour individual of any individual of the community belongs, the higher the information of the system will be because its organisation (i.e. diversity) will be higher, and that organisation could be considered as a result of the interactions of the ecosystem (Margalef, 1974). The highest diversity would be that every individual belongs to a different species, i.e. as many species as individuals.

In any case, even if we apply one of those formulae (or others which have also been proposed), as mentioned above, it is impossible to assess the complete diversity

of an ecosystem as we cannot take all its organisms into account. We will assess the diversity of one or a few taxocoenosis about which we possess enough information. At this point, when studying the diversity of the different types of organisms in an ecosystem, it is frequent to find that high diversity in one group is correlated with high diversity in the others, i.e. there is usually some congruency between the diversities of the different groups. This general statement is sometimes contradicted as in the cases in which high diversity in one group does not predict the same level in others (Margalef, 1991). An illustrative example for this is the case of the European temperate forest: the diversity of vascular plants is low, specially in the cases where soil is nutrient poor, but the number of different genome types (species) of bacteria found in one gram of soil reaches 4000. In a forest, decomposers and symbionts play a major role in the ecosystem, much more relevant than in the earlier stadia of succession. In temperate central European forests higher diversity is positively correlated to higher anthropogenic influence (Karrer, 1994), but these are observations only concerning vascular plants and ignoring the rest of organisms. If we consider the different stadia of succession in relation to different perturbation regimes, in the Mediterranean region, and regarding only the vascular plants, the younger stadia of succession, such as the scrubs, are usually species richer and contain more endemic (stenochorous) species than the mature forests. Evenness, as a component of diversity, is usually also positively correlated with perturbation (moderate) while maturity usually leads to strong dominance. In forests, due to the dominance of the arboreal element, dominance strongly increases, while in the understorey only a few vascular plants can live under the canopy in contrast to in seral scrub, where relative abundance of the different species is more balanced.

### **Factors determining biological diversity**

Diversity varies extremely between different ecosystems and biomes, between different groups and between different territories. These variations have been largely explained by climate conditions, by the soil fertility, by the primary production, by the structure of the vegetation and by disturbance regime, but there is still one factor of major importance which affects the diversity of vascular plants in a quantitative and qualitative sense: it is the historical factor. It is known that old floras are usually richer than new ones, just

because they have had more time to evolve and diversify. So, we have the amazing richness of the tropical rain forest or of some tropical islands. If we compare the floristic richness of the Eurosiberian region, with ca. 12,000 vascular plant species with the Mediterranean region with 25,000 living in a much smaller territory (Médail & Quézel, 1887) where climatic stress regime is as severe or even more than in the former, we have to think about the historical factor to explain this (refugee area for the flora during Quaternary glaciations). We can even translate this to a local scale if we compare the floristic diversity of a mature community such as a forest (temperate or Mediterranean) with a rock crevice or scree community, then we find that the floristic composition of both types is formed by quite different types of plants, not only because of biotype or ecology, but also because of chorology and history. Endemics usually constitute a great part of the floristic set of the crevices communities while in forests they are rare. Concerning this, there is a history of isolation and strong speciation which has long been studied by specialists (Favarger & Contandriopoulos, 1960; Küpfer, 1974).

It can be useful to assess diversity using different formulae, but in general we have to admit that this gives an impoverished idea as far as all species are considered equivalent (Terradas, 2001). Species, even in the same taxocenosis as the vascular plants, play very different roles in the ecosystem (epiphytes, trees, sciophytes, etc. in a forest) and, as pointed out above, can have very different significances from the chorological and historic (biogeographical) point of view. Those differences should be taken into account when assessing the ecologic value of the different communities of a territory.

It is known, as pointed out above, that competition along succession leads to low diversity due to the dominance of the strongest competitors in the mature stages of succession. On the contrary, moderate disturbance rates improve diversity as the number of different habitats increase offering more opportunities for organisms to live and develop in them. Moderately disturbed areas, e.g. those which are submitted to traditional exploitation regimes (dehesa, bocage, etc.), reach high diversity values. The threat nowadays in some developed countries is the modern agricultural exploitation model, where the disturbance regime is much more severe and provokes the replacement of those landscapes by much less diverse ones.

In the general concern of preserving biological diversity, there is the strategy of identifying areas of major biodiversity in order to concentrate protective

efforts upon them. Such areas have been called “hot-spots” (Médail & Quézel, 1997; Myers, 1990) and they can constitute a set of red alert areas to protect biodiversity. For that reason we need a sort of cartography of biodiversity to an adequate scale in order to identify such areas, and a cartography requires a huge amount of information about living beings, information which only reaches a sufficient level in terms of quantity and quality in some areas and for some types of organisms. There is an urgent need to improve the catalogues and inventories in the areas and groups where knowledge and data are insufficient.

### Vegetation as indicator of biological diversity

If we want to be efficient when designing a strategy for conservation of biodiversity, it is necessary to focus on the groups which are particularly relevant in the functional processes of the ecosystems or those that are good indicators of them (Terradas, 2001).

As stated by Pielou (1991) we can assume that “plant diversity governs animal diversity and is itself governed by the abiotic environment”. Then, vegetation is a very useful element as an indicator of biological diversity of terrestrial ecosystems in all its aspects and levels. The advantages of vegetation can be quoted as follows:

1. Vegetation assembles the primary producers of all terrestrial ecosystems;
2. Vegetation provides the structure as well as most of the biomass to the terrestrial ecosystems;
3. Most of the components of the terrestrial vegetation, vascular plants and bryophytes, are known to science. They are one of the taxonomically best studied group of organisms and this permits us to use very important information which is contained in the specific level of diversity. The profitable use of this information is far from being accurately performed. To use the huge number of species at a global scale introduces the problem of how to process this information and how many people should be involved in such a data processing. To avoid this, the Plant Functional Types approach has been developed in order to reduce the vegetation to a few types. Such PTFs approach can be useful for some purposes but for biodiversity, species contain such rich and valuable information that it would be unforgivable to miss it;
4. Vegetation is easy to inventory, specially in the form of maps, which provide the land managers with an extremely useful tool for management.

### The phytosociological data as an inventory of biodiversity

Several attempts have been made to use plant communities for biodiversity assessment, mostly targeted for conservation purposes in different parts of the world (Costa *et al.*, 1999; Ewald, 2002; Gould & Walker, 1999; Matthews *et al.*, 1999; Rey & Scheiner, 2002), obtaining valuable results at different scales, but we are still far from obtaining all the possible information on biological diversity by means of the analysis of plant communities and the data accumulated along many decades of field work. The studies of Gould & Walker (1997, 1999) use the phytosociological typology of the plant communities of a small area for an analysis extracting some interesting conclusions such as that the site species diversity of an area ( $\gamma$ ) is correlated with the number of community types and their distinctiveness ( $\beta$ ) rather than with the within community diversity ( $\alpha$ ). The floristic richness of each community is not related with the total floristic richness of an area but the latter is affected by the landscape heterogeneity and the distinctiveness of the plant communities. This reveals that the diversity at these two scales is determined by different factors. Ewald (2002) assesses the diversity of the understorey in several forest associations in the Alps.

An extremely interesting paper is that by Karrer (1994) who analyses the diversity elements included in a phytosociological table and applies the Shannon index to the relevés set. Other attempts to quantify diversity using the Shannon-Weaver index have been carried out by Peñas (1997) applying it to samples of scrub communities in southern Spain previously determined by phytosociological procedures.

Another interesting approach has been made by Decoq (2002) who has analysed biodiversity at several levels: synusia, phytocoenosis, tesela (sigmetum) and catena (geosigmetum) in a river basin applying the Shannon and Pielou's indexes in an attempt to establish relationships with disturbance regimes and stress intensities. A particularly valuable and complete work which facilitate the use of phytosociological relevés in the assessment of biodiversity is that of Haeupler (1982) focused on the estimation of the evenness of the plant communities from the field data.

As stated by Van der Maarel (1997), vegetation science (phytosociology p.p.max) with the large tradition in vegetation mapping and in typifying plant communities, offers a wide set of tools for approaching inventories of ecosystem diversity. When thinking about phytosociology as a data source for biodiversity assessment, it is

necessary to understand that the phytosociological data sampling has mostly been carried out with the purpose of defining community types or syntaxa (syntaxonomical construction), not with the aim of assessing phytodiversity in any way. Nevertheless, we now have the legacy of a huge bulk of data which, although unevenly distributed across the European continent, deserve some sort of treatment in order to exploit them for estimations of biodiversity. Only for Spain and Portugal the last compilation (Rivas-Martínez *et al.*, 2001) has achieved over 2,500 associations for the Iberian Peninsula and the islands. Another apportionation, of lower accuracy but of broader scope, is the recent synthetic compilation of the diversity of European vegetation (Rodwell *et al.*, 2002) which compiles 928 alliances for that continent.

According to Haeupler (1982) and Karrer (1994), there are several diversity elements contained in a plant community as defined in phytosociology:

❖ At the infraspecific level

Individuals, clones  
Age classes  
Size types  
Ecotypes  
Charyotypes

❖ At the specific level

Species, populations  
Quantitative relationships (density, etc.)  
Sociability and vitality degree

❖ At the supraspecific level

Life forms  
Size classes  
Caryotypes (preguntar genética)  
Phenologic groups  
Ecologic groups  
Phytosociologic groups  
Flower-ecology groups  
Dispersal strategies groups  
Chorologic groups  
Metabolic groups  
Hemerobic groups  
Productivity groups  
Synusiae

We can think about some of the advantages of the phytosociological information:

✧ *Cost*

It is assumed that for practical reasons it is convenient

to collect the necessary field data quickly and cheaply and the results obtained must be meaningful to land managers and to professional ecologists (Pielou, 1991). Under this criterion, phytosociological data collecting results highly adequate as it is a procedure with low economic and time costs, the data can be easily stored and are easy to interpret for management purposes.

✧ *Methodological homogeneity*

An important advantage of the phytosociological data is that all researchers have been working following a standard methodology, all the data have been collected more or less in the same way and become comparable to a certain extent. This has permitted to them to be used as a unique set for typological purposes, regardless of the author, the origin or the time when they have been taken.

✧ *Size and extent of the data set*

As a unified procedure, most of the data collected in the history (relevés) are comparable and form a huge data mass over large areas which constitutes an invaluable data set. It is known that about  $3 \times 10^9$  exemplars exist stored in all the Natural History collections of the world belonging to all types of organisms collected during the last 300 years by generations of botanists, zoologists and other specialists. A part of them are plants of all the herbaria, and they constitute the reference collections on which the knowledge of the plant diversity of the world is based. But how big is the data set of phytosociological relevés?. For almost a century, phytosociologists of several generations have accumulated hundreds of thousands of relevés mostly in Europe which constitute nowadays perhaps one of the most valuable data set of nature resources existing today in our continent. Those have been probably some of the reasons why the European Union decided to use phytosociological units to describe a major part of the habitats list (annex 1) in the Habitats Directive.

### Attributes of the phytosociological data

Synthetic units of syntaxonomy, specially those of lower ranks, i.e. Associations and subassociations, establish community types perfectly identifiable with habitats types and the data supporting those units include a complete information of the vascular plants forming them: the species, their frequency and their abundance. This is a sort of quantification of phytodiversity.

✧ If we consider a phytosociological table, it is possible

to consider it as an expression of the  $\alpha$  diversity (concerning vascular plants) of a particular habitat. Its expression will be the species list.

- \* The associations present in an area can represent the  $\beta$  diversity, as they summarize the diverse existing habitats. Environmental heterogeneity will multiply the community types and increase their differences. The assessment of this  $\beta$  diversity using those syntaxa needs a sort of inventory or quantification of the relative abundance and distribution of each type together with the assessment of their reciprocal degree of distinctiveness. This can be calculated using the similarity-dissimilarity indices combined with the abundance assessment of each type or using presence-absence data (Wilson & Shmida, 1984). The cartography of those community types with the subsequent quantification using image analysis will be an important approach in the near future. It is evident that vegetation mapping provides spatially distributed information relevant not only for assessment but also for modeling the distribution of wildlife and planning its management.
- \* The complete set of plant communities of an area contain practically the total number of plant species, i. e. the  $\gamma$  diversity.

As the genetic and taxonomical levels of biodiversity are insufficient to develop correct strategies for conservation because they do not reflect patterns and processes which have a spatial dimension (Cabello *et al.*, 2001), the ecosystem, landscape and geographical levels have to be worked out. In those spatial dimensions, one of the tools provided by syntaxonomy is the use of the different units of various syntaxonomical ranks produced by the synsystematic. This permits us to use units adapted to different geographical scales, from local to continental, for estimations of biodiversity. Another approach, much more important, is that developed by the so called Integrated Phytosociology (Alcaraz, 1996) also called Dynamic-Zonal Phytosociology, which organises the plant communities under two principles: dynamism and ecological gradient. Dynamic phytosociology established the concept of sismetum a few decades ago. This includes all the community types which are linked by dynamical relationships in an ecologically homogeneous area (tesella in the sense of Bolòs 1963). The different sigmata can also be ordered in geosigmata following the gradients found in an area. This permits us to organize the landscape mosaic units defined by syntaxonomy in a double frame: dynamic and zonal, offering an interesting model for a systematic study of

the landscape diversity. As mentioned above, such analysis has been tested recently by Decoq (2002) and an approach of assessment of biodiversity in the spatial dimension has been made by Cabello *et al.* (2001) using three hierarchical levels with units partially based on concepts produced by Integrated Phytosociology.

A landscape will be more diverse the more different the units in the mosaic are and the smaller the sizes of these units (grain). Those elements are function of two groups of factors:

The ANTHROPIC factor (cultural): the model of land use, the man-induced perturbation regime, etc. The formalisation of the successional units defined in every ecologically homogeneous area (tesella) results in the sigmata definition.

The NATURAL factor: this can be expressed by the diversity observed between different sigmata due to the ecological heterogeneity of the territory, which results in the zonal ordination of them (geosigmatum).

If we want to approach the geographical level, we can compare how different two separate territories are by comparing their respective geosigmata. Notably, an interesting approach has been carried out by Izco (1998) in comparing different geographical areas through the analysis of the sigmata along several transects.

Summarising, we can glimpse the following aspects of the exploitation of the phytosociological data and units for biodiversity assessment purposes:

- \* It is possible to estimate the  $\alpha$  diversity using the tables of relevés of associations and subassociations
- \* It is possible to estimate the  $\beta$  diversity by assessing the distinctiveness, number and relative abundance of the different associations present in a surveyed area
- \* It is possible to estimate the  $\gamma$  by extracting the total number of lower rank taxa from the tables (unless a complete catalogue is provided)
- \* It could also be possible to consider the  $\phi$  diversity as the total number of syntaxa of lower rank (community types) of a given territory, parallel to the  $\gamma$  diversity for species.
- \* It could be possible to estimate diversity degrees at various landscape and geographical scales by using the concepts and units provided by the Integrated Phytosociology or Dynamic-Zonal Phytosociology

Perhaps we can accept an additional definition of Phytosociology as an *intersection of phytodiversity and ecology*. Indeed, this definition highlights an aspect which is also intrinsic to the nature of the data sampled in the field work of phytosociologists because those data are species lists with estimations of cover-abundance

of each species, taken in a sampling plot defined by the site conditions and homogeneous structure. The plant community types are thus determined by the site conditions and constituted by the grouping of the species performing a balance between floristic and ecologic information. In some way it is true that Phytosociology is a discipline which *describes plant diversity in the different habitats and in the landscape*. Thus, the relation with biodiversity becomes evident, it is.... really undissociable.

## References

- Alcaraz F., 1996. Fitosociología integrada, paisaje y biogeografía. In: Loidi, J. (ed.) *Avances en Fitosociología*: 59-94. Ed. Univ. País Vasco.
- Bolòs O. 1963. Botánica y Geografía. Mem. R. Acad. Ci. Artes Barcelona 34: 443-480.
- Cabello J., Cueto M., Peñas J., Rodríguez-Tamayo M.L. & Mota J.F., 2001. Cartografía jerárquica de la vegetación: una aproximación metodológica al inventario de la biodiversidad en los subdesiertos de Almería. In: Cano, E. et al. (eds.) *Valoración y gestión de espacios naturales*: 269-280.
- Costa J.C., Capelo J., Espirito Santo M.D., Lousã M., Monteiro A., Mesquita S., Vasconcelos M.T. & Moreira I., 1999. Plant communities of the lagoons of the Portuguese Coastal Superdistrict – a multivariate approach. *Hydrobiologia* 415: 67-75.
- Decoq G., 2002. Patterns of plant species and community diversity at different organization levels in a forested riparian landscape. *J. Veg. Sci.* 13: 91-106.
- Ewald J., 2002. Understorey plant richness in mountain forests of the Bavarian Alps. *Phytocoenologia* 32 (1): 85-100.
- Favarger C. & Contandriopoulos J., 1960. Essai sur l'endémisme. *Bull. Soc. Bot. Suisse* 71: 384-408.
- Gaston K.J., 1996a. What is biodiversity?. In: Gaston, K.J. (ed.) *Biodiversity. A biology of numbers and difference*: 1-9. Blackwell Science Ltd.
- Gaston K.J., 1996b. Species richness: measure and measurement. In: Gaston, K.J. (ed.) *Biodiversity. A biology of numbers and difference*: 77-113. Blackwell Science Ltd.
- Gitay H. & Noble I.R., 1997. What are Plant Functional Types and how should we seek them? In: Smith, T.M., H.H. Shugart & F.I. Woodward (eds.) *Plant functional types. Their relevance to ecosystem properties and global change*: 3-19. Cambridge Univ. Press.
- González Bernáldez F., 1991. Diversidad biológica, gestión de ecosistemas y nuevas políticas agrarias. In: Pineda, F.D. et al. (eds.) *Diversidad biológica*: 23-31. Fund. Ramón Areces. Madrid.
- Gould W.A. & Walker M.D., 1997. Landscape-scale patterns in plant species richness along an arctic river. *Can. J. Bot.* 75: 1748-1765.
- Gould W.A. & Walker M.D., 1999. Plant communities and landscape diversity along a Canadian Arctic river. *J. Veg. Sci.* 10: 537-548.
- Haeupler H., 1982. Evenness als Ausdruck der Vielfalt in der Vegetation. Untersuchungen zur Diversitäts Begriff. *Dissertationes Botanicae* 65. 268 pp. Cramer. Vaduz.
- Hawksworth D.L. & Kalin-Arroyo M.T., 1995. Magnitude and distribution of biodiversity. In: Heywood (ed.) *Global Biodiversity Assessment*: 107-191. UNEP. Cambridge Univ. Press.
- Heywood V. & Baste I., 1995. Introduction. In: Heywood (ed.) *Global Biodiversity Assessment*: 1-19. UNEP. Cambridge Univ. Press.
- Izco J., 1998. Diversidad fitosociológica. Riqueza de cabezas de series sucesionales en relación con la altitud. *Acta Bot. Barc.* 45 (Homenatge a Oriol de Bolòs): 525-534.
- Karrer G., 1994. Nachhaltigkeit und Biodiversität in Wäldern – aus der Sicht der Vegetationskunde. In: Trzesniowski, A. (ed.) *Dimensionen de Nachhaltigkeit. XX Tagung der Fachgruppe Wald- und Holzwissenschaften*. Univ. f. Bodenkultur Wien: 45-61. Wien.
- Küpfer P., 1974. Recherches sur les liens de parenté entre la flore orophile des Alpes et celle des Pyrénées. *Boissiera* 23: 1-322.
- Leakey R. & Lewin R., 1996. *The sixth extinction: Patterns of life and the future of humankind*. Doubleday, Anchor, New York.
- Magurran A.E., 1988. *Ecological diversity and its measurement*. Princeton Univ. Press. Princeton.
- Margalef R., 1962. La teoría de la información en Ecología. *Mem. R. Acad. Ciencias y Artes de Barcelona* 32: 13.
- Margalef R., 1991. Reflexiones sobre la diversidad y significado de su expresión cualitativa. In: Pineda, F.D. et al. (eds.) *Diversidad biológica*: 105-112. Fund. Ramón Areces. Madrid.
- Margalef R., 1974. *Ecología*. Ed. Omega. 951 pp. Barcelona.
- Matthews W.S., Van Wyk A.E. & Van Rooyen N., 1999. Vegetation of the Sileza Nature Reserve and neighbouring areas, South Africa, and its importance in conserving the woody grasslands of the Maputaland Centre of Endemism. *Bothalia* 29 (1): 151-167.
- Médail F. & Quézel P., 1997. Hot-spots analysis for conservation of plant biodiversity in the Mediterranean basin. *Ann. Missouri Bot. Gard.* 84: 112-127.
- Myers N., 1990. The biodiversity challenge: Expanded hot-spots analysis. *The Environmentalist* 10: 243-256.
- Noss R.F., 1997. Hierarchical indicators for monitoring changes in biodiversity. In: Meffe, G.K. & C.R. Carroll

- (eds.) Principles of conservation biology 2<sup>nd</sup> ed.: 88-89. Sinauer Publ. Sunderland.
- Peñas J., 1997. Estudio fitocenológico y biogeográfico de la sierra de los Filabres (Andalucía Oriental, España). Análisis de la diversidad de los matorrales. Tesis Doctoral. Univ. Granada.
- Pielou E.C., 1991. The many meanings of diversity. In: Pineda, F.D. *et al.* (eds.) *Diversidad biológica*: 113-115. Fund. Ramón Areces. Madrid.
- Primack R.B., 1998. *Essentials of conservation biology*. 2nd ed. Sinauer Publ. Sunderland.
- Raunkjaer O., 1916. *Life form and terrestrial plant geography*. Clarendon Press. London.
- Rey Benayas J.M. & Scheiner S.M., 2002. Plant diversity, biogeography and environment in Iberia: patterns and possible causal factors. *J. Veg. Sci.* 13: 245-258.
- Rivas-Martínez S., Fernández-González F., Loidi J., Lousã M. & Penas A., 2001. Syntaxonomical checklist of vascular plant communities of Spain and Portugal to association level. *Itinera Geobot.* 14: 5-341.
- Rodwell J.S., Schaminée J.H.J., Mucina L., Pignatti S., Dring J. & Moss D., 2002. The Diversity of European Vegetation. An overview of phytosociological alliances and their relationships to EUNIS habitats. EC-LNV. Report nr. 202/054. Wageningen, NL.
- Shannon C.E. & Weaver W., 1963. *The mathematical theory of communication*. Univ. Illinois Press. Urbana.
- Simpson E.H., 1949. Measurements of diversity. *Nature* 163: 688.
- Terradas J., 2001. *Ecología de la vegetación. De la ecofisiología de las plantas a la dinámica de comunidades y paisajes*. Ed. Omega 703 pp. Barcelona.
- Usher M.B., 1991. Biodiversity: a scientific challenge for resource managers in the 1990s. In: Pineda, F.D. *et al.* (eds.) *Diversidad biológica*: 33-40. Fund. Ramón Areces. Madrid.
- Van der Maarel E., 1997. *Biodiversity: from Babel to biosphere management*. 60 pp. Opulus Press.
- Whittaker R.H., 1960. Vegetation in the Siskiyou Mountains, Oregon and California. *Ecological Monographs* 30: 279-338.
- Whittaker R.H., 1972. Evolution and measurement of species diversity. *Taxon* 21: 213-251.
- Wilson M.V. & Shmida A., 1984. Measuring beta diversity with presence-absence data. *Journal of Ecology* 72: 1055-1064.