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MULTIVARIATE ANALYSIS – A TOOL FOR BRYOSOCIOLOGICAL STUDIES. CASE STUDY FOR THE BRYOPHYTE EPIPHYTIC COMMUNITIES FROM THE UPPER ARIEŞ RIVER BASIN (ROMANIA)

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Abstract: The research has been performed in the upper basin of the Arieş River (Apuseni Mountains), an area of *c*.580 km^2. 11 associations and two subassociations have been identified on tree bark. They belong to 3 classes, 4 orders and 4 alliances. Most of these communities are recorded from *Fagus* bark, three associations have been identified from *Salix* trunks. Less suitable for the development of bryophyte communities are *Picea, Abies, Fraxinus* and *Malus*, probably because their bark contains more tannins and resins.

The bryophyte communities were established using the characteristic species according to Marstaller (1993). For a better identification of the bryophyte communities, different dendrograms have been performed, using quantitative and qualitative index. The Spearman correlation facilitated the species diagram, which marks out the coenotic core. The ordination denotes the fine ecological differences among communities.

Keywords: epiphytic bryophyte communities, hierarchical clustering, correlations, ordination.

Introduction

Bryophytes are one of the main components of forest communities, playing here an important role in species richness. Due to their bioindicator values, mosses are among the first organisms to react to subtle modifications in the quality of the environment, especially concerning humidity [8]. Knowledge about the structure of bryophyte communities represents an important instrument in the evaluation of the quality of the natural habitat. The purpose of the present paper is to augment the classical methods of identification of epiphytic moss communities, using more modern methods (classifications, ordinations, correlations).

The research has been carried out in the upper basin of the Arieş River, located in the north-western part of Romania (northern Apuseni Mountains), and covering an area of 580 km^2. A large part of the left side of the Arieş River belongs to the Natural Park of the Apuseni Mountains. The highest altitude is at 1849 m on the Biharia Peak and the lowest is 565 m, at the confluence between the Arieşul Mic and Arieşul Mare Rivers. The study area has an amphitheatre shape, bordered by the main peaks of the Bihor Mountains, the Găina Massif and the western part of the Muntele Mare Mountains.

The region has a mountain climate, with an average annual temperature of 7.5 ^{o}C and an average annual precipitation of 724 mm. The high altitude determines a change of this climatic

factor, with average annual temperature decreasing from the base of the mountain (7.5 ^{o}C), towards the top (3 ^{o}C).

Under these conditions beech, spruce and mixed forests predominate. Oak and hornbeam trees occur only in small stands, towards the lower limit of the study area. The riparian forests have been dramatically reduced to a few, small patches and isolated trees (mostly willows and alders) along streams.

The Apuseni Mountains represent an interesting region for all naturalists. Numerous publications mention bryophyte species from this region: Fuss, Győrffy, Schiffner, Papp, Ştefureac, Boros & Vajda, Plămadă, Péterfi, Goia, Goia & Schumacker [4,5,6].

Method

A total of 82 epiphytic relevés have been recorded according to the methodology of the Central European School. Bryophyte communities have been inventoried on living trees of different ages and species: *Fagus sylvatica, Carpinus betulus, Picea abies, Salix alba, Fraxinus excelsior* and *Malus domestica.*

The sample area varied between 100 cm^2 and 3 m^2 depending on the phytocoenosis cover. The aspect, the inclination of the sample surface, the altitude, the general coverage, and the species of the host tree, were recorded in each relevée. The abundance-dominance has been assigned for each species, according to the Braun-Blanquet scale modified by Tüxen and Ellenberg [3]. We adopted the coeno-taxonomic system published by Marstaller [10].

The classification into associations has been accomplished both on the basis of classical methods – with special regard to the characteristic species [5] – and by means of statistical methods (hierarchical classification, ordinations, correlations). Multivariate analysis has been achieved using SINTAX 5.0 [9]. The ordination has been carried out with PC-ORD 3.01, using *Detrended Correspondnce Analyssis* (DCA). Due to the large number of relevés, for every association, we have used a synthetic relevé, in which, for every species, *Combinated Synoptic Value* (CSV=ADm * K) was calculated, resulting in a reduced matrix.

The results obtained, shown as a diagram, permit the distribution, in a narrow space and in terms of eco-coenotic gradient, of the associations and of the species. This is deduced on the basis of the ecological valences of the species and on their methods of grouping. Among the large number of species, only a few have an elevated Tau correlation towards the axis. These correlations are represented on the diagram.

The correlation has been established by means of Spearman coefficient, using species-relevés matrix.

The species nomenclature was updated according to Grolle [7] for liverworts and Corley & *al.* and Corley & Crundwell [1,2] for mosses.

Results and Discussions

The present study reveals the existence of 11 bryophytes associations and two subassociations in the upper Arieş Basin, classified into three suballiances, four alliances, four orders and three classes as follows:

I. FRULLANIO-LEUCODONTETEA SCIUROIDIS Mohan 1978 em. Marst. 1985
Orthotrichetalia Had. in Kl. et Had. 1944
Ulotion crispae Barkm.1958
1. *Orthotrichetum pallentis* Ochsn. 1928
2. *Pylaisietum polyanthae* Felf. 1941
- *orthotrichetosum obtusifoliae* Marst. 1985

II. NECKERETEA COMPLANATAE Marst. 1986
Neckeretalia complanatae Jez. et Vondr. 1962
Neckerion complanatae Šm. et Had. 1944
Pseudoleskeello nervosae - Homomallienion incurvati Marst.1992
3. *Pterigynandretum filiformis* Hil. 1925
4. *Homalothecio sericei - Porelletum platyphyllae* Størm. 1938
Brachythecio populei - Homalienion trichomanoidis Marst. 1992
5. *Anomodontetum attenuati* Cain et Sharp 1938
6. *Brachythecietum populei* Phil. 1972
7. *Isothecietum myuri* Hil. 1925
Neckerenion complanato - besseri Marst. 1992
8. *Anomodonto viticulosi - Leucodontetum sciuroidis* Wisn. 1930

III. CLADONIO - LEPIDOZIETEA REPTANTIS Jez. et Vondr. 1962 em. Marst. 1993
Dicranetalia scoparii Barkm. 1958
Dicrano scoparii - Hypnion filiformis Barkm. 1958
9. *Dicrano scoparii - Hypnetum filiformis* Barkm. 1958
- *plagiothecietosum laeti* Marst. 1986
10. *Orthodicrano montani - Hypnetum filiformis* Wisn. 1930
Brachythecietalia rutabulo - salebrosi Marst. 1981
Bryo - Brachythecion Lec. 1975 em. Marst. 1987
11. *Brachythecio salebrosi - Drepanocladetum uncinati* Marst. 1989

The identification of the associations was made, first, by means of classical methods – based on the characteristic species and then by hierarchical classifications, using several methods (Minimum variety of new clusters, Complete Linkage, Group average) and coefficients (for binary data – Sorensen, and for ratio data scale – Bray-Curtis and Similarity ratio). The relevés which did not fit within the desired cluster (according to the classical methods) were reviewed. These methods and indexes have been applied to the entire matrix (containing all relevés), as well as to the reduced matrix (from which the species which were present in only one relevée, with a minimal value of abundance-dominance (+=0.5%) were eliminated). In some cases, this method facilitated the correct framing based on species recognition. In the case of corticolous communities, the quantitative indices, especially Bray-Curtis, were those that better reflected the grouping of the relevés, mainly in case of some different inter-stages sequence transitions (Fig. 1).

Concerning the vegetation classes which represent the corticolous moss communities, *Neckeretea complanatae* Marst. 1986 and *Frullanio - Leucodontetea sciuroidis* classes Mohan 1978 em. Marst. 1985 are separated in different clusters and better delimited in the case of using the quantitative index, especially by using the *Minimum variance* procedure. The Bray–Curtis

index is applied for the reduced matrix. The largest cluster contains the phytocoenoses from the *Cladonio - Lepidozietea reptantis* class Jez. et Vondr. 1962 em. Marst. 1993; the biggest part belongs to a subcluster that is considered transitional towards the sapro-lignicolous communities. The transition becomes possible in the case of a bark richer in tannins and resins offered by conifers or willows.

Among all corticolous species, a very good correlation exists between the species of the *Frullanio-Leucodontetea sciuroidis* class Mohan 1978 em. Marst. 1985 or its subunits (Fig. 2). We have to mention the case of the species *Pylaisia polyantha, Orthotrichum stramineum* and *Orthotrichum speciosum*. *Orthotrichum obtusifolium* is very well correlated with this species, although in the bryological literature the coenotaxonomic value could be considered characteristic for the order *Orthotrichetalia* Had. in Kl. et Had. 1944. The species *Frullania dilatata, Radula complanata* also present high values of correlation, thus occurring frequently in the bryocoenoses of the *Neckeretea complanatae* class Marst. 1986.

Metzgeria furcata is considered to be differential for the *Ulotion crispae* alliance Barkm. 1958 and characteristic for the *Neckeretea complanatae* class Marst. 1986. The values of the correlation index argue the species value characteristic to the entire class, but our data show that it is not significantly correlated with the species from the *Ulotion crispae* alliance Barkm. 1958.

Leucodon sciuroides is very well correlated with *Frullania dilatata* and well correlated with *Orthotrichum stramineum.* This species, due to its broad ecological amplitude represents a link between the two classes of corticolous bryophytes.

Pseudoleskeella nervosa is well correlated with the characteristic or illustrating species from the *Neckeretea complanatae* class Marst. 1986.

Concerning the association's ordination (Fig. 3) it presents a distribution along the axis, starting from the pioneer stages of the bark and heading towards communities developed on rotten wood. As a result, in the case of the first axis, the predominant factor is the chemical reaction of the bark. In relation to the second axis a much larger continuity appears, on one side the communities and species being present which tolerate dryness and low luminosity, and on the other limit, species and communities preferring a moderate and constant atmospheric humidity.

Final considerations

The modern methods of multivariate analysis come to support coeno-taxonomy, facilitating a much more careful framing of the phytocoenoses in certain associations and also the capture of a few ecological or successional aspects. The analysis of dendrograms, ordinations and correlations, confirm the system proposed by Marstaller, 1993, which we have chosen initially only because we have considered it to be much more complete, due to a much richer data base.

The best grouping of the bryocoenoses was made only in the case of the dendrograms obtained based on the quantitative indexes. The associations represented by a small number of relevés are meagrely grouped, because they cannot manage to impose themselves as a coeno-taxonomic entity, lining up to other clusters, especially when they have the same ecological or successional preferences.

The successional stages have a progressive feature determined by the change in the wood chemistry. The species dominant in the diverse succesional stages comprised in eco-coenotic groups, by a high correlation, and the ecological gradient responsible for this dynamic are represented by indirect ordinations.

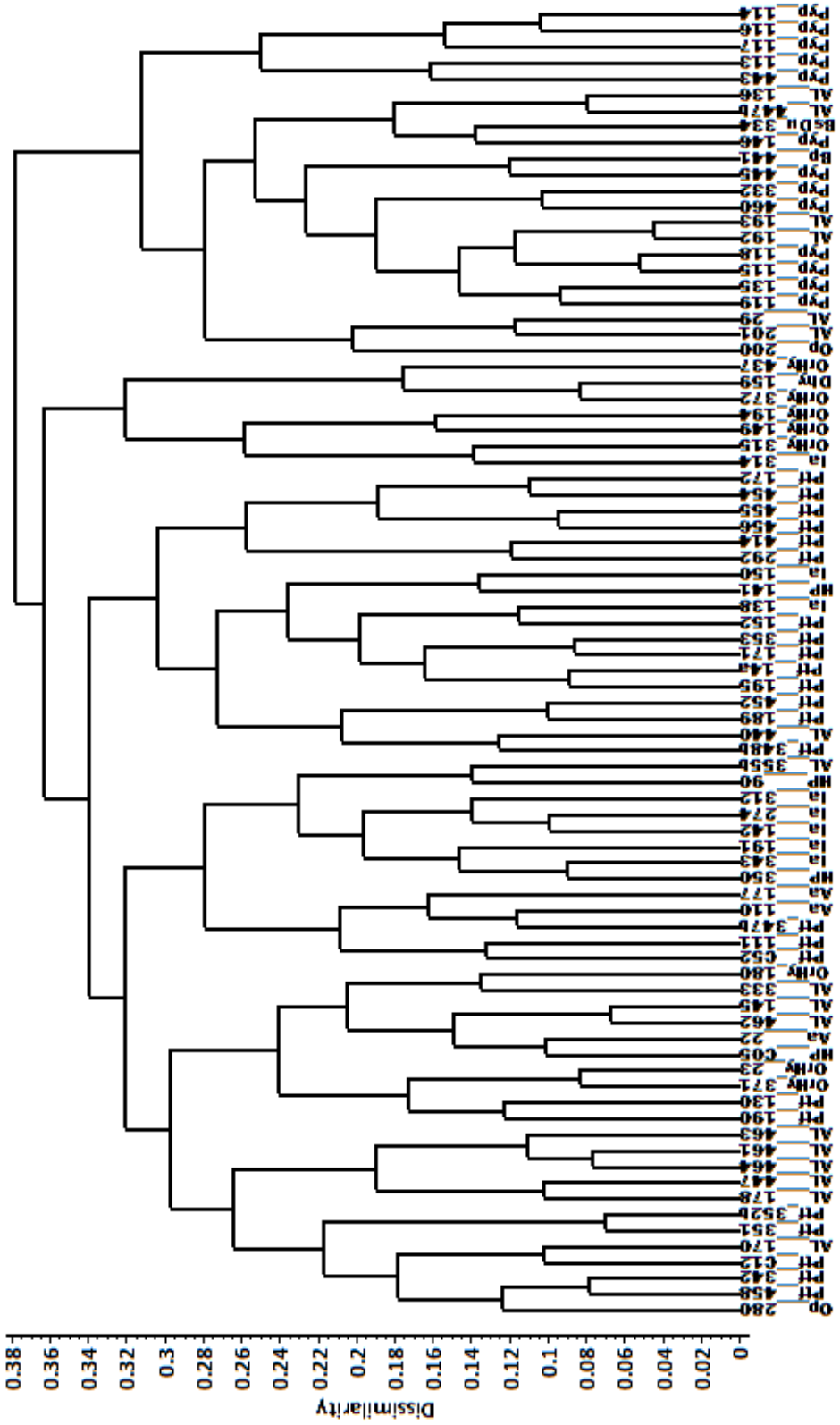
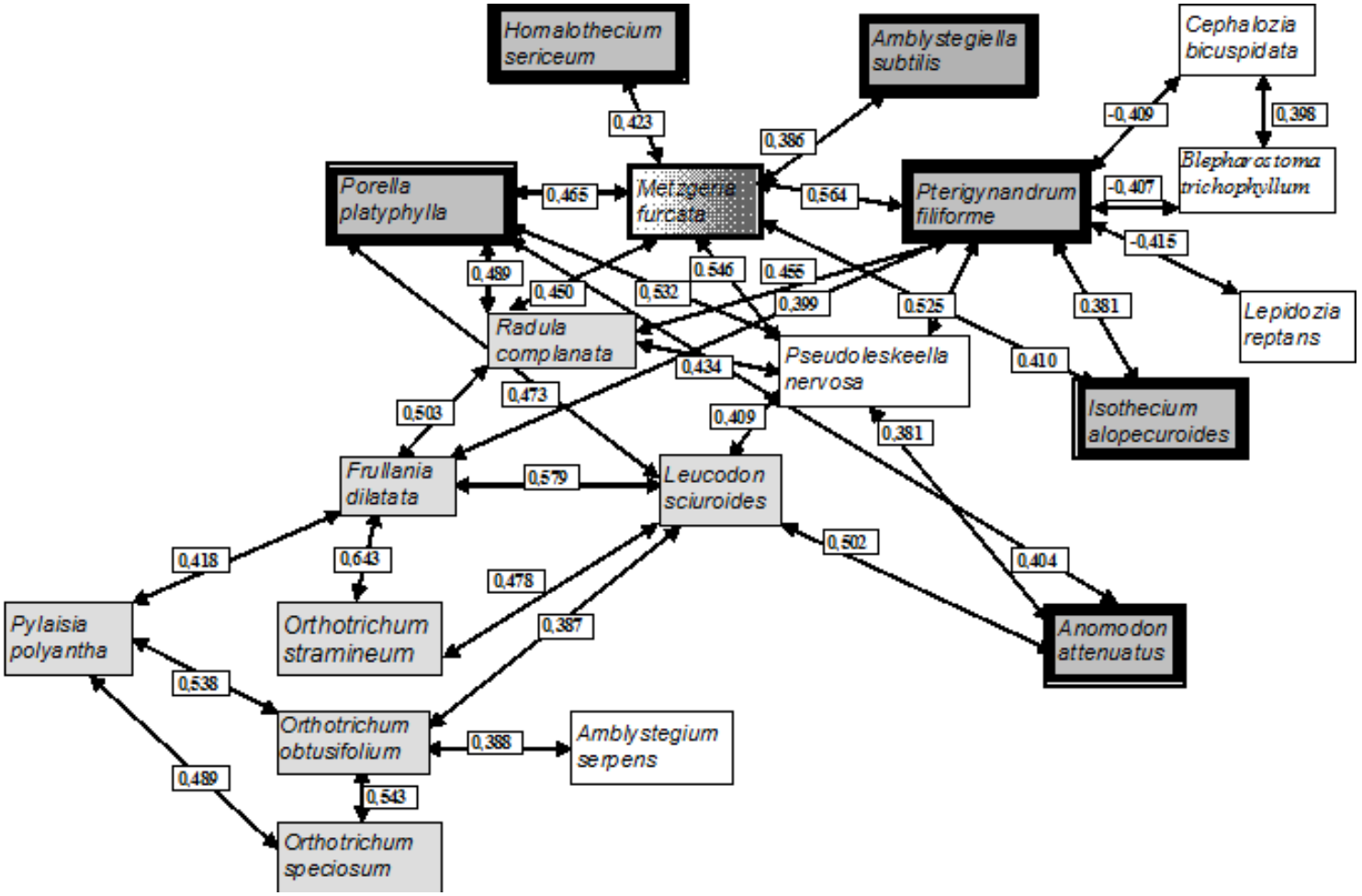


Fig. 1: Hierarchical classification of the epiphytic bryophyte communities (Minimum variance of new clusters/Bray Curtis) for the reduced matrix.



Species with coenotaxonomical value from the *Neckeretea complanatae* class

Species with coenotaxonomical value from the *Frullanio-Leucodontetea* class

Species with coenotaxonomical value from the *Frullanio-Leucodontetea* class and characteristic to the *Neckeretea complanatae* class

Fig. 2: Significant correlation (p<0,0001) between corticolous species

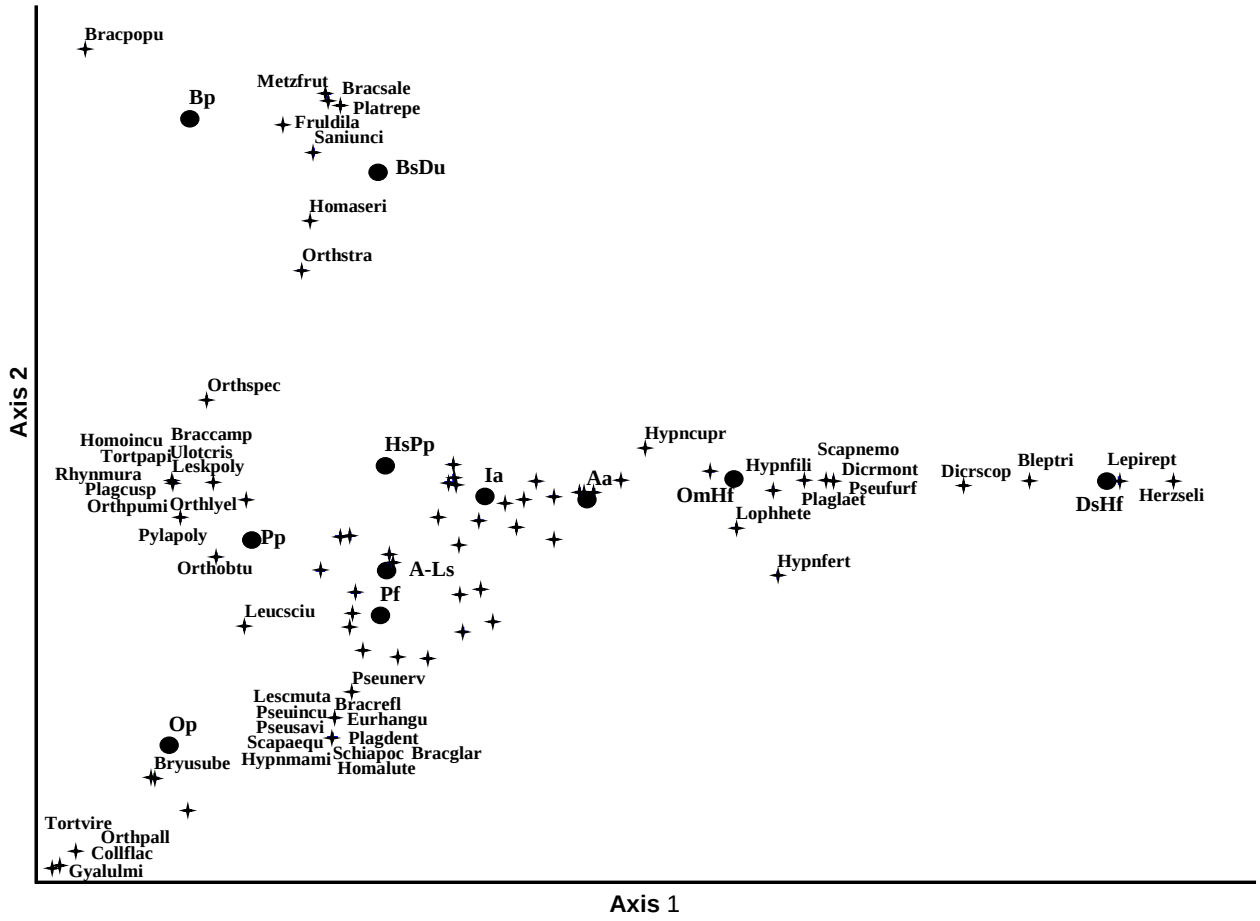


Fig. 3: Indirect ordination of the epixylic relevés and species from the upper Basin of the Arieş River

The knowledge concerning eco-coenotic groups allow us to make a few assumptions regarding biodiversity, these species being the representatives of some well-established assemblies. Changes in the number of species of the moss communities are the consequence of the variation of some environmental parameters, especially the chemical reaction of the bark and humidity. Their high sensibility to environmental changes requests an appropriate forest management, considering all components of biodiversity.

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ANALIZA MULTIVARIATĂ, UN INSTRUMENT ÎN STUDIILE BRIOSOCIOLOGICE - STUDIU DE CAZ DIN BAZINUL SUPERIOR AL ARIEȘULUI (ROMANIA)

(Rezumat)

Studiile au fost efectuate în bazinul superior al Arieșului (Munții Apuseni), pe o suprafață de cca. 580 km^2. Pe ritidomul arborilor au fost identificate 11 asociații și 2 subasociații, ce sunt încadrate în trei clase, 4 ordine și 4 alianțe. Cele mai multe comunități au fost identificate pe ritidom de fag, trei asociații au fost identificate pe sălcii. Ritidomul de *Picea*, *Abies*, *Fraxinus* și *Malus* este mai puțin propice dezvoltării comunităților de briofite, probabil datorită conținutului mai ridicat de taninuri și rezine.

Încadraea comuntăților de briofite s-a realizat pe baza speciilor caracteristice conform sistemului de clasificare propus de Marstaller (1993). S-au realizat mai multe dendrograme, folosind indici calitativi și cantitativi, pentru o mai bună identificare asociațiilor. Diagrama realizată pe baza corelațiilor Spearman, a pus în evidență nucleul cenotic. Diferențele ecologice fine între diferitele asociații s-au pus în evidență cu ajutorul ordonărilor.

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