DIVERSITY ANALYSIS OF *FESTUCO RUBRAE-AGROSTETUM CAPILLARIS* HORV. 1951 GRASSLANDS FROM THE STÂNIŞOARA MOUNTAINS SW SLOPES

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Community diversity is an indicator of functionality and potential resilience to habitat alteration. The studied grassland communities of the Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 belong to two sub-associations: *typicum* Coldea 1991 and *caricetosum-montanae* Pop, Cristea, Hodişan 2000. Regarding their diversity, the sub-associations are generally alike. For both sub-associations the low evenness values decreased the high species richness values, and *vice-versa*. Few species are dominant while all the others have similar low abundance. The observed diversity resemblance of the studied sub-associations is supported by their ecological characteristics.

Key words: grasslands, Shannon index, evenness, species richness, SHE analysis.

INTRODUCTION

The paper presents the diversity of two grassland sub-associations of the Class *Molinio Arrhenatheretea* R. Tx. 1937 em R. Tx. 1970 – *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *typicum* Coldea 1991 and *caricetosum-montanae* Pop, Cristea, Hodişan 2000 – from the Oriental Carpathians. Both sub-associations belong to the Order *Arrhenatheretalia* R. Tx. 1931, Alliance *Cynosurion* R. Tx. 1941. These plant communities are important due to their high productivity, which is partly the result of their diversity. In addition, diverse communities are generally more resilient to habitat disturbance [11].

MATERIAL AND METHODS

The studied area, which is the left side of Izvoru Muntelui-Bicaz reservoir, is 136 km^2 and represents a part of the Stânişoara Mountains from the Oriental Carpathians [14].

For the identification of plant associations, we used phytosociological research methods according to the Central-European school [1]. Our results were compared with the syntaxonomic Romanian and foreign literature: Coldea (1991), Passorage (1992), Oberdorfer (1994), Coldea et Chifu (1994), Pott (1992, 1995), Mucina (1997), Sanda *et al.* (1997) etc. [2, 7, 8, 9].

Diversity was represented through species richness (S), Shannon index (H) and Shannon evenness (E_s). The formula of the Shannon index is $H = -\sum p_i \ln(p_i)$, where p_i is the decimal fraction of the species i abundance. With the value of H, one can calculate the species abundance equitability or evenness, which reveals how different the studied community is, compared to an ideal equitable community. The evenness formula is $E = H/H_{max}$ (E_s value is between 0–1) where $H_{max} = \ln(S)$ or the value of H calculated with the same number of species, but equal p_i values [3, 11]. Another way to assess diversity was by performing the SHE analysis (SHE: S = species richness, H = Shannon index diversity, E = evenness). This technique (Buzas and Hayek (1996) and Hayek and Buzas (1997, 1998)) allows the independent and yet simultaneous evaluation of the species richness and evenness contributions to the community diversity [6]. The diversity measures used in SHE analysis are the above-mentioned S and H together with Buzas and Gibson's evenness E. This time E was calculated with the equation $E = e^H/S$ ($0 < E \leq 1$) where e is the natural logarithm base. The advantage of this formula is that H can be decomposed as the sum of $\ln(S) + \ln(E)$ ($e^H = SE$ so $H = \ln(S) + \ln(E)$). Furthermore, because $E \leq 1$, $\ln(E)$ will be a negative number. Therefore, H diversity equals its maximum value, $\ln(S)$, less the amount of evenness, $\ln(E)$ [10].

The distribution of species abundance in each plant community, as another diversity measure, was compared to different theoretical models: geometric, log series, log-normal and "broken-stick". Species abundance equitability increases from the geometric series to the "broken-stick" one [11]. For computation, we used the Abundance Curve Calculator by Dr. James A. Danoff-Burg, and performed the chi-square goodness of fit test.

For the diversity measures statistical description we calculated the measures of the central tendency, variability, and the confidence interval of the mean with 95% probability [5]. The significance of the differences between the diversities of the sub-association was tested with the Mann-Whithney test [4].

RESULTS AND DISCUSSION

The plant communities of the Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 belong to two sub-associations: *typicum* Coldea 1991 and *caricetosum-montanae* Pop, Cristea, Hodişan 2000. The identified dominant species of the association were *Festuca rubra* and *Agrostis capillaris*. The identified differential species of the sub-association *cariscetosum-montanae* were *Carex montana*, *Cirsium pannonicum*, *Brachypodium pinnatum*, *Inula salicina* and *Ranunculus polyanthemos* [12, 13]

The plant communities of the sub-association *typicum* were identified in the following locations: 1. Potoci – Potoci Hill, 2-07-1998, 2. Grozăveşti, 15-07-2002,

3. Buhalniţa, 15-07-2002, 4. Hangu – Sasu Valley, 14-07-2002, 5. Hangu – valley basis, 14-07-2002, 6. Rugineşti – Prislopaşu Hill, 13-07-2002.

Diversity measures analysis (Table 1, Figure 1) shows that the relevé 1 had the highest H value (2.188), comprised 51 species and represented 55.7% of an ideal community with maximum diversity for the same number of species. All the other 5 relevés had approximately half of the diversity of relevé 1. Although it was second species rich one, relevé 4 had the lowest H and E values.

Table 1

Diversity measures of Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *typicum* Coldea 1991 (H – Sahnnon index, E_s – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness)

Relevé	H	E_s	E	S	ln(E)	ln(S)	ln(E)/ln(S)
1	2.188	0.557	0.17485	51	–1.74383	3.931826	–0.44352
2	1.26	0.349	0.095282	37	–2.35092	3.610918	–0.65106
3	1.256	0.351	0.097537	36	–2.32752	3.583519	–0.64951
4	1	0.275	0.071534	38	–2.63759	3.637586	–0.72509
5	1.239	0.361	0.11136	31	–2.19499	3.433987	–0.63919
6	1.256	0.351	0.097537	36	–2.32752	3.583519	–0.64951

This fact is explained by the SHE analysis result (Fig. 1) – the high diversity given by species richness is lowered by the small value of the Buzas and Gibson's evenness. Relevé 4 represents only 27.5 % of a community with the same number of species and maximum diversity.

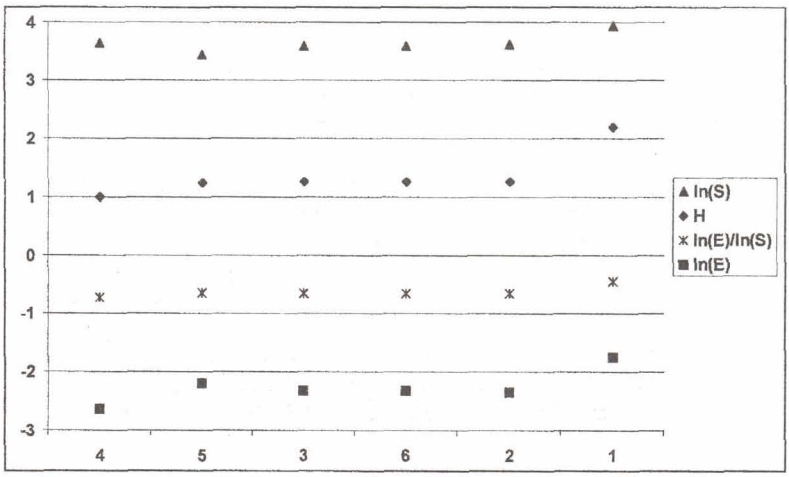

Fig. 1 – SHE analysis of Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *typicum* Coldea 1991 (1 – 6 – relevés in H ascending order, H – Sahnnon index, E_s – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness).

Among diversity measures, the fraction $\ln(E)/\ln(S)$ is the most constant one (Figure 1), which generally indicates a balance between species richness and evenness at sub-association level.

The concordance between species abundance distribution and the log-normal series is statistically significant (Table 2). All the probabilities are very close to 1, except for the first relevé. This situation means that the studied plant communities include few dominant species and many less-dominant ones.

Table 2

Goodness of fit of the species observed rank-abundance distribution to the log-normal theoretical distribution for Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *typicum* Coldea 1991 (X^2 – chi-square value, P – probability)

Relevé	X^2	P
1	22.45229	0.012959
2	3.323327	0.972759
3	3.197668	0.976382
4	1.398248	0.999219
5	2.605312	0.989251
6	3.197668	0.976382

Diversity indices mean values represent diversity of the sub-association as a whole (Table 3). Thus, at this level, H value is 1.366 ± 0.435, the evenness is 0.374 ± 0.099, and the average number of species is 38.166 ± 7.068 (Table 3).

Table 3

Descriptive statistics of diversity measures of Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *typicum* Coldea 1991 (H – Sahnnon index, E_s – Shannon evenness, S – species richness)

Statistics	H	E_s	S
Count	6	6	6
Mean	1.3665	0.374	38.16667
Median	1.256	0.351	36.5
Range	1.188	0.282	20
Minimum	1	0.275	31
Maximum	2.188	0.557	51
Standard Deviation	0.415019	0.095018	6.735478
Standard Error	0.169431	0.038791	2.749747
Confidence Level (95.0%)	0.435535	0.099715	7.068439

Sub-association *caricetosum-montanae* plant communities were identified from 1. Hangu – Audia stream valley, 23-07-1998, 2. Potoci – Potoci Hill – slope middle, 21-07-1998, 3. Potoci – Potoci Hill – slope basis, 21-07-1998, 4. Potoci – Potoci Hill – slope superior 1/3, 21-07-1998, 5. Potoci – Potoci Hill – slope

superior 1/3, 22-07-1998, 6. Hangu – Audia stream valley, 23-07-1998, 7. Rugineşti, 20-07-2000, 8. Rugineşti, 20-07-2000, 9. Hangu – Măceşu stream – valley basis, 22-07-2000, 10. Rugineşti, 20-07-2000, 11. Rugineşti – high plateau, 20-07-2000, 12. Hangu – Hangu Hill– right, 14-07-2002, 13. Hangu – slope middle, 14-07-2002, 14. Hangu, 14-07-2002, 15. Rugineşti, 13-07-2002, 16. Rugineşti – Rugineşti Hill – Plateau, 13-07-2002, 17. Rugineşti – Rugineşti Hill – Plateau, 13-07-2002, 18. Rugineşti – Prislopaşu Hill, 13-07-2002, 19. Rugineşti – Prislopaşu Hill, 13-07-2002.

The analysis of the diversity measures (Table 4, Fig. 2) shows that relevés 7, 5, 4 and 2 had the highest H values (higher than 2), included 64, 49, 49, and 50 species respectively and represented approximately 50% of a maximum diversity community with the same number of species.

Table 4

Diversity measures of Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *caricetosum-montanae* Pop, Cristea, Hodişan 2000 (H – Sahnnon index, E_s – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness)

Relevé	H	E_s	E	S	ln(E)	ln(S)	ln(E)/ln(S)
1	1.91	0.499	0.146806	46	–1.91864	3.828641	–0.50113
2	2.014	0.515	0.149865	50	–1.89802	3.912023	–0.48518
3	1.762	0.45	0.116481	50	–2.15002	3.912023	–0.54959
4	2.049	0.526	0.15837	49	–1.84282	3.89182	–0.47351
5	2.049	0.526	0.15837	49	–1.84282	3.89182	–0.47351
6	1.764	0.449	0.114426	51	–2.16783	3.931826	–0.55135
7	2.068	0.497	0.123578	64	–2.09088	4.158883	–0.50275
8	1.583	0.405	0.097391	50	–2.32902	3.912023	–0.59535
9	1.067	0.296	0.078558	37	–2.54392	3.610918	–0.70451
10	1.095	0.297	0.07473	40	–2.59388	3.688879	–0.70316
11	1.581	0.406	0.09918	49	–2.31082	3.89182	–0.59376
12	1.817	0.486	0.146509	42	–1.92067	3.73767	–0.51387
13	1.295	0.336	0.077681	47	–2.55515	3.850148	–0.66365
14	1.278	0.336	0.079766	45	–2.52866	3.806662	–0.66427
15	1.657	0.426	0.107011	49	–2.23482	3.89182	–0.57424
16	1.109	0.295	0.070496	43	–2.6522	3.7612	–0.70515
17	1.181	0.312	0.074037	44	–2.60319	3.78419	–0.68791
18	0.918	0.229	0.045532	55	–3.08933	4.007333	–0.77092
19	1.479	0.386	0.095403	46	–2.34964	3.828641	–0.6137

According to the SHE analysis, other plant communities that contained over 49 species, such as relevés 6, 8, 11, 15 and especially 18 (55 species), proved to be less diverse because of their low Buzas and Gibson's evenness, which, as mentioned before, decreases the value of the Shannon diversity index (Fig. 2).

At the sub-association level, there is an obvious equilibrium between species richness and evenness, across the plant communities (Figure 2 – ln(E)/ln(S) is approximately constant across relevés).

In all communities, except for 7, the distribution of species abundance significantly fitted the log-normal model (Table 5). This means that the grassland communities are dominated by a few species while most of them are rare. Relevé 7, which is the most diverse one, does not fit the log-normal model or any other model, probably because it contains many dominant species, but yet not sufficiently numerous to fit the "broken-stick" model.

At the sub-association scale, the medium values of the diversity measures are the following: the Shannon index value is 1.561 ± 0.183, the evenness is 0.406 ± 0.044 and the species richness is 47.68 ± 2.801 (Table 6).

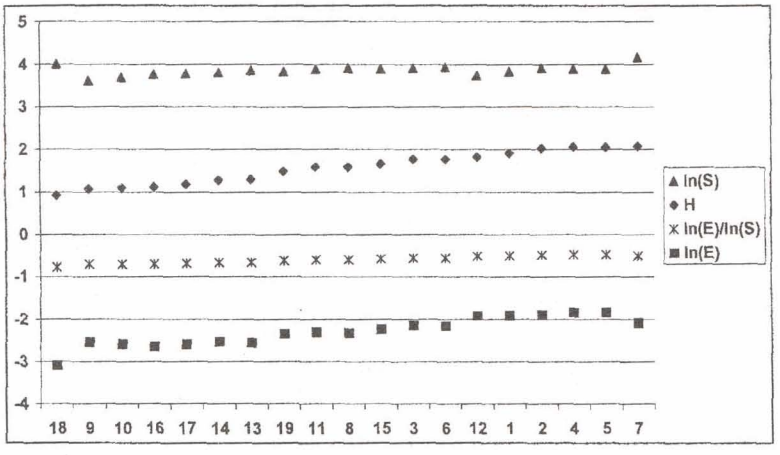

Fig. 2. SHE analysis of Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *caricetosum-montanae* Pop, Cristea, Hodişan 2000 (1 – 19 – relevés in H ascending order, H – Sahnnon index, Es – Shannon evenness, E – Buzas and Gibson's evenness, S – species richness)

Table 5

Goodness of fit of the species observed rank-abundance distribution to the lognormal theoretical distribution for Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *caricetosum-montanae* Pop, Cristea, Hodişan 2000 (X^2 – chi-square value, P – probability).

Relevé	X^2	P	Relevé	X^2	P
1	13.61617	0.19123	11	10.0999	0.431773
2	17.47458	0.064501	12	11.02886	0.355274
3	12.26188	0.267912	13	4.726495	0.908684
4	17.67588	0.060683	14	2.879364	0.984122
5	17.67588	0.060683	15	10.63247	0.386859
6	12.61455	0.246028	16	2.259746	0.993934
7	25.8977	0.00388	17	3.80532	0.955702
8	8.098513	0.619215	18	2.08001	0.995689
9	2.448676	0.991603	19	7.838334	0.644625
10	2.01697	0.996208			

Table 6

Descriptive statistics of diversity measures of Ass. *Festuco rubrae-Agrostetum capillaris* Horv. 1951 – *caricetosum-montanae* Pop, Cristea, Hodişan 2000
(H – Sahnnon index, E_s – Shannon evenness, S – species richness)

Statistics	H	E_s	S
Count	19	19	19
Mean	1.561895	0.403789	47.68421
Median	1.583	0.406	49
Range	1.15	0.297	27
Minimum	0.918	0.229	37
Maximum	2.068	0.526	64
Standard Deviation	0.379948	0.092728	5.812368
Standard Error	0.087166	0.021273	1.333449
Confidence Level(95.0%)	0.183129	0.044693	2.801474

Diversity comparison of the studied sub-associations reveals that, apparently, the sub-association *caricetosum-montanae* is slightly more diverse than the sub-association *typicum* (Tables 3, 6). In fact, the differences concerning H and E_s at sub-association level were not statistically significant, according to the Mann-Whitney test ($U = 40$, $p > 0.05$, for H and $U = 48$, $p > 0.05$ for E_s). The single diversity measure, which was significantly different, was species richness (S). Actually, the one-tail test ($U = 18$, $p < 0.05$) indicates that S for *typicum* is smaller with almost 10 species than the S of *caricetosum-montanae*. However, this difference is not enough to inflict a significant distinction between the studied sub-associations overall diversity.

Hence, the conclusion is that regarding their diversity, the sub-associations are similar, except for a small difference between their number of species.

This conclusion is also supported by certain ecological characteristics of the sub-associations. Thus, both of them occur in similar soil conditions – brown luvic, brown true mesobasic and brown acid soils, which are rich in humus (8%) and total nitrogen, low saturated in bases and having a *p*H of 4.4–5.4. The altitude interval, in which the plant communities were identified, was between 600– 900m. Although the sub-association *typicum* exists at lower altitudes (608–730 m), it makes no significant difference in diversity, compared to *caricetosum-montanae*.

Both sub-associations contain a significant amount of species that belong to phytosociological class *Calluno-Ulicetea*, and that are mostly ruderals. Ruderals are adapted to cope with habitat alteration (especially man-made) [11]. Regarding bioforms, floristic elements and ecological indices, the communities of both sub-associations are alike – both are dominated by hemicryptophytes, Eurasian elements, mesophytes, mesothermophilous species and pH-tolerant species [12, 13].

A final absolute assessment of the studied sub-associations diversity would be that they represent approximately 40 % of maximum diversity.

CONCLUSIONS

The plant communities of the Ass. *Festuco rubrae-Agrostetum capillaris* Horv.1951 belong to two sub-associations: *typicum* Coldea 1991 and *caricetosum-montanae* Pop, Cristea, Hodişan 2000.

The plant communities of the sub-association *typicum* represent 37% of maximum potential diversity and contain approximately 38 species in average.

The plant communities of the sub-association *caricetosum-montanae* represent 40% of maximum potential diversity and contain approximately 48 species in average.

The difference of diversity between the sub-associations is not statistically significant, except for the species richness, which in return proved to be ecologically insignificant with regard to the overall diversity.

For both sub-associations, there is an obvious balance between species richness and equitability, across plant communities. Generally, that means that low evenness values decreased high species richness values, and *vice-versa*.

The communities of both sub-associations fit the log-normal species abundance model, which, in ecological terms, means that few species are dominant while all the others have similar low abundance.

The observed diversity resemblance of the studied sub-associations is supported by their ecological characteristics.

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