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The occurrence of arctic-alpine elements within high-mountain plant communities in relation to enviromental factors, functional types and phytogeography

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Carex rupestris, Vysoké Tatry Mts, Velická dolina Valley, 19th July 2006

"If this is a refugium, why are my feet so bloody cold?"
Buckland & Dugmore (1991)

Vysoké Tatry Mts, Mengusovská dolina Valley, 31st August 2006, M. Perný and I. Šibíková

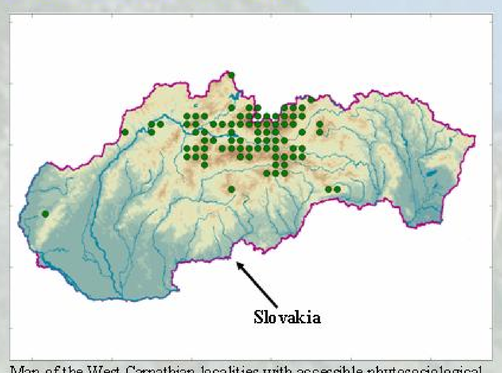
INTRODUCTION

High mountains of the Carpathians embedded within the other European mountain ranges characterised by various geological bedrock; miscellaneous climatic and soil features contribute to an exceptional variability of habitats, including refuges that provide optimal conditions for high-altitude plants. Under specific conditions the diverse mosaic of vegetation types developed with an abundance of relic and endemic taxa. The landscape heterogeneity and island phenomenon play important role in structuring of the plant communities.

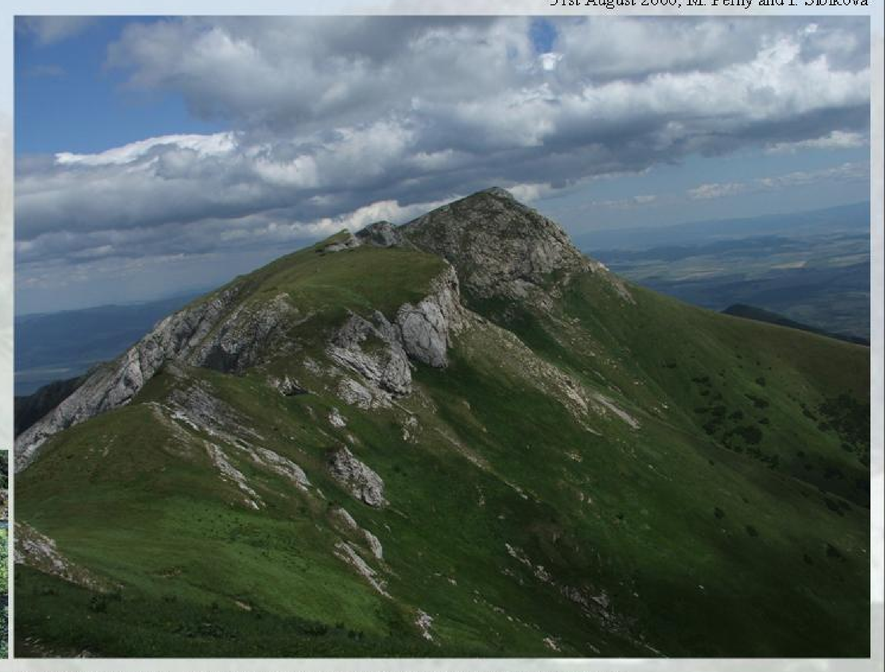
The evaluation of individual vegetation types should be done on the basis of complex knowledge and should follow not only the floristic composition of phytocoenoses and ecological characteristics, but also the general evolutionary assembly rules connected with phytogeography of the species.

This contribution serves view on processing of phytosociological relevés together with phytogeographical, functional and ecological data, paying particular attention to phytogeographical elements in the flora of Western Carpathians, life forms of individual taxa and Ellenberg's indicator values.

We used selected high-mountain plant communities of Western Carpathians with abundant arctic-alpine species as an excellent model system. On the other hand, this contribution handles with the distribution of arctic-alpine taxa within Western Carpathians and their abundance in individual vegetation types.

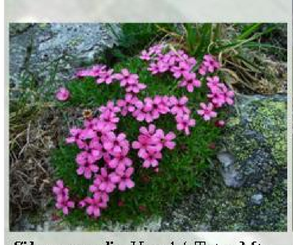


Map of the West Carpathian localities with accessible phytosociological relevés with the occurrence of at least one arctic-alpine species.



Belianske Tatry Mts, the refugium of many arctic-alpine species, 7th July 2007

Vysoké Tatry Mts, Mengusovská dolina Valley, 7th July 2006



Silene acaulis, Vysoké Tatry Mts, 7th July 2006

MATERIAL & METHODS

The data selection is based on the analysis of 49 459 phytosociological relevés obtained in June 2007 from the Slovak National Vegatation Database (ŠIBÍKOVÁ et al. 2008, www.ibot.sav.sk/cdf) and stored in a TURBOVEG database (HENNEKENS & SCHAMINÉE 2001). The data were exported into JUICE 6.4.6 software (TICHÝ 2002) for analysis. Only the relevés assigned to syntaxon at least at the level of alliance were included to the analysis. The detailed methodology is to find in work JAROLÍMEK & ŠIBÍK (2008).

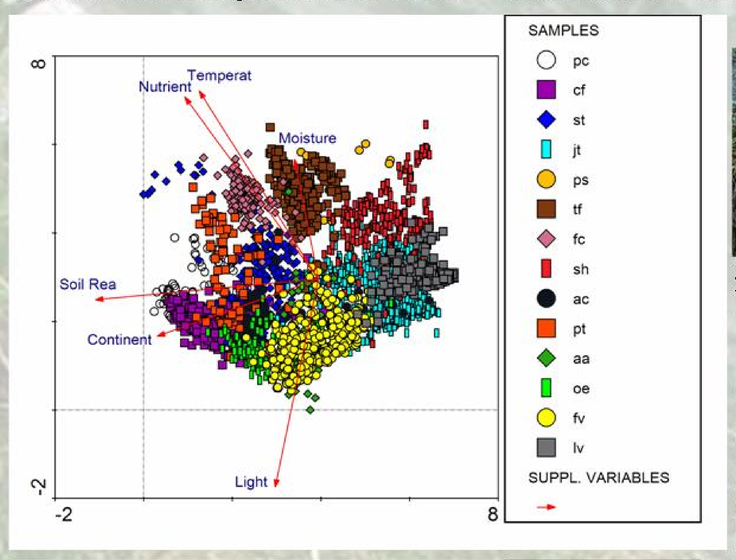
The data sets of 5 030 phytosociological relevés with the occurrence of at least 1 arctic-alpine taxa and of 3 510 relevés belonging to 14 alliances, which suited the condition that at least 25 % of total number of relevés in the alliance contains at least 2 arctic-alpine taxa, were used for individual analyses.

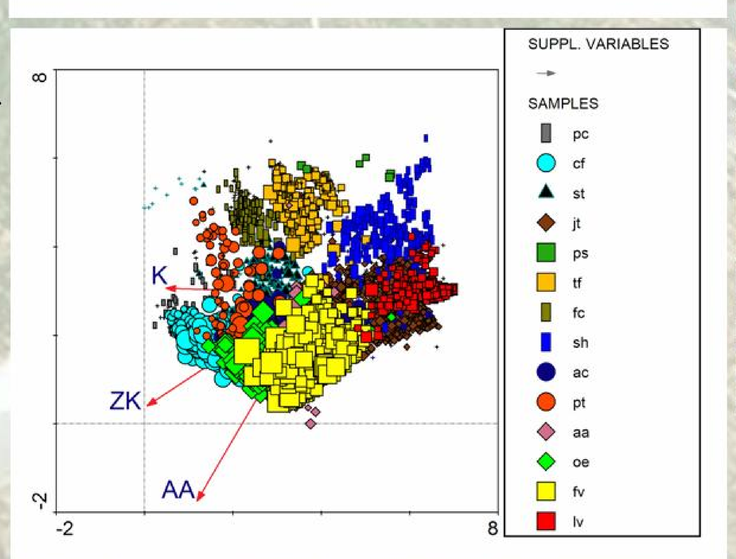
Fourteen alliances with prominent occurrence of arctic-alpine taxa (from the classes *Asplenietea trichomanis*, *Caricetea curvulae*, *Carici rupestris-Kobresietea bellardii*, *Elyno-Seslerietea*, *Loiseleurio-Vaccinietea*, *Montio-Cardaminetea*, *Mulgedio-Aconitetea*, *Salicetea herbaceae* a *Thlaspietea rotundifolii*) were compared with respect to environmental factors, species composition and frequency of phytogeographical elements and life forms. The classification of individual phytosociological relevés and the syntaxa names are in accord with the work JAROLÍMEK & ŠIBÍK (2008).

The main gradients in floristic composition were analysed by detrended correspondence analysis (DCA) in CANOCO 4.5 package (TER BRAAK & ŠMILAUER, 2002). Ellenberg's indicator values (ELLENBERG et al., 1992) were used as a supplementary data for interpretation of ordination diagram from the ecological point of view. In attribute data analysis, the numbers of species belonging to particular phytogeographical groups were used as a supplementary data and the frequency of arctic-alpine species as attribute data.

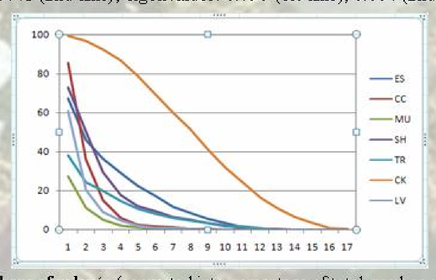
SPSS software and Statistica 8.0 (http://www.statsoft.com/) were used for correlation analyses and box and whisker plots constructing. The numbers of species belonging to particular phytogeographical groups and life forms were calculated for each relevé. The number of species referring to one group was correlated with environmental factors using Spearman's correlation coefficient. Particular vegetation types were compared with respect to environmental factors and with respect to the number of species of particular phytogeographical elements and life forms. The Tukey post-hoc test following one-way ANOVA was used in this multiple comparison. Box and whisker plots were constructed for environmental variables and frequency of individual phytogeographical elements and life forms in relation to particular vegetation type.

Vysoké Tatry Mts, Mengusovská dolina Valley, 7th July 2006





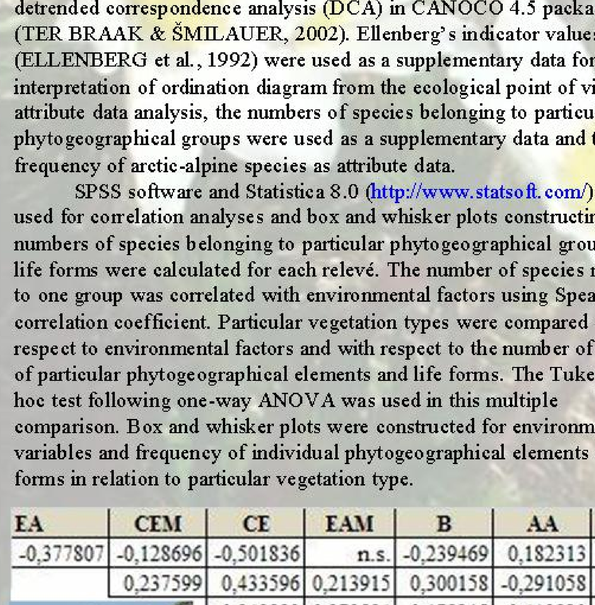
Ordination diagrams of DCA Analysis of 3 510 phytosociological relevés with prominent occurrence of arctic-alpine taxa. Ellenberg's indicator values were used as supplementary data (1st diagram). The numbers of arctic-alpine species were used as an attribute data and the numbers of species belonging to particular phytogeographical groups were used as a supplementary data. The arrows show the increasing numbers of Carpathian and West Carpathian endemics and arctic-alpine taxa in the relevés (2nd diagram). Lengths of gradient: 7.000 (1st axis), 6.448 (2nd axis); eigenvalues: 0.796 (1st axis), 0.664 (2nd axis).



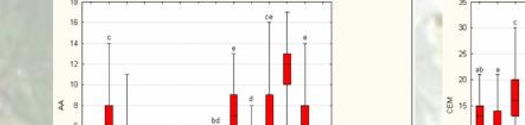
Decreasing numbers of relevés (converted into percentage of total number of relevés in the class) **with increasing numbers of arctic-alpine taxa per relevé in particular classes**. The occurrence of arctic-alpine taxa in plant communities of the class *Carici rupestris-Kobresietea* is evidential in comparison with other vegetation types in the Western Carpathians.

EA	CEM	CE	EAM	B	AA	K	ZK	H	CH	G	T	
-0,377807	-0,128696	-0,501836	n.s.	-0,239469	0,182313	n.s.	n.s.	-0,181209	n.s.	-0,127987	-0,170982	**Alt.**
	0,237599	0,433596	0,213915	0,300158	-0,291058	0,133506	n.s.	0,375401	-0,190380	0,295501	0,088927	**EA**
		0,348889	0,379584	0,178215	0,419820	0,579998	0,619476	0,874066	0,507189	0,569364	0,380992	**CEM**
			0,169814	0,072045	n.s.	0,348898	0,270971	0,503657	n.s.	0,309875	0,259429	**CE**
				0,297475	0,280421	0,346496	0,297950	0,582704	0,279533	0,403281	0,136622	**EAM**
					n.s.	n.s.	n.s.	0,232475	0,210574	0,219278	n.s.	**B**
						0,466063	0,580315	0,441184	0,681243	0,464637	0,189306	**AA**
							0,545930	0,700320	0,353518	0,512074	0,317339	**K**
								0,654085	0,585423	0,469735	0,305083	**ZK**
									0,377450	0,615221	0,300696	**H**
										0,366824	0,315986	**CH**
											0,232399	**G**

Correlation among occurrence of particular variables (phytogeographical elements, life forms and altitude) in particular vegetation types using Spearman's correlation coefficient. Significance level is P<0.001. **n.s.** non significant correlation, **alt.** altitude



The new locality of *Carex rupestris* in Slovakia, Vysoké Tatry Mts, Nefcerka Valley, 30th August 2006



Elyna myosuroides, Belianske Tatry Mts, 7th July 2007

		No. of relevés
	total	5030
1	*Bistorta vivipara*	1623
2	*Juncus trifidus*	1620
3	*Rhodiola rosea*	972
4	*Bartsia alpina*	947
5	*Pedicularis verticillata*	777
6	*Silene acaulis*	744
7	*Pedicularis oederi*	605
8	*Salix herbacea*	532
9	*Dryas octopetala*	482
10	*Arabis alpina*	454

		No. of relevés
	total	5030
1	*Arctous alpina*	2
2	*Juncus castaneus*	2
3	*Juncus triglumis*	2
4	*Carex atrofusca*	3
5	*Tofieldia pusila*	4
6	*Sibbaldia procumbens*	5
7	*Ranunculus pygmeus*	8
8	*Saxifraga cernua*	10
9	*Draba fladnizensis*	11
10	*Elyna myosuroides*	16

The most frequent and the rarest arctic-alpine species in the vegetation of the Western Carpathians

DISCUSSION & CONCLUSION

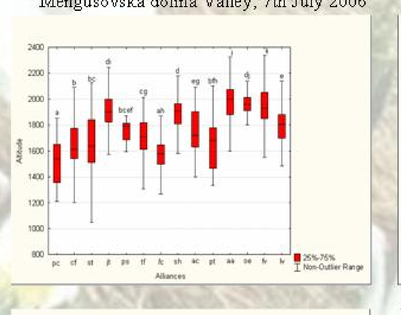
The highest number of arctic-alpine taxa occurs in the plant communities of the class *Carici rupestris-Kobresietea* in comparison with other vegetation types in the Western Carpathians and in proportion to other phytogeographical elements in the West Carpathian flora.

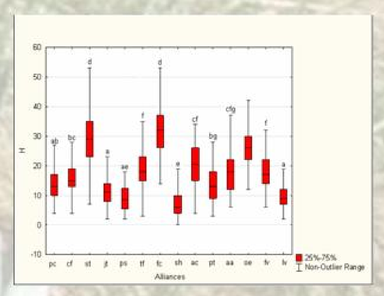
The abundance of arctic-alpine species was significantly correlated not only with the European high-mountain element, but also with the occurrence of Carpathian or Western Carpathian endemic taxa. One of the possible explanations is the island phenomenon of the highest mountains, which after the ice ages, owing to extremely broken relief, various geological bedrock, specific meso- and microclimate contributing to an exceptional variability of habitats gave rise not only to formation of refuges for relic taxa, but on the other hand, according to plasticity of individual taxa, the same habitats also provided suitable conditions for speciation and hence became the centre of endemism.

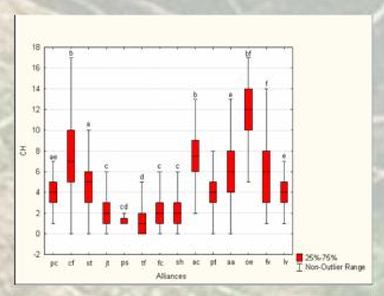
Evolutionary dispersion of the taxa, their glaciation survival, postglacial migration, ecological requirements and their ability of adjusting to new environmental conditions led individual taxa to creation of multiple repeating space arrangements or assemblies, which conform to present-day plant communities. While we are able to map the evolutionary history of the taxa and the ways of their dispersion from the area of their origin up to present-day distribution by means of numerous molecular methods (cf. TABERLET et al. 1998, STEHLIK 2003, SCHÖNSWETTER et al. 2006, BROCHMANN et al. 2003), phytosociological data provide the information about the current state of the vegetation in particular time and space. The question is, to what extent is conceivable to create theories of the evolution and evolutionary distribution of the plant communities, if the evolutionary history of individual taxa creating particular plant community is well known? Nowadays, several scientists (PROCHEŞ et al., 2005; KRAFT et al., 2007) are attracted by the possibility of the effective conjunction of taxonomical data (molecular, evolutionary) with vegetation (phytosociological) and ecological data (environmental, functional). The interdisciplinary character of such studies may cast more light on this problem in the near future.

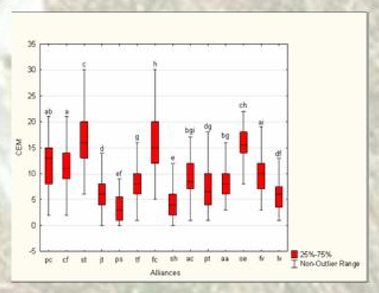
Juncus trifidus, one of the most frequent arctic-alpine species in the Western Carpathians, Vysoké Tatry Mts, Furkotská dolina Valley, 19th August 2005

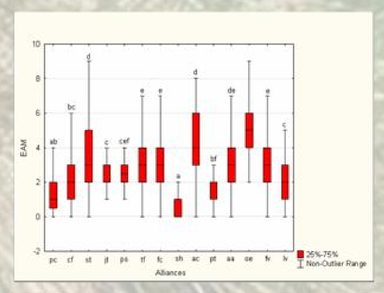
Pedicularis oederi and ***Salix reticulata***, Vysoké Tatry Mts, Mengusovská dolina Valley, 7th July 2006

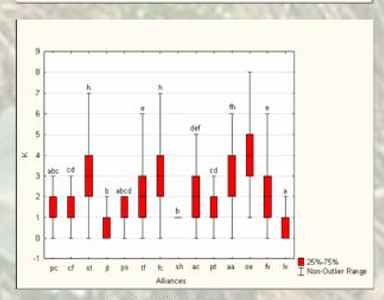


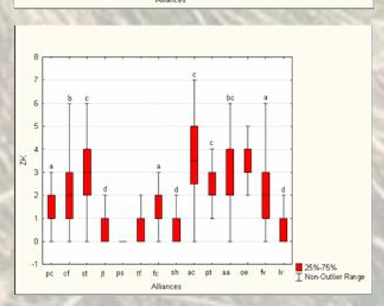












Box and whisker plots constructed for altitudinal distribution and frequency of individual phytogeographical elements and life forms in particular vegetation types. The box length is the interquartile range. The line across the box indicates the median. Significant differences among vegetation types (Tukey post-hoc test) are marked by index (a – j).

USED ABBREVIATIONS: Syntaxa names: aa *Androsacion alpinae*, **ac** *Arabidion caeruleae*, **cf** *Caricion firmae*, **fc** *Festucion carpaticae*, **fv** *Festucion versicoloris*, **jt** *Juncion trifidi*, **lv** *Loiseleurio-Vaccinion*, **oe** *Oxytropido-Elynion*, **pc** *Potentillion caulescentis*, **ps** *Philonotidion seriatae*, **pt** *Papaverion tatrae*, **sh** *Salicion herbaceae*, **st** *Seslerion tatrae*, **tf** *Trisetion fusci*, **CC** *Caricetea curvulae*, **CK** *Carici rupestris Kobresietea*, **ES** *Elyno-Seslerietea*, **LV** *Loiseleurio-Vaccinietea*, **MU** *Mulgedio-Aconitetea*, **SH** *Salicetea herbaceae*, **TR** *Thlaspietea rotundifolii*. **Phytogeographical elements: AA** Arctic-Alpine, **B** Boreal, **CE** Central-European, **CEM** Central-European Mountain, **EA** Euro-Asian, **EAM** Euro-Asian Mountain, **K** Endemic of Carpathians, **ZK** Endemic of Western Carpathians. **Life forms: G** Geophytes, **H** Hemicryptophytes, **CH** Chamaephytes, **T** Terophytes.

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