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FUNCTIONAL COMPARISION OF THE SUB-MEDITERRANEAN ILLYRIAN MEADOWS FROM TWO DISTINCTIVE GEOLOGICAL SUBSTRATES

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ABSTRACT

In this paper, floristic and functional approaches to the classification of different types of sub-Mediterranean Illyrian grasslands of the association Danthonio-Scorzoneretum villose *(alliance* Scorzonerion villosae*, order* Scorzoneretalia villosae*, class* Festuco-Brometea*) are compared. The data set includes table with 30 relevés from SW Slovenia, sampled in two contrasting geological bedrocks – flysch and limestone – and matrix with 18 traits determined for 119 plant species. We also tested an impact of different geological bedrock on the relative proportions of C-S-R plant strategies in the relevés. With DCA ordination, relevés from limestone and flysch were clearly divided in two groups. First DCA axis suggested a gradient of soil humidity and pH. On the basis of selected traits, 5 Plant Functional Types were clustered and interpreted with Twinspan analysis. PCA ordination of relevés on the basis of plant functional traits revealed that samples from limestone could be separated from those taken on flysch substrate also with functional approach. Relevés from limestone tend to have bigger shares of species, which propagate by seed and vegetatively, and competitors and herbs. Nevertheless, it could be concluded that there are no major functional differences between meadows from both geological substrates. The positions of all relevés in standard C-S-R ternary diagram showed that that the relative proportions of C-S-R functional types were not influenced by different geological bedrock.*

Key words: dry grasslands, plant functional types, *Festuco-Brometea*, vegetation, C-S-R plant strategy, SW Slovenia

CONFRONTO FUNZIONALE DI PRATERIE SUB-MEDITERRANEE ILLIRICHE DI DUE SUBSTRATI GEOLOGICI DISTINTI

SINTESI

Nell'articolo vengono confrontati l'approccio floristico e quello funzionale alla classificazione di differenti tipi di vegetazione, sull'esempio di praterie illiriche sub-mediterranee dell'associazione Danthonio-Scorzoneretum villose *(alleanza* Scorzonerion villosae*, ordine* Scorzoneretalia villosae*, classe* Festuco-Brometea*). I dati comprendono una tabella con 30 relevé della Slovenia sud-occidentale, campionati su due substrati geologici contrastanti – flysch e calcare – e una matrice con 18 tratti funzionali determinati da 119 specie vegetali. Gli autori verificano inoltre l'impatto di diversi tipi di substrato geologico sui rapporti relativi delle strategie ecologiche C-S-R delle piante rinvenute nei relevé. Con l'ordinamento DCA, i relevé su calcare e su flysch vengono chiaramente divisi in due gruppi. Il primo asse DCA suggerisce un gradiente di umidità del suolo e del pH. In base ai tratti funzionali selezionati sono stati raggruppati cinque Tipi Funzionali Vegetali ed interpretati con l'analisi Twinspan. L'ordinamento PCA dei relevé, basato sui tratti vegetali funzionali, ha evidenziato che i campioni provenienti dal substrato calcareo potrebbero venir separati da quelli provenienti dal flysch anche con l'approccio funzionale. I relevé del calcare tendono ad avere una porzione più grande di specie, che si riproducono sia vegetativamente che per via sessuata tramite semi, competitori e piante erbacee. Tuttavia gli autori concludono che non ci sono maggiori differenze funzionali tra le praterie di entrambi i substrati geologici. Le posizioni di tutti i relevé nel diagramma ternario standard C-S-R indicano che i rapporti relativi dei tipi funzionali C-S-R non vengono influenzati da substrati geologici differenti.*

Parole chiave: praterie secche, tipi vegetali funzionali, *Festuco-Brometea*, vegetazione, C-S-R strategie vegetali, Slovenia SO

INTRODUCTION

Classifying plants according to morphology and reproductive attributes has a long history in botany and plant geography (Kleyer, 1999). The renewed interest in classifying species into groups relating to function rather than to taxonomy *(e.g.* Keddy, 1992; Lavorel *et al.*, 1997; Westoby, 1998; Weiher *et al.*, 1999) has triggered the search for traits that express meaningful differences in ecological behaviour among plant species. There has been an increasing interest in using non-phylogenetic based classifications when the focus is turned on predicting the dynamics of vegetation rather than their taxonomic identity (Gitay, 1999; Cornelissen *et al.*, 2003). Classifying plant species according to their taxonomic and phylogenetic relationships has strong limitations when it comes to answering important ecological questions at the scale of ecosystems, landscapes or biomes (Woodward & Diament, 1991; Keddy, 1992; Körner, 1993). These questions include those on responses of vegetation to atmospheric chemistry, land use and natural disturbance regimes. A promising way for answering such questions (and many other ecological questions) is by classifying plant species on functional grounds (Diaz *et al.*, 2002). These alternative classes are often referred to as plant functional types (PFTs) or groups (Grime *et al.*, 1988; Leishman & Westoby, 1992; Gitay & Noble, 1997).

Plant functional types are non-phylogenetic and non-taxonomic groupings of species and can be defined as groups of plant species sharing similar functioning at the organismic level, similar responses to environmental factors *(e.g.* temperature, water availability, nutrients, fire and grazing), and/or similar roles in (or effects on) ecosystems or biomes *(e.g.* productivity, nutrient cycling, flammability and resilience) (Walker, 1992; Chapin *et al.*, 1996; Noble & Gitay, 1996; Diaz & Cabido, 19997; Lavorel *et al.*, 1997; Grime, 2001).

The first step in defining PFTs is to choose a list of key traits that are believed to be important for both understanding and prediction of phenomena relevant for our research. The set of traits or types differ among applications (Woodward & Cramer, 1996).

Plant traits can be obtained by measurements in the filed, laboratory, or from the literature. They usually refer to life-history (life span, life cycle), morphology (plant height, lateral spread, life form, spinescence, species leaf area (SLA), and regeneration *(e.g.* ability to reproduce vegetative, flowering period...) (Kaligarič *et al.*, 2005).

In order to get insights into functional traits, the C-S-R strategy should be considered as well. The C-S-R scheme takes into account a number of different plant traits (Grime *et al.*, 1997; Grime, 2001; Hodgson *et al.*, 1999). The C-S-R plant strategy scheme proposed by Grime (1974) has been widely recognised as a highly developed plant strategy scheme (*e.g.* McIntyre *et al.*, 1995; Lavorel *et al.*, 1997; Westoby, 1998). It is built on the assertion that three major determinations of species exist, namely competition (C), stress (S) and disturbance (R). The competitors exploit conditions of low stress and low disturbance, the stress-tolerators are species that occupy habitats with high stress and low disturbance, and the ruderals are adapted to low stress and high disturbance (Grime, 2002).

In this paper we aim to identify different types of sub-Mediterranean Illyrian grasslands of the association *Danthonio-Scorzoneretum villosae* (alliance *Scorzonerion villosae*, order *Scorzoneretalia villosae*, class *Festuco-Brometea)* on the basis of species composition and plant functional traits. The data set includes table with 30 relevés from SW Slovenia, sampled in two contrasting geological bedrocks – flysch and limestone – and matrix with 43 traits determined for 119 plant species.

The first objective was to reveal how the classification of the relevés from limestone and flysch, based on species composition, match with functional classification, based on plant traits. The second objective was to test if different geological bedrock has any impact on C-S-R strategies.

MATERIALS AND METHODS

Study area

Study areas are the Primorski kras (Littoral Karst) and Slovenian part of Istria, both within the sub-Mediterranean phytogeographic area (Wraber, 1969) with sub-Mediterranean climate (Ogrin, 1996). Precipitation varies from 900 mm and up to 2,500 mm in the High Karst. The strong "bora" wind causes desiccation and erosion. The mean annual temperature is 12°C to 8°C, minimum is –15°C and maximum 34°C (Kaligarič *et al.,* 2006). The Littoral Karst consists of calcareous limestone, which is penetrable to water, dryer and with more or less alkaline pH reaction. On the other hand, Slovenian Istria is a typical flysch (calcareous sandstone) area. In contrast to calcareous limestone, flysch is a substrate with considerably higher water retention. The soil is humus and moisture rich, pH is neutral or slightly acid (Kaligarič, 1997). Hence, the soil is more fertile.

Vegetation survey

We analysed 30 vegetation relevés of association *Danthonio-Scorzoneretum villosae*, which were collected in SW Slovenia from both flysch (18 relevés) and limestone (12 relevés) substrates. Relevés were collected using standard procedure of the Braun-Blanquet approach (Bran-Blanquet, 1964; Westhoff & van der Maarel, 1973; Dierschke, 1994).

Tab. 1: Plant traits, recorded on 119 vascular plant species of sub-Mediterranean Illyrian meadows (SW Slovenia) from two distinct geological substrates, limestone and flysch. Scales of measurement were originally categorical (cat), continuous (cont) or binary (bin).
Tab. 1: Rastlinski funkcionalni znaki za 119 rastlinskih vrst submediteranskih ilirskih travnikov (JZ Slovenija) na dveh različnih geoloških podlagah, apnencu in flišu. Podatki so bili v originalu kategorični (cat), zvezni (cont) ali binarni (bin).

Traits		Abbreviation and description	Data source
Life form	cat	Ch = chamaephytes Ge = geophytes He = hemicryptophytes Th = therophytes	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Martinčič *et al*. (2007)
Life cycle	cat	Ann = annual Bien = biennial Peren = perennial	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Martinčič *et al*. (2007)
Growth form	cat	Tuss = tussocks Rose = rosette Lea_st = leafy stem Ro_lea = rosette and leafy stem	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Martinčič *et al*. (2007); Rothmaler (1995)
Vegetation propagation	cat	VegPro_0 = absent Stol = stolons Rhiz = rhizomes	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Martinčič *et al*. (2007); Rothmaler (1995)
Storage organs	cat	Tube = tuber StorOrg_0 = absent	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Martinčič *et al*. (2007)
Spinescence	bin	Spin_1 = present Spin_0 = none	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Martinčič *et al*. (2007)
Hairiness	cat	HairLow = low HairHigh = high HairNo = no	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Poldini (1991); Martinčič *et al*. (2007)
Plant height	cont	Height1 = < 5 cm Height2 = 5-25 cm Height3 = 25-75cm Height4 = 75-125 cm Height5 = 125-150 cm Height6 = > 150 cm	own measurements
Specific leaf area (SLA)	cont	SLA1 = < 10 mm^2/mg SLA2 = 10-13 mm^2/mg SLA3 = 13-16 mm^2/mg SLA4 = 16-19 mm^2/mg SLA5 = 19-22 mm^2/mg SLA6 = > 22 mm^2/mg	own measurements; LEDA database (Kleyer *et al*., 2008)
Leaf dry matter content (LDMC)	cont	LDMC1 = < 5 mg/g LDMC2 = 5-5.29 mg/g LDMC3 = 5.30-5.59 mg/g LDMC4 = 5.60-5.89 mg/g LDMC5 = > 6 mg/g	own measurements; LEDA database (Kleyer *et al*., 2008)
C-S-R strategy	cat	C = competitors S = stress-tolerators R = ruderals	own measurements; BiolFlor database (Klotz *et al*., 2002)
Flowering start		Flow_St = months	Hegi(1958, 1963, 1964, 1965, 1966, 1974, 1987); Poldini (1991); Martinčič *et al*. (2007)
Flowering end	cat	Flow_End = months	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Poldini (1991); Martinčič *et al*. (2007)
Flowering period	cat	Flow_Per = months	Hegi (1958, 1963, 1964, 1965, 1966, 1974, 1987); Poldini (1991); Martinčič *et al*. (2007)
Leaf persistence	cat	LP_2 = summer green LP_4 = persistent green	own measurements; BiolFlor database (Klotz *et al*., 2002)
Leaf anatomy	cat	Scler = scleromorphic Meso = mesomorphic	own measurements; BiolFlor database (Klotz *et al*., 2002)
Type of reproduction	cat	Rep1 = by seed/by spore Rep2 = mostly by seed, rarely vegetatively Rep3 = by seed and vegetatively Rep4 = mostly vegetatively, rarely by seed	own measurements; BiolFlor database (Klotz *et al*., 2002)
Guild	cat	Gpoa = grass Gsedge = sedge Gwood = woody plant Gherb = herb Gfab = fabaceae	own measurements; BiolFlor database (Klotz *et al*., 2002)

Selection and measurements of plant traits

While selecting most significant or informative traits, we followed different literature sources (Hodgson *et al.*, 1999; Kahmen *et al.*, 2002; Cornelissen *et al.*, 2003). We selected 18 traits for each species. Traits were chosen from our own database (protocol standardized by Cornelissen *et al.*, 2003). Information on species traits was also taken from two existing trait databases BiolFlor (Klotz *et al.*, 2002) and LEDA (Kleyer *et al.*, 2008). Species was characterized by basic traits as well as composite traits (such as C-S-R strategy). Due to the different species sets, we focused on traits that were easy to measure. The traits selected were: "life form", "life cycle", "growth form", "vegetation propagation", "storage organs", "spinescence", "hairiness", "plant height", "specific leaf area (SLA)", "leaf dry matter content (LDMC)", "CSR strategy", "flowering start", "flowering end", "flowering period", "leaf persistence", "leaf anatomy", "type of reproduction" and "guilds".

The scale of measurement of plant traits was originally continuous or categorical, but they were all transformed into categorical scales for analyses. The list of traits with description of classes in matrix and the sources of information are presented in Table 1.

Allocating a C-S-R plant functional type to plant species and vegetation samples (relevés)

The C-S-R scheme takes into account a number of different plant traits (canopy height, dry matter content, flowering period, flowering start, lateral spread, leaf dry weight, SLA). To determine the one of 19 C-S-R functional types (Hodgson *et al.*, 1999) for 119 plant species recorded in 30 analysed vegetation relevés of sub-Mediterranean Illyrian meadows (association *Danthonio-Scorzoneretum villosae),* we used data from look-up table with C-S-R types for 1000 European species (source J. G. Hodgson, UCPE Sheffield). For species of unknown type we used a rapid method for attribution of C-S-R type from simple measurements and data published by Hodgson *et al.* (1999).

A functional signature can be derived for a sample of vegetation. The signature is a numerical index which concisely represents the total balance between the different functional attributes that are present among the component species (Hodgson *et al.*, 1999). Using the methodology of Hunt *et al.* (2004), the relative proportions of C-S-R functional types for our 30 samples (relevés) of vegetation were calculated and plotted in C-S-R space.

Classification and ordination analysis

To classify the relevés according to their species composition, we built a 119 species x 30 relevés matrix (all matrices available by authors on request). Braun-Blanquet cover-abundance data for the species were converted into a 1 to 9 scale (van der Maarel, 1979). This matrix was then subjected to ordination methods – Detrended Correspondence Analysis (DCA) (Hill & Gauch Jr., 1980). The DCA with detrending by segments was used to estimate the heterogeneity in the species data. Gradient length for the first DCA axis was 3.0, indicating that both the linear and unimodal ordination methods are suitable for the analysis. We decided to use the unimodal (DCA) ordination method (Lepš & Šmilauer, 2003).

In order to identify groups of species with similar traits, we built a 43 traits x 119 species matrix. The scales of measurements of plant attributes were originally continuous, categorical or binary, but they were all transformed into categorical or binary scales prior to the analysis. The number of traits in the matrix increased from 18 to 43 due to the fact that the categorical variables were all re-coded into different numbers of dummy variables – one for each possible level of the factor (Tab. 1). Example: trait "life cycle" has three levels of the factor (1) annual; (2) biennial and (3) perennial species. We submitted the matrix to divisive clustering – Two Way INdicator SPecies ANalysis (TWINSPAN) (Hill, 1979). It was run using the TWINSPAN for Windows version 2.3 (Hill & Šmilauer, 2005).

In order to identify the predominant plant traits for studied meadows, the matrix of 43 traits by 119 species was multiplied by the matrix of 119 species x 30 relevés. The result was a matrix of 43 traits x 30 relevés that was analysed by the means of Principal Component Analysis (PCA) (Goodall, 1954). The values of the traits data were log-transformed prior to PCA analysis.

The ordination methods (PCA, DCA) and visualization of their results were carried out using the Canoco and CanoDraw programs (ter Braak & Šmilauer, 2002).

Nomenclature

Taxonomic nomenclature is in agreement with Martinčič *et al.* (2007), while for the names of the syntaxa we follow Kaligarič (1997).

RESULTS AND DISCUSSION

Species composition analysis

The total number of vascular plant species recorded in 30 relevés of studied species rich grasslands was 119 with 88 on limestone (mean = 30 $\pm$ 5.3 s. d. per plot, N=12) and 105 (mean = 34 $\pm$ 4.5 s.d. per plot, N = 18) on grasslands from flysch. All species are listed in Appendix 1. There are 74 common species, 14 species exclusive to the limestone grasslands and 31 exclusive to the grasslands on the flysch. Higher species diversity of

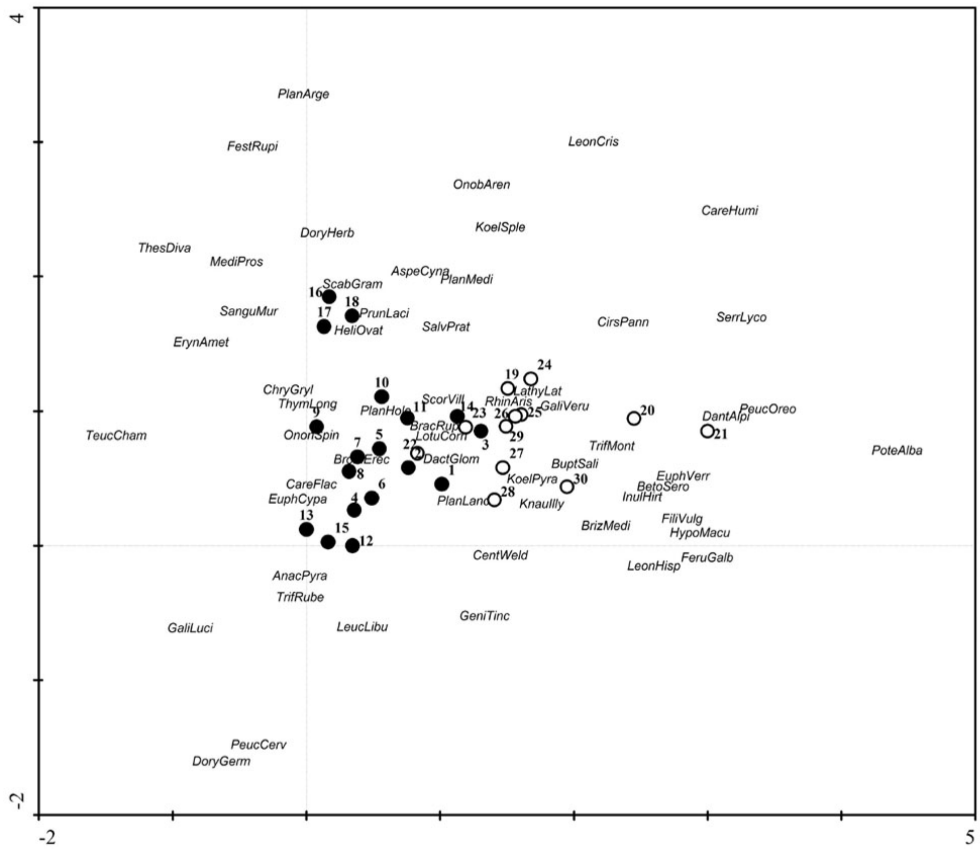

Fig. 1: DCA ordination diagram of relevés (N = 30, 119 species) of sub-Mediterranean Illyrian meadows from two distinctive geological substrates. Eigenvalues: axis 1 = 0.382; axis 2 = 0.181; 21.3% of variance in species explained by both axes. Shown species have the highest weight. Relevés are divided in two groups according to the geological substrate: ● – relevés from flysch; ○ – relevés from limestone. Abbreviations of species explained in Appendix 1. Relevés numbers correspond to those in Appendix 1.

Sl. 1: DCA-ordinacija popisov (N = 30, 119 vrst) submediteranskih ilirskih travnikov z dveh različnih geoloških podlag. Lastne vrednosti: os 1 = 0,382; os 2 = 0,181; obe osi razložita 21,3% variabilnosti v vrstni sestavi. Prikazane vrste imajo najvišji vpliv. Popisi so ločeni v dve skupini glede na geološko podlago: ● – popisi na flišu; ○ – popisi na apnencu. Razlage okrajšav za vrste so v Prilogi 1. Številke popisov ustrezajo številkam popisov v Prilogi 1.

grasslands from flysch is probably connected with higher species pool in this area, which is closer to the Adriatic Sea and milder climate, which contribute a share of Eu-Mediterranean species, lacking on the limestone, being slightly distant from the sea.

To support this statement, we refer to *e.g.* Poldini (1991): in the atlas of regional flora, one of the richest areas was in lower altitudes, near the sea. Differences in floristic composition were first analysed with DCA analysis of the 119 species x 30 relevés matrix. DCA ordination is shown in figure 1. Eigenvalues for first two DCA axes are 0.382 and 0.181. First two axes explain together 21.3% variability in the species composition. Relevés are rather continuously arranged along the DCA Axis 1 (Fig. 1). Environmental gradient could be interpreted on the basis of the species ordination. The species with the lowest scores (-X) are those characteristically found on deeper soil, with more humus and moisture and neutral to slightly acid pH: *Peucedanum cervaria, Dorycnium germanicum, Teucrium chamaedrys, Galium lucidum, Trifolium rubens, Chrysopogon gryllus* and *Carex flacca*. *Potentilla alba*, *Hypochoeris maculata*, *Carex humilis*, *Inula hirta* were some of the species receiving the highest scores in the first DCA, *i.e.* they are associated with sites with more warm, dry and basiphilous conditions. Dispersion of relevés along the first axis of the DCA suggested a gradient of soil humidity and soil pH. Relevés of the most humid and neutral to slightly acid soil on the flysch (Nos. 1 to 18) are positioned on the left side, and relevés of the very dry shallow limestone soils with high pH (No. 19–30) are positioned on the right side of the DCA ordination biplot.

Plant functional types

On the basis of Twinspan analysis of the 43 traits x 119 species matrix (Fig. 2), we distinguished five groups (clusters) that could be interpreted as plant functional types (PFT).

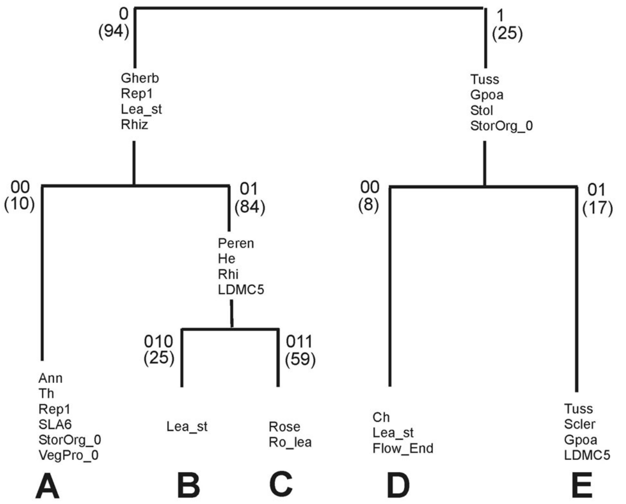

Fig. 2: Simplified TWINSPAN classification tree (dendrogram) of 119 species. For each division number of group, numbers of species (in brackets) in group and indicator traits are shown. Abbreviations of plant traits are explained in Table 1.
Sl. 2: Poenostavljen diagram TWINSPAN-klasifikacije (dendrogram) za 119 vrst. Za vsako delitev so prikazani število skupine, število vrst v skupini (v oklepaju) in indikatorski funkcionalni znaki. Okrajšave za funkcionalne znake so razložene v Tabeli 1.

Group A included 10 species. They were all annual species (therophytes) (Ann, Th) with relatively high values for SLA (SLA6). Height values of SLA tend to correspond with relatively low investments in leaf "defences" and short leaf lifespan. Species in resource-rich environments tend to have larger SLA than those in environments with resource stress (Cornelissen *et al.*, 2003). Species from group A reproduce by seeds (Rep1), they do not have storage organs (StorOrg_0) and they do not propagate vegetatively (VegPro_0). We could find here *Blackstonia perfoliata, Linum catharticum, Rhinanthus* spp., *Trifolium campestre* and *Centaurium erythrea*. Groups B and C represented perennial species (Peren), hemicryptophytes (He) with rhizomes (Rhi) and with higher values for LDMC (LDMC 5). Species from group B were mostly tall hemicryptophytes (He) with leafy stem (Lea_st), like *Achillea collina, Buphthalmum salicifolium, Centaurea triumfetti* subsp. *adscendens* and *C. pannonica, Leucanthemum liburnicum, Dianthus tergestinus* and *Onobrychis arenaria*. Group C is characterized by rosette (Rose) and hemirosette (Ro_lea) plants: *Carlina acaulis, Eryngium amethystinum, Globularia punctata, Hypochoeris maculata, Leontodon hispidus, Plantago* spp., *Potentilla alba, Tragopogon orientalis* and *Trifolium montanum*. The last two groups, D and E, were separated from others already at the first cut level. 8 species from group D were mainly chamaephytes (Cham) with leafy stem: *Chamaespartium sagittale, Teucrium chamaedrys and Thymus longicaulis*. In comparison to others, this group included significantly higher share of late flowering species. The most homogenous was group E with 17 species, where we could find tussock-forming species, with scleromorphic leaves and high LDMC values. All this information indicated that this group was rich on grasses (fam.

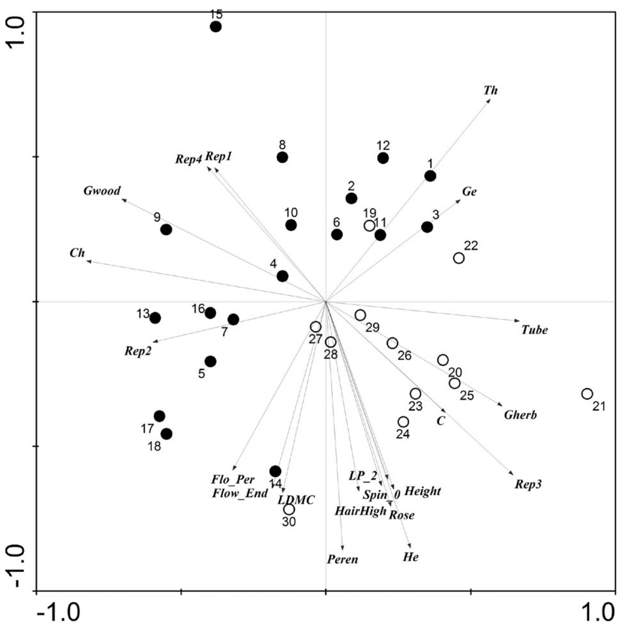

Fig. 3: PCA ordination diagram of matrix 3 with 30 relevés and 43 traits. Eigenvalues: axis 1 = 0.30; axis 2 = 0.18; 42.6% of variance in species explained by both axes. Shown traits (21) have the highest weight. Relevés divided in two groups according to the geological bedrock: ● – relevés from flysch; ○ – relevés from limestone. Abbreviations of plant traits explained in Table 1. Relevés numbers correspond to those in the Appendix 1.
Sl. 3: PCA-ordinacija matrike 3 s 30 popisi in 43 rastlinskimi funkcionalnimi znaki. Lastne vrednosti: os 1 = 0,30; os 2 = 0,18; obe osi razložita 42,6% variabilnosti v vrstni sestavi. Prikazani funkcionalni znaki (21) imajo najvišji vpliv. Popisi ločeni v dve skupini glede na geološko podlago: ● – popisi na flišu; ○ – popisi na apnencu. Razlage okrajšav za funkcionalne znake so v Prilogi 1. Številke popisov ustrezajo številkam popisov v Prilogi 1.

Poaceae) and grass-like plants (fam. *Cyperaceae) (e.g. Anthoxanthum odoratum, Bothriochloa ischaemum, Brachypodium rupestre, Briza media, Bromopsis erecta, Carex flacca* and *C. humilis, Chyrsopogon gryllus, Danthonia alpina* and *D. decumbens, Festuca pratensis* and *F. rubra, Koeleria pyramidata, Poa pratensis...*).

A PCA ordination of matrix 3 with 43 traits x 30 relevés was performed in order to differentiate the analyzed sub-Mediterranean Illyrian meadows on the basis of five PFT according to the two distinct geological substrates. Ordination graph is presented in figure 3. Only 21 traits with the highest weight (most significant) are shown in the ordination diagram. The angles between arrows indicate correlations between traits. Relevés with high proportion of species reproducing by seeds and vegetatively (Rep3) had also high shares of herbaceous plants (Gherb) plants and competitors (C). Relevés with high proportion of hemicryptophytes (He) had also many perennial (Peren) and tall species (Height).

Traits the most correlated with relevés scores of PCA axis 1 (eigenvalue = 0.30) were tuber (Tube) and chamaephytes (Ch).

In the PCA ordination of all relevés on the basis of plant traits (Fig. 3), relevés from limestone were grouped in the lower right side of the ordination biplot. Those relevés had bigger shares of species, which propagate by seed and vegetatively (Rep3), competitors (C) and herbs (Gherb). Nevertheless, it could be concluded that there are no major functional differences between meadows from both geological substrates.

CSR strategies

In figure 4, the positions of all calculated signatures for 30 relevés of sub-Mediterranean Illyrian meadows from two contrasting geological substrates are presented in standard C-S-R ternary diagram. Relevés are grouped in the upper part of the triangle, showing relative importance of C component (competition). The second objective was to test if different geological bedrock resulted in significant differences in C-S-R strategies. No significant differences was found, except for the two relevés from limestone: they show influence of stress-tolerators (wind-exposed positions, dryer calcareous substrate), and a few relevés from flysch have higher impact of C component (consisted of typical competitors in fertile soil and favourable climate). Unless it could be concluded that the relative proportions of C-S-R functional types are not influenced by different geological bedrock.

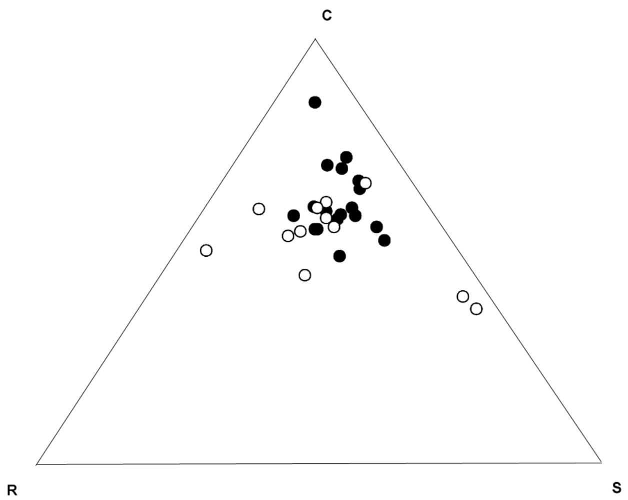

Fig. 4: C-S-R ordination of vegetation of relevés (N = 30, 119 species) of sub-Mediterranean Illyrian meadows from two contrasting geological substrates. ● – relevés from flysch; ○ – relevés from limestone.
Sl. 4: C-S-R-ordinacija popisov (N = 30, 119 vrst) submediteranskih ilirskih travnikov iz dveh različnih geoloških podlag. ● – popisi na flišu; ○ – popisi na apnencu.

FUNKCIONALNA PRIMERJAVA SUBMEDITERANSKIH ILIRSKIH TRAVNIKOV Z DVEH RAZLIČNIH GEOLOŠKIH PODLAG

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POVZETEK

V pričujočem članku smo primerjali floristični in funkcionalni pristop pri klasifikaciji tipov vegetacije na primeru sub-mediteranskih ilirskih travišč asociacije Danthonio-Scorzoneretum villose *(zveze* Scorzonerion villosae, *reda* Scorzoneretalia villosae, *razreda* Festuco-Brometea*). Baza podatkov je obsegala tabelo s 30 popisi travišč iz SZ Slovenije, zbranih na dveh različnih geoloških podlagah – flišu in apnencu – in matrike z 18 funkcionalnimi znaki, ki smo jih določili za 119 rastlinskih vrst. Naš cilj je bil tudi ugotoviti, ali različna geološka podlaga vpliva na deleže posameznih C-S-R-ekoloških strategij rastlin v popisih.*

Najprej smo analizirali raznolikost floristične sestave z indirektno analizo gradientov (DCA) in na podlagi ordinacije popisov in vrst ugotovili, da so se popisi razporedili sorazmerno zvezno vzdolž gradienta vlažnosti (oz. sušnosti) ter kemijske reakcije (pH) tal. Popisi z različnih geoloških podlag so bili med sabo jasno ločeni. S klasifikacijsko analizo Twinspan matrike 43 funkcionalnih znakov × 119 rastlinskih vrst smo določili 5 skupin vrst, ki smo jih interpretirali kot funkcionalni tipi, ki se pojavljajo na obravnavanih suhih traviščih.

Za ugotavljanje razlike med popisi na apnencu in flišu na podlagi izbranih funkcionalnih znakov rastlin smo matriko 43 funkcionalnih znakov × 119 vrst pomnožili z matriko 119 vrst × 30 popisov. Kot rezultat smo dobili matriko 43 funkcionalnih znakov × 30 popisov, ki smo jo nato analizirali z indirektno ordinacijsko metodo glavnih komponent (analizo PCA). Na grafu se je na podlagi funkcionalnih znakov rastlin oblikovalo kar nekaj manjših skupin popisov. Tudi tokrat so se popisi iz apnenca razporedili skupaj, in sicer desno spodaj v grafu. To pomeni, da so med zbranimi funkcionalnimi znaki tudi takšni, ki imajo večje deleže vrst (npr. kompetitorji (C), zelišča (Gherb), razmnoževanje s semeni in vegetativno (Rep3)) ali pa manjše deleže vrst (npr. lesne vrste (Gwood)) v popisih na apnencu v primerjavi s popisi na flišu. Vendar pa po analizi teh znakov ugotavljamo, da le-ti nimajo večjega pomena in zaključujemo, da ni značilnih razlik med travišči na apnencu in flišu glede na funkcionalne znake in tipe rastlin. Tudi razporeditev popisov v trikotniku C-S-R na podlagi relativnih deležev posameznih C-S-R-ekoloških strategij rastlin v popisih ne dokazuje značilnih razlik med popisi na apnencu in flišu.

Ključne besede: suhi travniki, rastlinski funkcionalni tipi, *Festuco-Brometea*, vegetacija, C-S-R strategije rastlin, JZ Slovenija

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Appendix 1: 30 relevés of sub-Mediterranean Illyrian grasslands of the association *Danthonio-Scorzoneretum villosae* ***(alliance*** *Scorzonerion villosae*, ***order*** *Scorzoneretalia villosa*, ***class*** *Festuco-Brometea).* ***Relevés were sampled in SW Slovenia in two contrasting geological bedrocks – flysch and limestone.***
Priloga 1: 30 popisov submediteranskih ilirskih travnikov asociacije *Danthonio-Scorzoneretum villosae* ***(zveza*** *Scorzonerion villosae*, ***red*** *Scorzoneretalia villosae*, ***razred*** *Festuco-Brometea).* ***Popisi so bili zbrani v JZ Sloveniji na dveh različnih geoloških podlagah – fliša in apnenca.***

		Flysch																		Limestome											
	Relevé number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
	Number of species per relevé	29	44	32	31	38	35	37	35	32	29	28	31	28	37	30	40	35	36	27	26	26	24	28	28	24	29	41	38	30	33
Species	Species abbreviations																														
Achillea collina	*AchiColl*									+							+	+	+							+					
Anacamptis pyramidalis	*AnacPyra*		+	+		+	+		+		+	+	+																		
Anthericum ramosum	*AnthRamo*														+						+	1									
Anthoxanthum odoratum	*AnthOdor*																											1	1	1	
Anthyllis vulneraria subsp. *polyphylla*	*AnthPolyp*			+		+									+					+					+						
Asperula cynanchica	*AspeCynan*												+		+	+	+	+	1	+					+		+	+	+		
Asperula purpurea	*AspePurp*							1							+		+														
Betonica serotina	*BetoSero*	2	+	+										+	+					+		+			+	+	1				1
Blackstonia perfoliata	*BlacPerf*				r		+	+	+							+															
Botryochloa ischaemum	*BotrIsch*																1	1	1												
Brachypodium rupestre	*BracRupe*	+	1	1	1	2	3	1	1		1	1	3	+	2		2	1	2		1			1		1	+	2	1		2
Briza media	*BrizMedi*	1	2	2	+	1	1	1	1	+		1		+	+	+				1	1	2	1	2	+	1	2	1	1	1	1
Bromopsis erecta	*BromErec*	2	3	4	2	2	2	4	2	3	2	2	2	3	2	4	3	3	3	1			2	2		1	3	2	2	3	1
Buphthalmum salicifolium	*BuptSalic*		+	+	+	1	1					1	+		+	+			+	+	+	+		+	+	1	+	+		+	
Campanula glomerata	*CampGlom*																				+	+									
Campanula rapunculus	*CampRapu*										+	+						+										+	+	+	
Carex flacca	*CareFlac*	+	+		+	2	1	+	+	+	+		+	+		+	+		1	1			+				2				
Carex humilis	*CareHumi*														1			1	1	2	2	2			+						
Carex montana	*CareMont*																											1		1	1
Carlina acaulis	*CarlAcau*		+																		+										
Carlina corymbosa	*CarlCory*						+							+		+	+	+													
Centaurea triumfettii subsp. *adscendens*	*CentAdsc*														+		+													+	
Centaurea pannonica	*CentWeld*	+	+	+	+	+		+	+	+	+		+	+		+	+				+		+	+	+		+	2	1	+	1
Centaurium erythrea	*CentEryt*						+						+			+															
Chamaespartium sagittale	*ChamSagi*					+																									
Chrysopogon gryllus	*ChryGryl*	3	2	2	4	2		1	3	3	4	3	+	1	1	2	3	3	2				3					2	2		
Cirsium pannonicum	*CirsPann*		+	1				+				+								1				1	1		3	+		+	1
Dactylis glomerata	*DactGlom*		1	+	1	+		1	1		+	+	1	+	+	+	1	1	1				+			1		1	+	1	3
Danthonia alpina	*DantAlpi*	+	2	3																	2	3		+	+	+		1		1	
Danthonia decumbens	*DantDecu*																				1	1									
Daucus carota	*DaucCaro*			+													+	+	+									1			
Dianthus tergestinus	*DianTerg*														+		+	+													
Dorycnium germanicum	*DoryGerm*				2	1	1	+					1	2		+							1						+		
Dorycnium herbaceum	*DoryHerb*	1	1	2					+		2						1	1													
Eryngium amethystinum	*ErynAmet*	r	1			+	+	+	1	+				+	+	+	1	1	+												
Euphorbia cyparissias	*EuphCypa*		+				+						+	+	+				1					+							

		Flysch																		Limestome											
	Relevé number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
	Number of species per relevé	29	44	32	31	38	35	37	35	32	29	28	31	28	37	30	40	35	36	27	26	26	24	28	28	24	29	41	38	30	33
Species	Species abbreviations																														
Euphorbia nicaeensis	*EuphNica*				1	1			+	+				+		+															
Euphorbia verrucosa	*EuphVerr*	1	+	1				+														1			+		+	+	+	1	1
Ferulago galbanifera	*FeruGalb*			+			+				r		1								1	1			+	+	+		1		2
Festuca rubra	*FestRubr*																											1	2		1
Festuca rupicola	*FestRupi*								+	+				+			2	2	2		+		+								
Filipendula vulgaris	*FiliVulg*	+			+							+			1						+	1	+	+		+	+	2	1		2
Fumana procumbens	*FumaProc*															r	+														
Galium lucidum	*GaliLuci*	1	+	+		+	+	1					+	2		1	+	1													
Galium verum	*GaliVeru*				2				+	+	2	2			2					+			+	+	+		+	1	1	1	2
Genista germanica	*GeniGerm*							r								+												+	1		+
Genista tinctoria	*GeniTinc*				+	+		+							+	+													+	1	+
Geranium sanguineum	*GeraSang*						+								1																
Gladiolus illyricus	*GladIlly*	+																				+									
Globularia punctata	*GlobPunc*		+						+						+	+															
Gymnadenia conopsea	*GymnCono*					+	+													+											
Helianthemum ovatum	*HeliOvat*		1			+	+		+	+	+	+				1	1	1	+	+							+	1	+		+
Hieracium pilosella	*HierPilo*							+			+				+		1		+												
Hippocrepis comosa	*HippComo*														+		1		+										+		
Hypericum perforatum	*HypePerf*								+																				+		
Hypochoeris maculata	*HypoMacu*																			+		+			+	+	1	2	3		1
Inula hirta	*InulHirt*	2	1	2	+	+														+	+	+	+			+	+				
Knautia illyrica	*KnauIlly*	+	2		+	+	+	+	+		+	+	+	+	+				+	+	+	+	+		+		+	1	1	1	+
Koeleria pyramidata	*KoelPyra*	+	+	1				2	+		+	+			+								+	+		+		2			2
Koeleria splendens	*KoelSple*				+	2	+										1		1		+	+									
Lathyrus latifolius	*LathyLaty*			+				r	+	+	+	+												1	+	+		+	+	1	+
Lathyrus pratensis	*LathPrat*					+		+						+					+											+	1
Lembotropis nigricans	*LembNigr*				+								+	+	+	+															
Leontodon crispus	*LeonCris*																+	+	+	+		+			+					1	
Leontodon hispidus	*LeonHisp*						+						1								1		+	1	+			1	1	1	1
Leucanthemum liburnicum	*LeucLibu*	+	+	+		+	r		2	+						+							+	+				+	+		
Linum catarthicum	*LunCath*	+	+	+																+			+					+		+	
Linum flavum	*LinuFlav*		+	2																											
Linum tenuifolium	*LinuTenu*	+	+			+										+		+	+	+											
Lotus corniculatus subsp. *hirsutus*	*LotuCorn*	+		+	+	+	+	1	+	+	1	+	+		+	+	+		+	+			1		+		+	+	+	1	+
Medicago falcata	*MediFalc*				+								+	+				+													
Medicago prostrata	*MediProst*		+		+	+		1	1	1	1	2					+	+	+				+	+							
Odontites lutea	*OdonLute*		+										+			+															
Onobrychis arenaria	*OnobAren*		1														1	+	1	1				+	1	+	+			2	
Ononis spinosa	*OnonSpin*	+	+		1	2	1	2	+	+	2	1	+	+			1		+				+	+		+			1	1	
Pastinaca sativa	*PastSati*											r		+																	
Peucedanum cervaria	*PeucCerv*	2	3		+		+	2	+				2			2															
Peucedanum oreoselinum	*PeucOreo*														+						1	1		+						+	3
Picris hieracioides	*PicrHier*									+			+				+	+	+												
Pimpinella saxifraga	*PimpSaxi*	1													+																

		Flysch																		Limestome											
	Relevé number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
	Number of species per relevé	29	44	32	31	38	35	37	35	32	29	28	31	28	37	30	40	35	36	27	26	26	24	28	28	24	29	41	38	30	33
Species	Species abbreviations																														
Plantago argentea	*PlanArge*																2	2					+		+		+				
Plantago holosteum	*PlanHolo*		+		+	+		1	+	+									+	+				+	+	+			+		
Plantago lanceolata	*PlanLanc*				+		+			1			+		+			+	+									2	1	1	1
Plantago media	*PlanMedi*		+	1		+	1	1			1	1		+	+		1	1	+		+			1	2	1	+	1	1	+	
Poa pratensis	*PoaPrat*																											+			+
Polygala nicaeensis subsp. *mediterranea*	*PolyNicae*																					1									
Potentilla alba	*PoteAlba*																				2	3									1
Potentilla australis	*PoteAust*																+								+		+				
Potentilla erecta	*PoteErec*																					+							+		+
Prunella grandiflora	*PrunGrand*					+															+	+				+	+				
Prunella laciniata	*PrunLaci*	+		+				+	1		+								+							+					
Ranunculus bulbosus	*RanuBulb*																+		+												
Ranunculus nemorosus	*RanuNemo*																											+	+		1
Rhinanthus glacialis	*RhinAris*	+	+										+			+	1			+	+	+	+	+	1	1	+				
Rhinanthus freynii	*RhinFrey*			+					+																				+		
Rhinanthus minor	*RhinMino*		+									2																+	+	+	
Rumex acetosa	*RumeAcet*																											+			+
Salvia pratensis agg.	*SalvPrat*			+		+	+	+	+	+	1	2	+				+	+			+			1		+	+	+		+	+
Sanguisorba muricata	*SanguMuri*		+		+	+	+	+	+	+	+	+						+	+				+	+							
Satureja montana subsp. *variegata*	*SatuVari*					+													+												
Scabiosa grammuntia	*ScabGram*			+			+	+			1	1				+	+	+						+	+			+			
Scorpiorus subvillosus	*ScorSubv*									+	+		+																		
Scorzonera villosa	*ScorVillo*		1			1		2	2	2	2	+	+	2		+	+	2		3	+			2	3	2	+	1	1	2	+
Senecio jacobaea	*SeneJaco*		r												+													+	+		
Serratula lycopifolia	*SerrLyco*																				1	1	1		+	2	1				
Stachys recta agg.	*StacRect*						+	+					+	+																	
Teucrium chamaedrys	*TeucCham*		1						+	+			+	+			+	1													
Teucrium montanum	*TeucMont*		+	1			+			+					+					+											
Thalictrum minus	*ThalMinu*			+											+					+		+									+
Thesium divaricatum	*ThesDiva*		+		+		+	2		1							1	+	+												
Thymus longicaulis	*ThymLong*	+	+		+	+		+	+	+	+			+		+	+	1	+		+							+			
Tragopogon pratensis subsp. *orientalis*	*TragOrie*	+		+							+	+			+					+							+				
Tragopogon tommasinii	*TragTomm*				+	+	1	+																							
Trifolium campestre	*TrifCamp*								1	+		+																			
Trifolium montanum	*TrifMont*					+	2				+				+					+		+		+	+		+	1	2	2	
Trifolium pratense	*TrifPrat*				+			r	+	+		+																+	1		
Trifolium rubens	*TrifRube*	1	1		+	+	+			+			+	+	+			+					+	+							
Veronica barrelieri	*VeroBarr*									+								+						+							
Vicia cracca	*ViciCrac*									+				+																	

Relevés numbers in Table 1 correspond to the following relevѐs from the original table: No. 1–30: Kaligarč, 1997: Tab. 1, relevés No. 1, 2, 5, 7, 10, 12, 14, 16, 18, 19, 20, 21, 23, 24, 25, 27, 29, 30, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42 and 43.