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FLORISTIC AND COMMUNITY DIVERSITY OF SUB-ALPINE AND ALPINE GRASSLANDS AND GRAZED DWARF-SHRUB HEATHS IN THE ROMANIAN CARPATHIANS

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SUMMARY.- Floristic diversity at community level and community diversity at landscape level are presented for the main grassland and dwarf-shrub communities in the sub-alpine and alpine zones in five mountain ranges of the Romanian Carpathians. The 30 plant communities studied had their floristic composition and distribution determined by geological substratum and pedo-climatic factors. The most diverse grasslands (Oxytropido-Elynetum, Seslerio haynaldianae-Caricetum) *were on calcareous substratum and on the mountain slopes* (Festucetum pictae), *whilst the lowest diversity was in the oligo-mesotrophic sub-alpine grasslands* (Scorzonero-Festucetum nigricantis, Alchemillo-Poetum alpinae, Violo-Nardetum). *The Shannon-Weaver diversity index for the communities increased almost linearly with the number of species per community, whilst community diversity in the five mountain ranges was a function of the number of communities per mountain range.*

RÉSUMÉ.-Nous présentons dans ce travail la diversité floristique au niveau de la communauté et la diversité de communautés au niveau du paysage pour les principaux types de paturages et de communautés à petits arbustes des étages subalpin et alpin de cinq chaines montagneuses des Carpathes en Roumanie. Aussi bien la composition floristique que la distribution des 30 communautés étudiées dépendent de la nature géologique du terrain et des facteurs édapho-climatiques. Les paturages les plus riches en diversité (Oxytropido-Elynetum, Seslerio haynaldianae-Caricetum) *se developpent sur substrat calcaire et sur les versants des montagnes* (Festucetum pictae); *par contre la plus faible diversité a été rencontrée dans les paturages oligo-mesotrophes subalpins* (Scorzonero-Festucetum nigricantis, Alchemillo-Poetum alpinae, Violo-Nardetum). *L'index de diversité de Shannon-Weaver augmente quasi linéairement avec le nombre d'espèces de chaque communauté, tandis que la diversité des communautés dans les cinq chaines était conditionné par le nombre total des communautés dans chaque cordillère.*

RESUMEN.-Damos a conocer la diversidad florística a nivel de comunidad y la diversidad de comunidades a nivel de paisaje para los principales pastos y matorrales bajos de los pisos subalpino alpino en cinco cordilleras de los Cárpatos rumanos. Tanto la composición florística como la distribución de las 30 comunidades vegetales estudiadas vienen condicionadas por el sustrato geológico y los factores edafo-climáticos Los pastos más diversos (Oxytropido-Elynetum, Seslerio haynaldianae-Caricetum) *ocupan terrenos calizos y laderas de montaña* (Festucetum pictae), *mientras que las comunidades más pobres en especies* (Scorzonero-Festucetum nigricantis, Alchemillo-Poetum alpinae, Violo-Nardetum) *eran pastos oligo-mesotróficos subalpinos. El índice de diversidad de Shannon-Weaver sube casi linealmente en relación con el número de especies de cada comunidad, mientras que la diversidad de comunidades en las cinco cordilleras está en relación con el número total de ellas para cada sistema montañoso.*

Keywords: Sub-alpine and alpine grassland, dwarf-shrub heath, vegetation diversity.

1. Introduction

Sub-alpine and alpine grasslands and dwarf-shrub heath communities occur at altitudes between 1700-2500 m a.s.l. in the Romanian Carpathians. In the Eastern Carpathians they can descend about 150 m lower than in the Southern Carpathians because of the more northerly latitude of the former. Sub-alpine and alpine grasslands and dwarf-shrub communities are distinctly different in physiognomy from the saxicolous or chionophilous communities of the alpine zone. Their distribution and diversity are influenced by geological and edaphic factors, topography, and climate (temperature, rainfall and wind).

The areal cover of sub-alpine and alpine grasslands and dwarf-shrub heath has been estimated at 120000 ha (PUŞCARU-SOROCEANU, 1963), which is 2% of the area of the Romanian Carpathians and 0.5% of Romania's surface area.

The sub-alpine and alpine grasslands are defined for the purposes of this study as all plant communities dominated by species of the Poaceae and Cyperaceae which are used in the summer as pastureland for sheep and horses. They comprise four main groups, namely sub-alpine grassland (*Calamagrostion villosae*), oligo-mesotrophic sub-alpine grasslands (*Potentillo-Nardion*), acid alpine grassland (*Caricion curvulae*) and calcicole alpine grassland (*Festuco-Seslerion bielzii*). Dwarf-shrub heath communities include sub-alpine dwarf-shrub and alpine prostate dwarf-shrub heath (*Rhododendro-Vaccinion*).

Community is used inter-changeably with vegetation association in this paper. Floristic (species) diversity is used to describe floristic diversity within

communities and community diversity is used to compare the diversity of individual functional vegetation groups and mountain ranges on the basis of the areal cover of the communities. All species names follow POPESCU & SANDA (1998); community names are after COLDEA (1991).

The aims of the present paper were to (a) compare species diversity among 30 sub-alpine and alpine plant communities (classified into five functional vegetation groups), (b) compare the vegetation diversity among five mountain ranges (Bucegi, Făgăras, Parâng, Retezat and Rodna Mountains) and (c) compare the overall diversity of the functional vegetation types over the five mountain ranges.

2. Material and Method

The sub-alpine and alpine grasslands and dwarf-shrub heaths in the Rodnei, Bucegi, Făgăras, Parâng and Retezat Mountains of the Romanian Carpathians (Figure 1) were selected because the vegetation types cover large areas and had been mapped to scales of 1:50000 and 1:100000 in the above ranges. This made them amenable to estimating areal cover for each community directly from the maps as opposed to other vegetation types of the alpine belt (e.g. saxicolous and chionophilous types) which tend to form only small patches of only some tens of square metres.

We chose one representative relevé for each community from published data for each of the five mountain ranges (PUŞCARU, 1956; BORZA, 1934; GHIŞA, 1941; BUIA, 1962; BOŞCAIU, 1971; COLDEA 1990). Altogether 150 relevés from 43 sites were included and classified into 30 communities using Sørensen similarity coefficient (COLDEA, 1991). Species diversity for individual communities was calculated by using the Shannon-Weaver index (H). For each relevé we replaced the Braun-Blanquet scores (5, 4, 3, 2, 1 and +) by the corresponding mean percentage cover values (87.5%, 62.5%, 37.5%, 17.5%, 5% and 0.1%) after TÜXEN & ELLENBERG (1937). For each community the H values were derived by averaging the diversity indices of corresponding relevés. Thereby the diversity index of a community depended on the number of the species per community and the percentage cover of each species.

The area of every community was determined by planimetry from vegetation maps at scales of either 1:50000 or 1:100000. The 30 communities were divided into five functional vegetation types. Four of these corresponded to phytosociological alliances (*Caricion curvulae, Calamagrostion villosae, Potentillo-Nardion* and *Festuco-Seslerion bielzii*), whilst the fifth (*Rhododendro-Vaccinion*) contained the dwarf-shrub communities of three

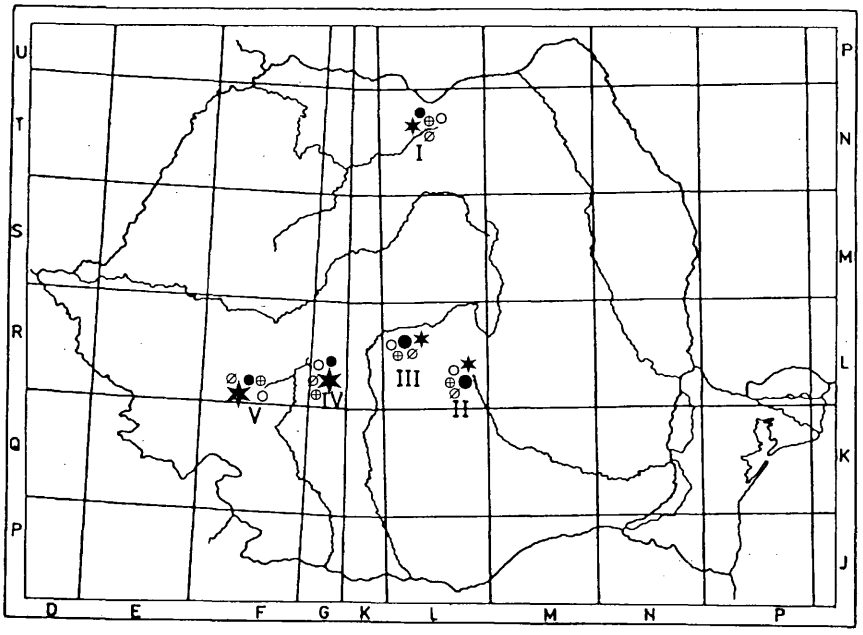

Figure 1. Relative areal cover of the five functional groups comprising sub-alpine and alpine grasslands in five massifs of the Romanian Carpathians: I, Rodnei Mts., II, Bucegi Mts., III, Făgăras Mts., IV, Parâng Mts. and V, Retezat Mts. ● - *Caricion curvulae*, ∅ - *Calamagrostion villosae*, O - *Festuco-Seslerion bielzii*, ✳ - *Potentillo-Nardion* and ⊕ - *Rhododendro-Vaccinion*. Symbol size is proportional to percentage cover: small, 0-25%, medium, 26-50% and large, > 51%.

different alliances (*Loiseleurio-Vaccinion, Rhododendro-Vaccinion* and *Junipero-Bruckenthalion* (BOŞCAIU, 1971; COLDEA 1991). When calculating community diversity, we used the area measurements for each community in proportion to the total area of each functional vegetation type over the five mountain ranges, or the total area occupied by the sub-alpine and alpine communities in each mountain range after THOMPSON & BROWN (1992).

The Shannon-Weaver index was calculated for every mountain range/functional vegetation group according to the formula:

$$H = -\sum_{i=1}^{s} P_i \ln P_i$$

where s is the range of communities present at each functional vegetation group, or mountain range and P_i is the proportion of the areal coverage of community i within the total area of the functional group over the five mountain ranges, or to the total area within each mountain range.

3. Results and Discussion

3.1 *Species diversity*

Table 1 gives the classification of the 30 communities, with data about altitude, species richness and number of endemics in each community.

The 150 relevés had a total of 345 cormophytic species, 55% of the total number of cormophytic species in the alpine zone of the Carpathians (BELDIE 1967, COLDEA 1991). Of the 345 species, 56 were local, endemic Carpathian, or Carpatho-Balkanic. The basiphilous communities in the *Festuco-Seslerion bielzii* had the greatest number of endemic species, while the dwarf-shrub communities had the least (Table 1). Some endemic Carpathian species endangered by over grazing included *Lychnis nivalis, Thlaspi dacicum, Alopecurus laguriformis, Cerastium lerchenfeldianum, Trisetum fuscum, Silene zawadskii, Poa molinerii, Leontodon repens* and *Leontodon pseudotaraxaci.*

The mean H diversity index calculated for each community had values between 1.31 and 2.41 (Table 1). The lowest indices were found in the *Scorzonero-Festucetum nigricantis* (1.31), *Alchemillo-Poetum alpinae* (1.33) and *Violo-Nardetum* (1.53) communities in the anthropogenic grasslands, which are intensively grazed and consequently have a high sheep manure supply. Therefore, in these communities, belonging to *Potentillo-Nardion* alliance, the syndynamic evolution is determined by the nutrient content of soil.

The highest H diversity indices were calculated for the *Festucetum pictae* (2.41) and *Hyperico-Calamagrostetum* (2.19) sub-alpine meadows and for those on calcareous substratum (*Seslerio haynaldianae-Caricetum* (2.38), *Oxytropo-Elynetum* (2.30), and *Poetum violaceae* (2.10). The high diversity values could be explained by the combination of high species richness and evenness (co-dominance) in these communities. Typical alpine grasslands of the *Caricion curvulae* (1.31-1.74) and the *Rhododendro-Vaccinion* and *Junipero-Bruckenthalion* (1.36-1.65) heaths had intermediate H values.

3.2 *Community diversity in the five mountain ranges*

The H diversity index for each mountain range was a function of the prevalent geological and pedological characters and the number of plant communities present.

The highest values of the index were estimated in the Rodnei (0.725) and the Făgăras Mountains (0.692), where the highest number of plant communities were found (22 and 21, respectively) (Figure 2). In these mountains Mesozoic limestone dominates over large areas along with acid crystalline rocks. Slightly

lower values were found in the Bucegi (0.509) and Retezat Mountains (0.542), having a lower number of plant communities (20 and 19).

The combination of a lower number of communities (15) and the predominance of one of them, the *Violo-Nardetum* (85 %) resulted in the

No.	*Community (Association)*	*Altitudinal range a.s.l. (m)*	*Number of species with (endemics)*	*H*
	I. Al. Caricion curvulae			
1.	Primulo-Caricetum curvulae	2000-2500	55 (11)	1.38
2.	Oreochloo-Juncetum trifidi	1800-2400	55 (7)	1.74
3.	Potentillo-Festucetum supinae	1800-2400	67 (13)	1.31
	II. Al. Calamagrostion villosae			
4.	Festucetum pictae	1750-2500	57 (10)	2.41
5.	Luzuletum alpino-pilosae	1900-2300	39 (8)	1.62
6.	Hyperico-Calamagrostetum	1650-2200	88 (12)	2.19
7.	Digitali-Calamagrostetum	1600-2000	65 (13)	1.45
8.	Phleo alpini-deschampsietum	1600-2200	67 (10)	1.48
	III. Al. Festuco-Seslerion bielzii			
9.	Oxytropido-Elynetum	1900-2500	75 (11)	2.30
10.	Festucetum bucegensis	2300-2500	26 (5)	1.69
11.	Festucetum saxatilis	1700-2000	75 (18)	1.68
12.	Seslerio-Festucetum versicoloris	1700-2100	58 (10)	1.48
13.	Diantho-Festucetum amethystinae	1800-2100	77 (15)	1.67
14.	Poo mollineri-Festucetum pachyphyllae	1800-1950	33 (12)	1.34
15.	Festucetum xanthinae	1500-1550	60 (14)	1.51
16.	Poetum violaceae	1900-2200	52 (10)	2.10
17.	Carduo-Festucetum carpaticae	1600-2200	62 (14)	1.73
18.	Seslerio heufflerianae-Caricetum	1600-1700	45 (13)	2.08
19.	Seslerio haynaldianae-Caricetum	1650-2300	92 (18)	2.38
20.	Seslerio bielzii-Caricetum	1850-2100	60 (7)	1.33
	IV. Al. Potentillo-Nardion			
21.	Poetum mediae	1800-2200	62 (9)	1.74
22.	Violo declinatae-Nardetum	1700-2300	51 (10)	1.53
23.	Scorzonero-Festucetum nigricantis	1650-2300	58 (7)	1.31
24.	Alchemillo-Poetum alpinae	1650-2000	31 (7)	1.33
	V. Al. Rhododendro-Vaccinion			
25.	Cetrario-Loiseleurietum	2000-2200	58 (5)	1.36
26.	Empetro-Vaccinietum	1650-1950	23 (3)	1.65
27.	Rhododendro-Vaccinietum	1800-2400	52 (5)	1.65
28.	Campanulo-Vaccinietum	1650-1900	52 (5)	1.63
29.	Junipero-Bruckenthalietum	1600-1800	39 (5)	1.62
30.	Campanulo-Juniperetum nanae	1650-2000	52 (6)	1.45

Published data (PUŞCARU, 1956; BORZA, 1934; GHIŞA, 1941; BUIA, 1962; BOŞCAIU, 1971; COLDEA 1990) from the Bucegi, Făgăras, Parâng, Retezat and Rodnei Mountains were used to calculate the Shannon-Weawer diversity indices for each community. The diversity values are means based on one relevé from each of the five mountain ranges.

Table 1. The altitudinal range, species richness (with the number of endemics per community) and the Shannon-Weawer diversity index values of the 30 sub-alpine and alpine grassland and dwarf-shrub communities identified in five mountain ranges of the Romanian Carpathians.

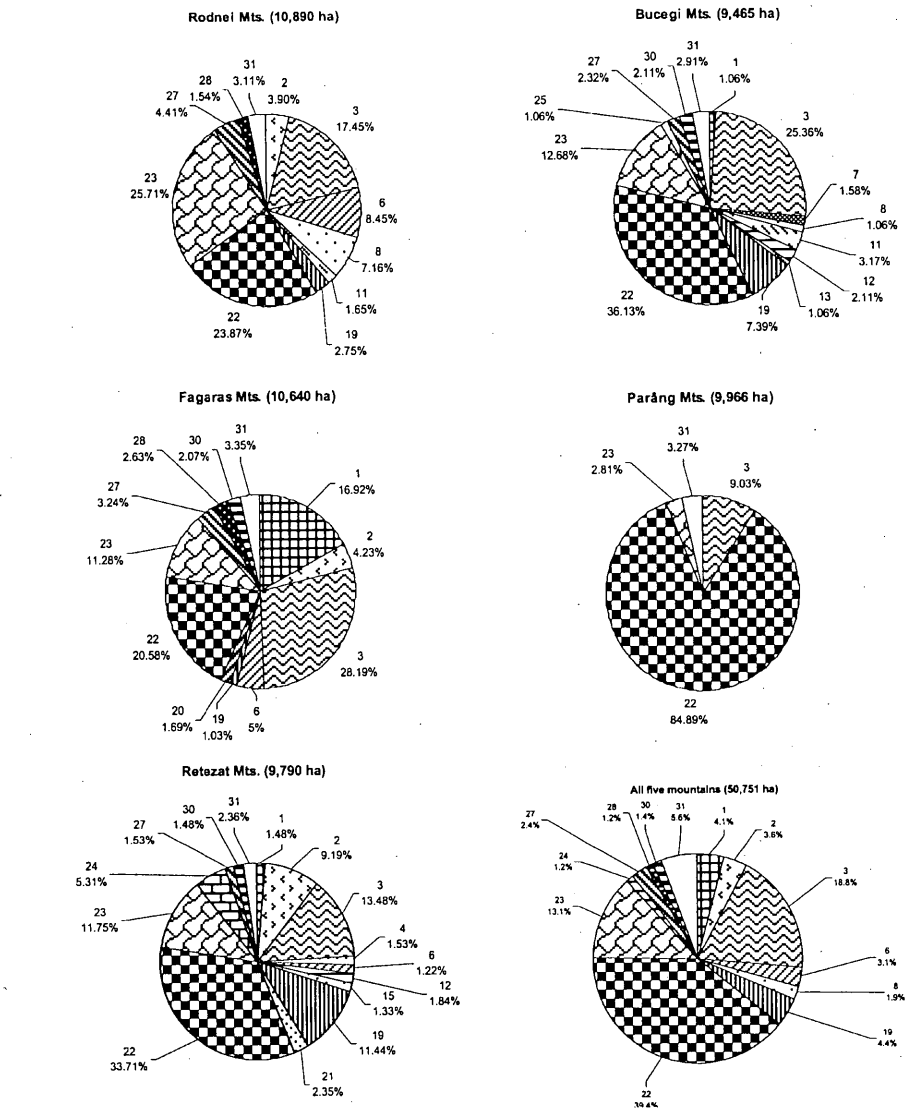

Figure 2. Proportion of sub-alpine and alpine grasslands in five mountain massifs of the Romanian Carpathians. 1, *Primulo-Caricetum*; 2, *Oreochloo-Juncetum*; 3, *Potentillo-Festucetum*; 4, *Festucetum pictae*; 6, *Hyperico-Calamagrostetum*; 7, *Digitali-Calamagrostetum*; 8, *Phleo-Deschampsietum*; 11, *Festucetum saxatilis*; 12, *Seslerio-Festucetum*; 13, *Diantho-Festucetum*; 15, *Festucetum xanthinae*; 19, *Seslerio haynaldianae-Caricetum*; 20, *Seslerio bielzii-Caricetum*; 21, *Poetum mediae*; 22, *Violo-Nardetum*; 23, *Scorzonero-Festucetum*; 24, *Alchemillo-Poetum*; 25 *Cetrario-Loiseleurietum*; 27, *Rhododendro-Vaccinietum*; 28, *Campanulo-Vaccinietum*; 30, *Campanulo-Juniperetum*; 31, Others (communities with area <1%)

lowest diversity index for the Parâng Mountains (0.249), where Mesozoic limestone is limited to small areas.

3.3 *Community diversity in the five grassland functional groups*

The relative percentage cover of each of the 30 communities combined over the five mountain ranges is shown in Figure 2. Eleven communities comprised 94.4% of the total cover with the other 19 communities covering 5.6%. The *Violo-Nardetum* (39.4%), *Potentillo-Festucetum* (18.8%) and *Scorzonero-Festucetum nigricantis* (13.1%) were by far the commonest types and accounted for 71.3% of the total areal cover.

The *Violo-Nardetum* and *Scorzonero-Festucetum nigricantis* belong to the oligo-mesotrophic sub-alpine grasslands which shows that this functional group was by far the most dominant vegetation type in the five mountain ranges.

3.4 *The main sources of diversity*

The main sources of diversity in the sub-alpine and alpine vegetation of the Romanian Carpathians are parent rock type, soil, topography and climatic factors (temperature, rainfalls, wind). These factors alone, or in combination influence species diversity and community diversity on a landscape scale.

Thus, on mountain summits (2100-2500 m) with extreme climatic conditions and with crystalline rocks, amphibolite and lithosols (Rodnei, Parâng and Făgăras Mountains), the alpine vegetation is acidophilous, belonging to the *Caricion curvulae* of the class *Juncetea trifidii* Klika et Hadac 1944. The dominant and co-dominant species in these communities are *Carex curvula, Juncus trifidus, Oreochloa disticha, Potentilla ternata, Festuca picta* and *Hieracium alpinum.*

In contrast, in mountains (1800-2500 m) with calcareous parent rock and rendzinic soil the vegetation is basiphilous (Rodnei, Bucegi and Făgăras Mountains). The vegetation there belongs to communities of the *Festuco-Seslerion bielzii* of the class *Elyno-Seslerietea* Br.-Bl. 1948 with *Festuca saxatilis, Festuca amethystina, F. versicolor, F. carpatica, F. xanthina, F. pachyphylla, Sesleria bielzii, Sesleria rigida* var. *haynaldiana* and *Carex sempervirens* as dominant and co-dominant species.

In addition to the above primary factors, there are secondary factors which affect species and vegetation diversity (*cf.* CHANETON & FACELLI, 1991; KWIATKOWSKA, 1994). Human impact has had a direct influence on soil

nutrient status and through land use has caused the appearance of new functional groups such as the *Potentillo-Nardion* and *Calamagrostion* (and the communities therein). The anthropic factor has also greatly enhanced the spreading of the dwarf-shrub communities in the sub-alpine zone following the clearing of the native woody vegetation (*Rhododendro-Pinetum mugi* and *Bruckenthalio-Piceetum*). For all the human influence over the centuries, however, the alpine and sub-alpine habitats in the Carpathians are the least altered habitats in Romania.

In conclusion, the floristic composition and community structure of the sub-alpine and alpine grasslands and dwarf-shrub in the Romanian Carpathians are mainly determined by geological and pedo-climatic conditions. The alpine grasslands on calcareous substratum (*Festuco-Seslerion bielzii*) and the typical sub-alpine ones (*Calamagrostion villosae*) have the highest diversity index, while oligo-mesotrophic sub-alpine grassland (*Potentillo-Nardion*), determined by soil trophicity have the lowest diversity index.

Functional vegetation groups	*Number of communities*	*Mean (SD) number of comunities per mountain range*	*Mean (SD) area (ha) per mountain range*	*Mean (SD) H per mountain range*	*Correlation between H an overall H'*
1	3	3 (0)	2589 (1435)	0.130 (0.054)	-0.523 (0.65)
2	5	3.6 (1)	611 (594)	0.080 (0.099)	+0.476 (0.42)
3	12	4.5 (2.3)	788 (563)	0.063 (0.039)	+0.343 (0.27)
4	4	3.2 (0.4)	5507 (1760)	0.190 (0.029)	-0.235 (0.76)
5	6	4.8 (0.4)	655 (237)	0.086 (0.065)	-0.234 (0.65)

Functional vegetation groups: 1, Caricion curvulae, 2, Calamagrostion, 3, Festuco-Seslerion, 4, Potentillo-Nardion, 5, Rhododendro-Vaccinion
Data for 43 alpine and sub-alpine sites.

Table 2. Shannon-Weawer diversity indices (H) for the five grassland functional groups of Romanian Carpathians

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