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RELATION BETWEEN ENVIRONMENTAL VARIABLES, SPECIES RICHNESS AND SPECIES COMPOSITION OF SLOVENIAN SEMI-DRY MEADOWS OF *MESOBROMION ERECTI* ALLIANCE

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ABSTRACT

Semi-dry meadows of the Central European alliance Mesobromion erecti *(class* Festuco-Brometea*) are habitats with high biodiversity. Our first aim was to recognize the variability of species composition of central, eastern, and southeastern Slovenian semi-dry grasslands. The second aim was to define which environmental variables affect to the greatest extent the species richness and species composition of those meadows. The vegetation was sampled using standard procedure of the Braun-Blanquet approach. From each plot the following soil parameters were measured: pH, humus, carbonates, potassium, phosphorus; some environmental variables were also estimated by the Ellenberg indicator values. Phytosociological relevés were classified by TWINSPAN. Five clusters were separated and their configuration checked in a CA-ordination. For the interpretation of floristical gradient, the environmental variables were correlated with the ordination axes using rank correlation test. It could be summarised that species richness is slightly positively affected by humus and nitrogen amounts. We could also conclude that soil parameters as pH, humus, carbonates, humidity and nitrogen contents are those environmental variables that mostly affect species composition of the Central Slovenian* Mesobromion *meadows.*

Key words: *Mesobromion erecti*, semi-dry meadows, species richness, classification, ordination, phytosociology, Ellenberg indicator values

RELAZIONE TRA VARIABILI AMBIENTALI, RICCHEZZA E COMPOSIZIONE DI SPECIE IN PRATERIE SEMIARIDE SLOVENE DELL'ALLEANZA *MESOBROMION ERECTI*

SINTESI

Le praterie semiaride dell'alleanza centro-europea Mesobromion erecti *(classe* Festuco-Brometea*) vengono considerate come habitat ad alta biodiversità. Scopo principale di tale studio è stato quello di riconoscere la variabilità della composizione di specie delle praterie semiaride in Slovenia centrale, orientale e sud-orientale. Lo scopo secondario invece era quello di definire quali variabili ambientali influenzano prevalentemente la ricchezza e la composizione di specie di tali praterie. Il campionamento della vegetazione è stato effettuato usando la procedura standard dell'approccio di Braun-Blanquet. In ciascuna delle aree sono stati rilevati i seguenti parametri: pH, humus, carbonati, potassio, fosforo; altre variabili ambientali sono state stimate attraverso l'indicatore di valori Ellenberg. I rilievi fitosociologici sono stati classificati con il TWINSPAN. Dalla classificazione sono emersi 5 cluster e la loro configurazione è stata verificata con l'ordinamento CA. Per l'interpretazione dei gradienti floristici le variabili ambientali sono state correlate con gli assi dell'ordinamento usando la correlazione di rango. Dai risultati ottenuti la ricchezza di specie risulta leggermente influenzata positivamente dall'humus e dalla quantità di azoto. La composizione di specie delle praterie di* Mesobromion *della Slovenia centrale, invece, si è rivelata influenzata in prevalenza da pH, humus, carbonati, umidità e contenuti di azoto.*

Parole chiave: *Mesobromion erecti*, praterie semiaride, ricchezza di specie, classificazione, ordinamento, fitosociologia, indicatore di valori Ellenberg

INTRODUCTION

The correlation between vegetation and environmental parameters is one of the most fundamental questions contributing to understanding plant species composition, structure in a particular habitat, landscape and region (Barbour *et al.*, 1987; Mucina, 1997). Although plant communities are dynamic entities undergoing continuous change in response to climate, land use patterns and intrinsic dynamics, understanding vegetation-environmental correlations at one point in time may help to predict possible shifts attributed to climate and land use changes (Burke, 2001).

Dry and semi-dry grasslands are one of the best-known vegetation types in Europe (Dierschke, 1997). Mostly they are of semi-natural origin (Ellenberg, 1996), *i.e.* they developed by forest grazing and clear-cutting (Pott, 1996) or after the abandonment of arable fields and vineyards (Schumacher *et al.*, 1995) and are maintained by various activities – mowing, grazing of domestic animals, cutting or burning of shrubs and trees (Kienzle, 1979; Pfadenhauer & Erz, 1980; Witschel, 1980).

In Slovenia, all secondary dry and semi-dry grasslands on basic, neutral and slightly acid soil on calcareous bedrock (limestone, dolomite, marl, flysch – a calcareous sandstone) under the tree line belong to the class *Festuco-Brometea* Br.-Bl. & R.Tx. ex Klika & Hadač 1944 em. Royer 1987 (Kaligarič, 1997a; Škornik, 2000). They are usually found in warm, sun-exposed areas. Those, in winter cold and in the summer extremely hot sites with shallow soil layer, often dry out completely through the action of wind and direct solar irradiation (Kierchner *et al.*, 1980; Vogel, 1981).

With about 700 vascular plants and 200 bryophytes and lichens, *Festuco-Brometea* grasslands are among the most species-rich habitats in Europe (Willems, 1990). In the last decades they have rapidly declined in their size and number in Central and Western Europe (Wolkinger & Plank, 1981) due to the changes in traditional land-use and extensive management (Horvat *et al.*, 1974; Willmans, 1975; Glavač *et al.*, 1979; Kinzel, 1983). The consequence is fragmentation and isolation of the remnant grasslands (Keymer & Leach, 1990). Other threat to this type of grasslands in Slovenia is their abandonment, where consequently secondary succession has changed many grasslands into scrub and forest (Kaligarič, 1997a, 1997b, 1998).

In Slovenia, vegetation of *Festuco-Brometea* class is quite clearly divided into two orders: the sub-Mediterranean-Illyrian order *Scorzoneretalia villosae* Horvatić 1975, which is distributed in the south-western (sub-Mediterranean) part of Slovenia (Kaligarič, 1997a), and the *Brometalia erecti* Koch 1926 order that presents continental dry and semi-dry grasslands, characterised by sub-Atlantic-sub-Mediterranean species (Mucina & Kolbek, 1993). *Brometalia erecti* order includes semi-dry and dry grasslands of western, central and southern Europe. This order is represented by four alliances (Dierschke, 1997). In Slovenia and in southern Europe, only alliance *Mesobromion erecti* (Br.-Bl. & Moor 1938) Oberdorfer 1957 can be found (Škornik, 2000). The *Mesobromion erecti* grasslands have slightly mesophilous character – they mostly appear on sites with deeper, moderate humid soil, with pH values around 7. Therefore they are often assigned as "semi-dry" or "semi-arid" grasslands ("Halbtrockenrasen"). As to floristic composition and synecology, this species-rich vegetation has an intermediate position between the extremely dry grasslands of the *Brometalia erecti* order, the acid grassland vegetation on nutrient-poor soils of the *Calluno-Ulicetea* class, and the mesophilous grassland vegetation of the *Arrhenatheretalia* order (Mucina & Kolbek, 1993).

Until now, only few qualitative descriptive studies of the *Brometalia erecti* vegetation in continental parts of Slovenia have been published (Tomažič, 1941, 1959; Petkovšek, 1970, 1974, 1977, 1978). The main objective of those studies was to describe the associations according to the Braun-Blanquet approach (Braun-Blanquet, 1964).

One of the major aims of the present work was to understand the variation in species composition and species richness of the central, eastern and south-eastern Slovenian semi-dry grasslands (*Mesobromion erecti* alliance) in ecological terms using field data and numerical methods.

MATERIAL AND METHODS

In the year 1999, 35 plots (size of 25 m^2) of semi-dry grasslands from the alliance *Mesobromion erecti* were selected in central, eastern and south-eastern Slovenia (Fig. 1). Vegetation on the plots was sampled using standard procedure of the Braun-Blanquet approach (Braun-Blanquet, 1964; Westhoff & van der Maarel, 1973; Dierschke, 1994). Taxonomic nomenclature follows Martinčič *et al.* (1999) except for *Bromus erectus*. The following taxonomically complicated groups are presented as aggregates (agg.): *Bromus condensatus*, *B. erectus* and *B. transsylvanicus* as *Bromus erectus* agg., *Brachypodium pinnatum* and *B. rupestre* as *Brachypodium pinnatum* agg.; *Leucanthemum ircutianum* and *L. vulgare* as *Leucanthemum vulgare* agg.; *G. mollugo*, *G. lucidum* and *G. album* as *Galium mollugo* agg. All the grasslands are used as meadows, mown twice or at least once a year. Management exclude fertilisation, grazing or other treatments.

From each plot the following soil parameters were analysed: 1. pH (measured in 0.1 N solution of KCl by glass electrode), 2. humus (Walkey-Black method), 3. carbonates ($CaCO_3$) (volumetric by Scheibler calcio-

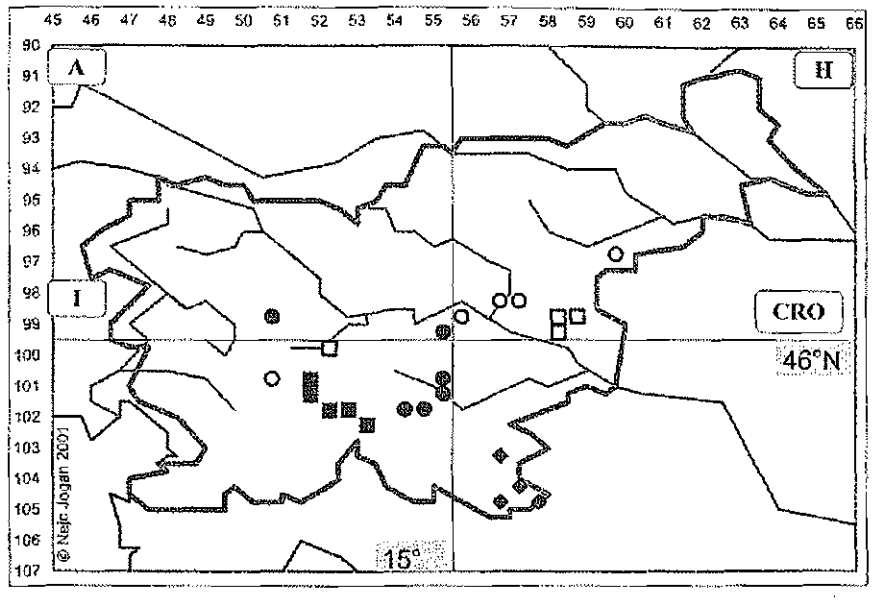


Fig. 1: Sampling plots distributed across central, eastern and south-eastern Slovenia. Legend: ◆ - 1st cluster, ○ - 2nd cluster, ● - 3rd cluster, □ - 4th cluster, ■ - 5th cluster.
Sl. 1: Vzorčišča v osrednji, vzhodni in jugovzhodni Sloveniji. Legenda: ◆ - 1. skupina, ○ - 2. skupina, ● - 3. skupina, □ - 4. skupina, ■ - 5. skupina.

metre), potassium (K_2O) (flame photometry), and phosphorus (P) (spectrophotometric measurements of the coloured complex). Some environmental variables were estimated by weighted (species frequencies are weights) averages of Ellenberg indicator values (Ellenberg *et al.*, 1991) for light, humidity, temperature and nitrogen content.

Species richness per 25 m^2 was defined for each plot.

For the numerical classification Two-Way-INdicator-SPecies-ANalysis (TWINSPAN; Hill, 1979) was applied. It was run using the computer program VEGI (Reiter, 1998). Correspondence Analysis (CA) was used to ordinate relevés (plots) using the computer package STATISTICA (Hirschfeld, 1935; Hill, 1973).

For the interpretation of gradients extracted from CA ordination the environmental variables and richness values were correlated with the ordination axes. All correlations were tested by Spearman's rank correlation test, which was carried out using non-parametric statistics in STATISTICA.

RESULTS AND DISCUSSION

Classification and ordination of the relevés

Phytosociological relevés of 35 plots are shown in Table 1. Sequence of the relevés is according to the TWINSPAN classification (Fig. 2). By classification procedure, five clusters with a size from 5-8 relevés (plots) were separated. For each cluster blocks of species, confirming slightly diverse species composition of the relevés, are shown in the table. Clusters do not represent phytogeographycally based units, nor management-dependent units. They entirely depend on ecological conditions, varying due to the soil characteristics. Cluster 1 includes 7 plots. Differential species of the cluster are *Agrostis capillaris, Festuca filiformis, Polygala vul-*

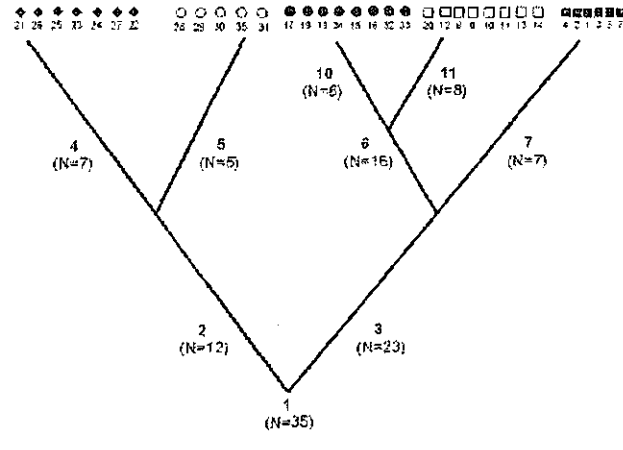


Fig. 2: TWINSPAN tree with 5end-clusters. The number of group and the number of plots (N) are shown for each node.
Sl. 2: TWINSPANOVO drevo s petimi skupinami. Št. skupine in št. popisov (N) sta prikazani za vsako presečišče.

garis, Carex pallescens and *Calluna vulgaris*, which are typical acidophilous species. The stands were mostly from Bela Krajina and occur on deeper, leached and slightly acid brown soils.

Cluster 2 with 5 plots has the following differential species: *Trisetum flavescens, Arrhenatherum elatius, Festuca pratensis, Lathyrus pratensis* and *Colchicum autumnale*. These species indicate more fertile and moist meadows, situated in different parts of central and eastern Slovenia (Fig. 1).

Cluster 3 and 4, with 8 plots each, are similar and without special differential species. They represent ecological situation "in between" the two poles.

Cluster 5 with 7 plots is differentiated with the group of basiphilous and termophilous species: *Carex humilis, Plantago holosteum, Polygala chamaebuxus, Gentiana verna subsp. tergestina, Knautia illyrica, Tragopogon tommasinii, Plantago argentea subsp. liburnica* and *Pseudolysimachion barrelieri. Pseudolysimachion barrelieri* subsp. *barrelieri*. Relevés presented in this cluster were collected from high Dinaric plateaus (Bloke, Menišija, Krim), where they occur on warm and dry sites with shallow and skeleton soil. Some species in this cluster are shared with cluster 4.

In the CA ordination, the 5 clusters appeared well-separated (Fig. 3). The first axis described 11.06%, the second 8.39%, the third 6.5% and the fourth 5.01% of the total variability. For the interpretation of the floristic gradients in sampled plots, only the most important ordination axis CA1 and CA2 were used.

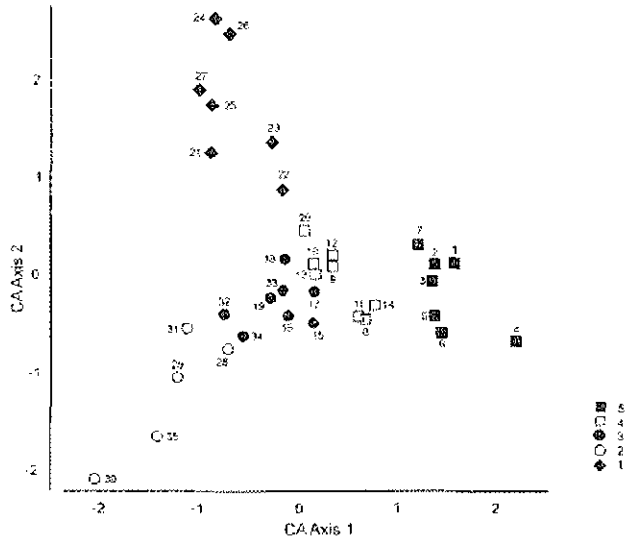


Fig. 3: CA (Correspondance Analysis) of Slovenian semi-dry grasslands (Mesobromion erecti alliance). 1-5 clusters defined by TWINSPAN are indicated.
Sl. 3: CA (Correspondence Analysis) ordinacija slovenskih polsuhih travišč (zveza Mesobromion erecti). Prikazane so skupine 1-5, določene s TWINSPAN analizo.

Environmental variables and species richness

Values of the measured and estimated environmental variables for 35 semi-dry grasslands stands are given in the Table 2. Values for calcite $CaCO_3$ vary a great deal - from totally decalcified leached soils as one extreme and to the soils very rich on $CaCO_3$ as the other. While some stands with the lowest values for $CaCO_3$ are also characterized by very low pH – they present stands on acid and leached soils on calcareous substrate (limestone, dolomite) from the central part of Dolenjska region and from Bela Krajina – some others may be decalcified, but not acidified. These relevés were collected on grasslands on deeper brown soils, which developed on marl and flysch. Phosphorous and potassium do not vary a great deal. Some plots have soil with higher humus content -- they mostly represent stands on shallow and skeleton calcareous soil – rendzinas from high Dinaric plateaus. Ellenberg values do not vary so much as measured soil parameters.

Species richness per 25 m^2 was the lowest for the relevés in the 1st cluster due to the slightly acid and decalcified soil conditions. The highest species richness was established for the 5th cluster with stands from shallow rocky soils with basic conditions with a peak of 69 species.

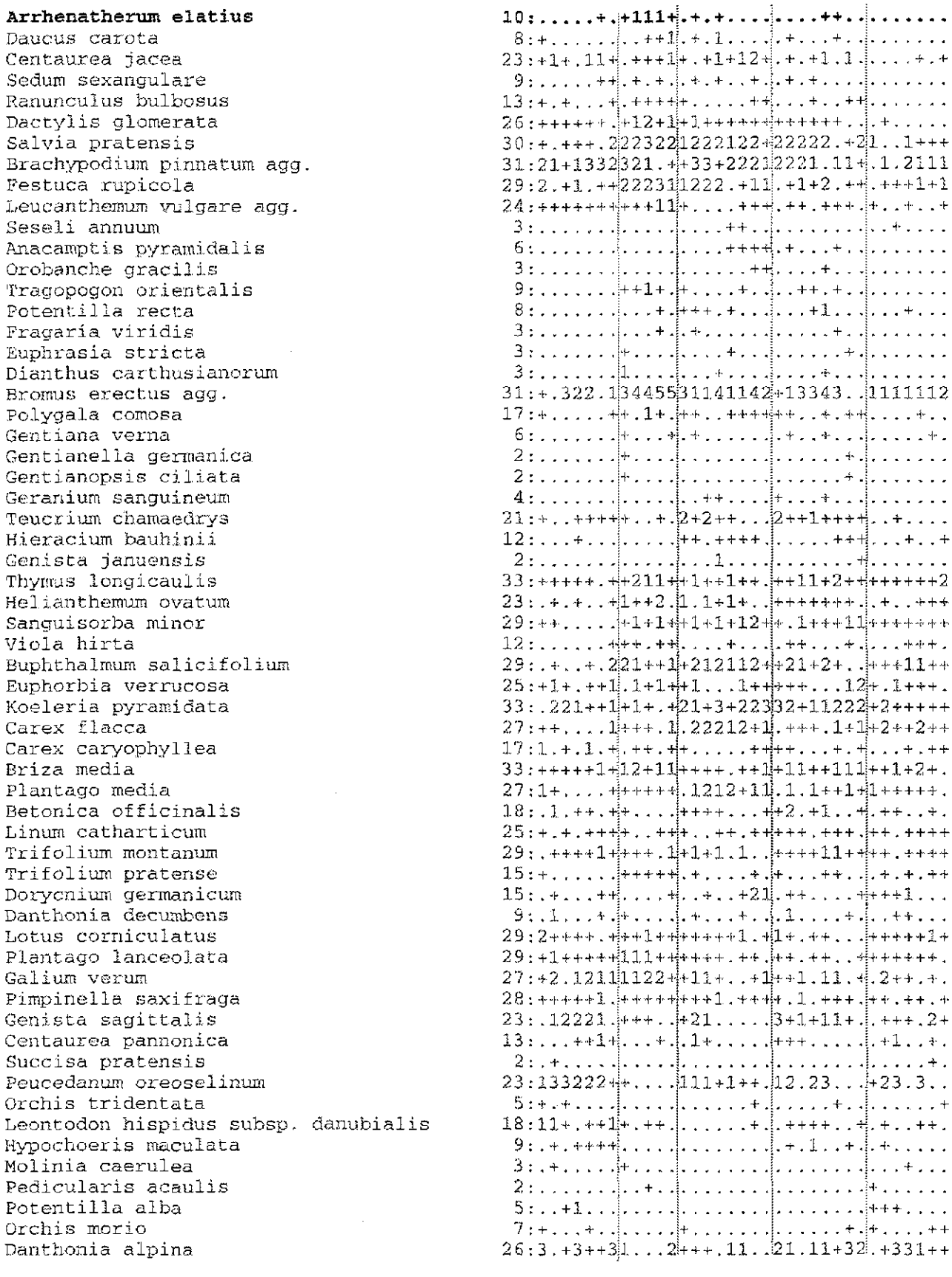
Correlations between environmental parameters, species richness and floristically based ordination

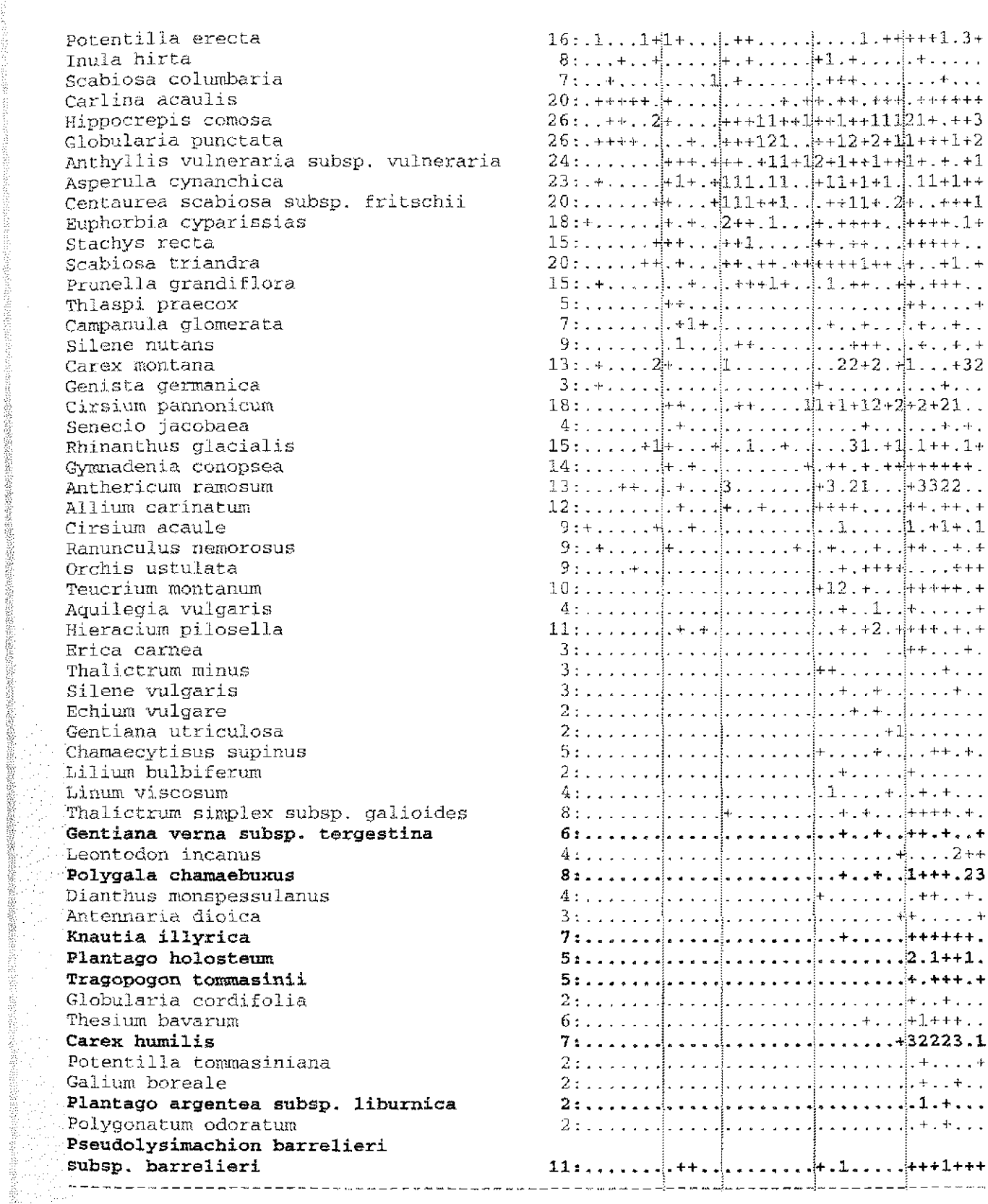
Before correlating floristically based gradients obtained from CA ordination with environmental parameters, the correlations among environmental variables were tested using Spearman's rank order correlation test. The Spearman rank order correlation coefficients (R) between single environmental variables were calculated. Some of the environmental variables were found to be significantly correlated (Table 3), *i.e.* CaCO3, which is positively correlated with pH, P, and K and negatively with humidity; pH is correlated with P and N values, *etc.* Species richness correlates positively with humus and nitrogen, which could be explained with natural fertility of the sampled meadows (fertilisation on plots were excluded).

Finally, CA sample scores (coordinates) were correlated against all environmental variables, using Spearman's rank order correlation test (Tab. 4). Many of the environmental variables were found to be significantly correlated with CA sample scores. The first axis of the Correspondence Analysis (CA1) was found to be positively correlated with humus, $CaCO_3$ and K_2O, and negatively with humidity. It could be interpreted as a gradient from plots on deep and humid, decalcified brown soils to the plots on dry, shallow, calcareous soils. The second axis (CA2) was found to be strongly

Tab. 1: Phytosociological relevés of 35 Slovenian semi-dry grasslands (Mesobromion erecti alliance) classified by TWINSPAN. Species, characteristic for each cluster are indicated in the table.
Tab. 1: Fitosociološki popisi 35 slovenskih polsuhih travišč (zveza Mesobromion erecti alliace), klasificirani s TWINSPAN analizo. V tabeli so označene vrste, značilne za posamezno skupino.

Relevé number	◆ 22222222 16534728	○ 22333 90517	● 11131133 98456230	□ 21001111 28901344	■ 00000000 21357676
Viola canina	4:.+..++.	.....	.....	.....	.....+.
Polygala vulgaris	**11:+++++++**	**...+.**	.....	.....	**.+...++**
Calluna vulgaris	**5:.2.++1+**	.....	.....	.....	.....
Veronica officinalis	3:.++..+.	.....	.....	.....	.....
Agrostis capillaris	**6:.21+1++**	.....	.....	.....	.....
Festuca filiformis	**6:211.2+1**	.....	.....	.....	.....
Carex pallescens	**6:.++++.++**	.....	.....	.....	.....
Rhinanthus minor	2:....++	.....	.....	.....	.....
Prunella laciniata	12:++1++11	++..+	.....	.++	.....
Luzula campestris	7:+.+.+1.	+11..	.....	.....	.....
Carlina vulgaris	3:+.+....	.....	...1.	.....	.....
Ononis spinosa	2:.....+.	.....	..+..	.....	.....
Anthoxanthum odoratum	10:+.++.+.	1++.+	.....	...+.	.....+.
Filipendula vulgaris	20:3322+2+	.2+.3	1+2+1+.+	2..1..	...+...
Cruciata glabra	14:.+..+++	+1++.	..++.	...++	...+...+..
Knautia arvensis	8:..+.+..	.111.	+..++.	.....	.....
Achillea millefolium	9:.+...++	+++..	..+...+.+	.....	.....
Rumex acetosa	4:.....+.	+++..	.....	.....	.....
Holcus lanatus	7:++..+..	.++.+	.....	+.....	.....
Knautia drymeia	10:.++..+.	+.+.+	+..+..1.	...+..	.....
Primula vulgaris	3:+.....	...+.	.....	+.....	.....
Peucedanum cervaria	4:...+..+	.....	...+..2	.....	.....
Centaurium erythraea	2:+.....	....+	.....	.....	.....
Lathyrus pratensis	**3:.....**	**.++2.**	.....	.....	.....
Veronica chamaedrys	3:.....	.++.+	.....	.....	.....
Ranunculus acris	3:.....	.+++.	.....	.....	.....
Trifolium campestre	2:.....	.+..+	.....	.....	.....
Festuca pratensis	**3:.....**	**.+1+.**	.....	.....	.....
Poa angustifolia	2:.....	.++..	.....	.....	.....
Trisetum flavescens	**5:+.....**	**.+1++**	.....	.....	.....
Agrimonia eupatoria	3:.....	..++.	.....+	.....	.....
Prunella vulgaris	3:.....	..+++	.....	.....	.....
Convolvulus arvensis	2:.....	..++.	.....	.....	.....
Cynosurus cristatus	2:.....	..+.+	.....	.....	.....
Rhinanthus alectorolophus	2:.....	..++.	.....	.....	.....
Pastinaca sativa	2:.....	...++	.....	.....	.....
Galium mollugo agg.	9:.....	+++.++	.++..+.	.+.....	.....
Vicia cracca	8:.....+.	.+1++	.+.+..+	.....	.....
Medicago falcata	5:.....	.++.1	+..+...	.....	.....
Picris hieracioides	6:.....	..+.+	.+...++	.....	.+.....
Veronica jacquinii	2:.....	.....	+..+...	.....	.....
Chrysopogon gryllus	3:.....	.....	1...33.	.....	.....
Aster amellus	2:.....	.....	...+1..	.....	.....
Clematis vitalba	2:.....	.....	.+....+	.....	.....
Medicago lupulina	7:.....	+.+++	.+....+	.....	.+.....
Colchicum autumnale	**5:.....**	**.++++**	.....	.....+	.....
Avenula pubescens	4:.....	.++1.	.....	.+.....	.....
Hypericum perforatum	12:.+.....	+++++	++.+....	.+.+...	.....+..


Arrhenatherum elatius
Daucus carota
Centaurea jacea
Sedum sexangulare
Ranunculus bulbosus
Dactylis glomerata
Salvia pratensis
Brachypodium pinnatum agg.
Festuca rupicola
Leucanthemum vulgare agg.
Seseli annuum
Anacamptis pyramidalis
Orobanche gracilis
Tragopogon orientalis
Potentilla recta
Fragaria viridis
Euphrasia stricta
Dianthus carthusianorum
Bromus erectus agg.
Polygala comosa
Gentiana verna
Gentianella germanica
Gentianopsis ciliata
Geranium sanguineum
Teucrium chamaedrys
Hieracium bauhinii
Genista januensis
Thymus longicaulis
Helianthemum ovatum
Sanguisorba minor
Viola hirta
Buphthalmum salicifolium
Euphorbia verrucosa
Koeleria pyramidata
Carex flacca
Carex caryophyllea
Briza media
Plantago media
Betonica officinalis
Linum catharticum
Trifolium montanum
Trifolium pratense
Dorycnium germanicum
Danthonia decumbens
Lotus corniculatus
Plantago lanceolata
Galium verum
Pimpinella saxifraga
Genista sagittalis
Centaurea pannonica
Succisa pratensis
Peucedanum oreoselinum
Orchis tridentata
Leontodon hispidus subsp. danubialis
Hypochoeris maculata
Molinia caerulea
Pedicularis acaulis
Potentilla alba
Orchis morio
Danthonia alpina



Potentilla erecta	16
Inula hirta	8
Scabiosa columbaria	7
Carlina acaulis	20
Hippocrepis comosa	26
Globularia punctata	26
Anthyllis vulneraria subsp. vulneraria	24
Asperula cynanchica	23
Centaurea scabiosa subsp. fritschii	20
Euphorbia cyparissias	18
Stachys recta	15
Scabiosa triandra	20
Prunella grandiflora	15
Thlaspi praecox	5
Campanula glomerata	7
Silene nutans	9
Carex montana	13
Genista germanica	3
Cirsium pannonicum	18
Senecio jacobaea	4
Rhinanthus glacialis	15
Gymnadenia conopsea	14
Anthericum ramosum	13
Allium carinatum	12
Cirsium acaule	9
Ranunculus nemorosus	9
Orchis ustulata	9
Teucrium montanum	10
Aquilegia vulgaris	4
Hieracium pilosella	11
Erica carnea	3
Thalictrum minus	3
Silene vulgaris	3
Echium vulgare	2
Gentiana utriculosa	2
Chamaecytisus supinus	5
Lilium bulbiferum	2
Linum viscosum	4
Thalictrum simplex subsp. galioides	8
Gentiana verna subsp. tergestina	**6**
Leontodon incanus	4
Polygala chamaebuxus	**8**
Dianthus monspessulanus	4
Antennaria dioica	3
Knautia illyrica	**7**
Plantago holosteum	**5**
Tragopogon tommasinii	**5**
Globularia cordifolia	2
Thesium bavarum	6
Carex humilis	**7**
Potentilla tommasiniana	2
Galium boreale	2
Plantago argentea subsp. liburnica	**2**
Polygonatum odoratum	2
Pseudolysimachion barrelieri subsp. barrelieri	**11**

Tab. 2: Values of measured and estimated environmental variables for 35 relevés of Slovenian semi-dry grasslands (Mesobromion erecti alliance). Legend: E = variables estimated by weighted averages of Ellenberg indicator values.
Tab. 2: Vrednosti izmerjenih in ocenjenih ekoloških parametrov za 35 popisov slovenskih polsuhih travišč (zveza Mesobromion erecti). Legenda: E = parametri, ocenjeni s tehtanimi srednjimi vrednostmi Ellenbergovih indeksov.

	Measured variable					Ellenberg values				Species richness/ 25 m²
relevés	$CaCO_3$ (%)	pH (in KCl)	P_2O_5 (mg/100 g)	K_2O (mg/100 g)	Humus (%)	Humidity^E	Light^E	Temperature^E	Nitrogen^E	
1	7.20	7.00	1.60	10.80	12.64	2.91	7.36	5.73	2.43	55
2	7.60	7.17	1.80	19.90	12.50	3.45	6.84	5.71	2.57	69
3	9.60	7.07	1.50	9.60	13.28	3.00	7.60	5.81	2.47	65
4	29.60	7.38	2.40	10.10	11.96	2.40	7.45	5.85	2.84	60
5	12.80	7.15	1.30	8.80	12.02	3.06	6.98	5.68	2.44	62
6	1.24	6.70	1.10	7.20	12.00	2.92	6.85	5.06	2.14	55
7	1.20	6.77	1.10	7.10	11.38	1.78	6.21	4.65	2.42	58
8	21.20	7.25	2.60	10.80	12.46	3.02	7.43	5.37	2.67	53
9	1.00	5.91	1.10	6.20	9.90	3.49	7.96	4.93	2.57	50
10	5.60	6.67	1.90	7.70	11.10	3.24	7.50	5.36	2.59	54
11	1.20	6.85	1.40	8.70	8.80	3.23	7.11	5.74	2.34	50
12	21.60	7.01	0.80	8.00	7.42	3.34	7.19	5.54	2.81	56
13	3.20	6.74	1.40	8.90	6.98	3.31	8.11	5.96	2.15	45
14	29.20	7.18	2.20	7.90	12.12	3.42	7.54	6.12	2.42	42
15	52.00	7.22	1.90	9.30	6.28	2.90	7.30	5.77	2.41	37
16	34.00	7.14	1.20	7.70	3.43	3.32	7.30	5.88	2.51	41
17	4.00	7.00	2.70	9.70	12.34	3.01	7.39	5.42	2.60	51
18	1.20	6.79	1.90	9.50	9.12	3.62	7.36	5.71	2.57	45
19	0.20	5.71	1.10	5.50	7.44	3.64	7.57	5.67	2.78	54
20	0.40	6.30	1.30	6.10	10.26	3.44	7.53	5.71	2.20	50
21	0.04	4.68	1.60	13.80	3.02	3.38	7.73	6.00	2.32	43
22	0.16	5.57	1.50	4.60	6.10	3.51	7.62	5.63	2.69	51
23	0.16	5.48	1.50	7.10	6.40	3.23	7.83	5.73	2.25	37
24	0.16	4.02	0.60	5.90	5.72	3.98	7.17	4.24	2.61	46
25	0.24	4.23	0.90	4.20	3.84	3.27	7.13	5.60	2.35	41
26	0.16	4.96	1.60	3.80	3.77	3.38	6.91	5.98	2.31	50
27	0.20	5.60	0.80	3.00	3.53	3.56	6.99	5.60	2.42	46
28	0.08	6.31	1.40	3.90	4.56	3.43	7.75	5.43	2.91	65
29	0.24	6.19	1.40	7.00	7.16	3.17	7.69	5.58	2.77	65
30	0.20	5.93	1.30	8.50	8.32	3.63	7.71	5.52	2.78	67
31	0.80	6.73	1.30	7.90	5.14	3.13	7.84	5.49	2.79	51
32	29.20	7.32	3.60	5.90	4.71	3.22	7.71	5.62	2.66	45
33	21.20	7.10	4.00	20.40	6.08	3.55	7.26	5.83	2.38	37
34	24.00	7.39	2.90	18.30	5.64	3.54	7.71	5.66	2.68	48
35	3.20	7.17	3.20	5.70	6.16	3.04	8.14	5.61	2.75	51

negatively correlated with soil pH, nitrogen and species richness. Along this axis we could follow the gradient from naturally fertile basic (calcareous) substrates towards acid and leached, infertile soils. The third axis and the fourth axis (as well as the others) are not visible in the two-dimensional ordination, but they are also less important, because they usually describe less than 5% of the total variability.

It is generalised for all types of meadows that fertilisation causes biodiversity loss. Furthermore, dry and semi-dry grasslands are also characterised by low supply of nutrients as the consequence of long lasting removal of aboveground biomass by mowing or grazing without additional fertilization (Gigon, 1968; Grime, 1990; Pils, 1994). But the low level of nutrients must be understood only relatively; due to the results of the present research

Tab. 3: Spearman rank order correlation coefficients (R) between environmental variables. Spearman R is given together with levels of probability # = p < 0.05, $ = p < 0.001.
Tab. 3: Spearmanovi korelacijski koeficienti (R) med ekološkimi parametri, skupaj s stopnjami verjetnosti # = p < 0.05, $ = p < 0.001.

Variable	$CaCO_3$	pH	P_2O_5	K_2O	Humu	Humi^E	Light^E	Temp^E	N^E	Sp.rich.
$CaCO_3$	1									
pH	**0.49#**	1								
P_2O_5	**0.45#**	**0.5$**	1							
K_2O	**0.55$**	0.31	**0.49#**	1						
Humus	**0.37#**	0.11	0.15	**0.45#**	1					
Humidity^E	**-0.41#**	-0.22	-0.21	-0.22	**-0.39#**	1				
Light^E	-0.17	**0.42#**	0.25	-0.05	-0.19	0.1	1			
Temperature^E	0.15	-0.03	0.09	0.27	0.1	-0.24	-0.18	1		
Nitrogen^E	0.07	**0.52$**	0.07	-0.05	0	0.11	0.33	-0.26	1	
Species richness	-0.05	0.17	-0.05	0.05	**0.53$**	-0.22	-0.08	-0.07	**0.5#**	1

Tab. 4: Spearman rank order correlation coefficients (R) between environmental variables and CA 1-4. R is given together with levels of probability # = p < 0.05, $ = p < 0.001.
Tab. 4: Spermanovi korelacijski koeficienti (R) med ekološkimi parametri in CA 1-4. R je prikazan skupaj s stopnjami verjetnosti # = p < 0.05, $ = p < 0.001.

Variable	CA1	CA2	CA3	CA4
$CaCO_3$	**0.53#**	-0.4	**-0.41#**	-0.01
pH	-0.06	**-0.83$**	-0.17	0.06
P_2O_5	0.08	-0.3	-0.28	-0.28
K_2O	**0.47#**	-0.26	-0.16	-0.11
Humus	**0.77$**	-0.22	0.18	-0.28
Humidity^E	**-0.45#**	0.33	-0.17	-0.09
Light^E	-0.39	-0.35	-0.19	-0.07
Temperature^E	0.27	0.03	-0.01	-0.18
Nitrogen^E	-0.23	**-0.44#**	0.17	-0.17
Species richness	0.27	**-0.41#**	**0.60$**	-0.33

it could be summarised that species richness is positively affected by humus and nitrogen amounts. Deeper and naturally fertile soils enable a very wide spectrum of species, starting from the contingent of *Brometalia* towards to the rich contingent of *Arrhenatheretalia* order as well. It could be interpreted that species richness on naturally fertile soils is high due to the neutrophilous and mesophilous species occurring in these conditions.

It is known that unfertilised semi-dry and dry meadows are colonised by many rare and threatened species, which are adapted to high solar irradiation, heat, drought and cold winter period, to nutrient poor conditions (Ellenberg, 1996) - interpreted also as mineral nutrient stress (Grime, 1976, 1990) – if these selected species are present, those meadows are automatically considered as "species-rich grasslands" due to the presence of "more important" species. Calcareous substrate is also known to increase species richness (Kinzel, 1983), but in our research the correlation between species richness, $CaCO_3$ and pH were not statistically significant. One reason is probably the fact that all the plots have developed on soils on calcareous substrates (dolomite, limestone, marl, flysch). The other reason could be the fact that mainly all sampled plots presented typical Slovenian semi-dry grasslands which were in very good condition, due to the favourable ecological characteristics of the localities and extensive management regime.

POVEZAVA MED EKOLOŠKIMI PARAMETRI, ŠTEVILČNOSTJO RASTLINSKIH VRST IN FLORISTIČNO SESTAVO SLOVENSKIH POLSUHIH TRAVIŠČ ZVEZE *MESOBROMION ERECTI*

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POVZETEK

Polsuha travišča zveze Mesobromion erecti *(Br.-Bl. & Moor 1938) Oberdorfer 1957 sodijo med habitate z visoko biodiverziteto. Floristično diverziteto lahko najpreprosteje označimo kot število vrst na določeni površini (v našem primeru je bila površina 25 m^2). Namen naše raziskave je bil na osnovi 35 raziskovalnih ploskev (sestojev polsuhih travišč, izbranih na območju srednje, vzhodne in jugovzhodne Slovenije) ugotoviti povezavo med floristično sestavo teh travišč, številčnostjo rastlinskih vrst in izbranimi ekološkimi parametri. Vsa izbrana travišča vzdržujejo z ekstenzivno nego – redno košnjo enkrat na leto brez gnojenja. Vegetacijo smo vzorčili po standardni Braun-Blanquetovi metodi. Hkrati s popisi smo na vzorčnih površinah vzeli tudi vzorce tal, ki so jim bile določene naslednje lastnosti: pH, količina organskih snovi, karbonatov ter deleža kalija in fosforja. Razmere na rastiščih smo ocenjevali tudi na podlagi tehtanih srednjih vrednosti Ellenbergovih ekoloških indeksov za svetlobo, vlago, temperaturo in vsebnost dušika. Klasifikacijo fitocenoloških popisov smo opravili z analizo TWINSPAN. Opravljena je bila tudi ordinacija popisov CA (Correspondence Analysis). Na podlagi obeh analiz smo dobili pet dobro ločenih skupin (klastrov) s 5 do 7 popisi. Za interpretacijo floristični gradientov, ki so se pokazali po ordinaciji CA, smo koordinate CA posameznih popisov s Spearmanovim korelacijskim koeficientom primerjali s pripadajočimi izmerjenimi in ocenjenimi ekološkimi parametri. Pri tem se je pokazalo, da so številni parametri v statistično značilni korelaciji s koordinatami CA. Prva ordinacijska os je v pozitivni korelaciji z vrednostmi za humus, karbonate, vlažnost in kalij in jo lahko interpretiramo kot gradient od popisov na globokih in vlažnih rjavih tleh, do popisov na plitkih, suhih, karbonatnih tleh. Druga os je v negativni korelaciji z vrednostmi pH in vsebnostmi dušika v tleh; vzdolž te osi lahko spremljamo gradient od naravno hranilnih, bazičnih tal do spranih, kislih in s hranilnimi snovmi revnih, pustih tal. Iz dobljenih rezultatov povzemamo, da je številčnost rastlinskih vrst na traviščih, ki sicer niso umetno dognojevana, v rahli pozitivni odvisnosti z vsebnostmi humusa in dušika v tleh. Iz ordinacije CA, ki temelji na floristični sestavi izbranih eksperimentalnih ploskev, lahko jasno razberemo nekatere ekološke gradiente. Zaključujemo, da so pH, vsebnost humusa, karbonatov in dušika v tleh ter vlažnost tal tisti ekološki dejavniki, ki najmočneje vplivajo na vrstno sestavo polsuhih travišč zveze* Mesobromion erecti *v osrednji, vzhodni in jugovzhodni Sloveniji.*

Ključne besede: *Mesobromion erecti*, polsuha travišča, številčnost rastlinskih vrst, klasifikacija, ordinacija, fitosociologija, Ellenbergovi ekološki indeksi

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