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PHYTOGEOGRAPHY AND SYNTAXONOMY OF SNOW-BED VEGETATION ON CALCAREOUS SUBSTRATES IN THE SOUTH-EASTERN ALPS: A NUMERICAL APPROACH

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ABSTRACT

*Based on cluster analysis and the phytogeographic peculiarities of the area, an assessment of the vegetation of snow-beds on calcareous soils (*Arabidetalia caeruleae*) in the South-eastern Alps was made. Eight distinct associations belonging to three alliances were recognised:* Saxifragetum stellaro-sedoidis, Saxifragetum hohenwartii *and* Ranunculo traunfellneri-Festucetum nitidae *(alliance* Arabidion caeruleae*),* Salici herbaceae-Arabidetum caeruleae *(alliance* Salici herbaceae-Arabidion caeruleae*),* Salicetum retuso-reticulatae, Homogyno discoloris-Salicetum retusae, Salici retusae-Geranietum argentei *and* Potentillo brauneanae-Homogynetum discoloris *(alliance* Soldanello alpinae-Salicion retusae*).* Saxifragetum stellaro-sedoidis *was further subdivided into three geographical variants, such as variants of* Achillea oxyloba, Ranunculus traunfellneri *and* Campanula pulla. *The* Drepanoclado uncinati-Heliospermetum pusilli *from the Liburnian Karst (Dinaric Mts.) showed clear floristic and phytogeographic distinctions and its placement into the Dinaric alliance* Salicion retusae *was confirmed.*

Key words: biogeography, syntaxonomy, endemic species, cluster analysis, snow-beds, the Alps, *Arabidetalia caeruleae, Thlaspietea rotundifolii*

FITOGEOGRAFIA E SINTASSONOMIA DELLA VEGETAZIONE DEL MANTO NEVOSO SU SUBSTRATI CALCAREI NELLE ALPI SUD-ORIENTALI: APPROCCIO NUMERICO

SINTESI

*In base alla "cluster analysis" ed alle peculiarità fitogeografiche dell'area, gli autori hanno preparato una valutazione della vegetazione del manto nevoso di terreni calcarei (*Arabidetalia caeruleae*) delle Alpi sud-orientali. Otto associazioni distinte, appartenenti a tre alleanze, sono state riconosciute:* Saxifragetum stellaro-sedoidis, Saxifragetum hohenwartii *e* Ranunculo traunfellneri-Festucetum nitidae *(alleanza* Arabidion caeruleae*),* Salici herbaceae-Arabidetum caeruleae *(alleanza* Salici herbaceae-Arabidion caeruleae*),* Salicetum retuso-reticulatae, Homogyno discoloris-Salicetum retusae, Salici retusae-Geranietum argentei *e* Potentillo brauneanae-Homogynetum discoloris *(alleanza* Soldanello alpinae-Salicion retusae*).* Saxifragetum stellaro-sedoidis *è stato ulteriormente suddiviso in tre varianti geografiche, ossia le varianti di* Achillea oxyloba, Ranunculus traunfellneri *e* Campanula pulla. Drepanoclado uncinati-Heliospermetum pusilli *proveniente dal Carso liburniano (montagne dinariche) si è chiaramente distinto floristicamente e fitogeograficamente, ed è stata confermata la sua collocazione nell'alleanza dinarica* Salicion retusae.

Parole chiave: biogeografia, sintassonomia, specie endemiche, cluster analysis, snow-beds, Alpi, *Arabidetalia caeruleae, Thlaspietea rotundifolii*

INTRODUCTION

The order *Arabidetalia caeruleae* comprises pioneer or permanent hygrophilous stands occurring on more or less stabilised calcareous screes and moraines with a long duration of snow cover, and from the altimontane to subnival belt in Central and south-eastern Europe (Braun-Blanquet, 1926; Horvat, 1931; Englisch *et al.*, 1993). The floristic composition, ecology and physiognomy of *Arabidetalia* stands are relatively well characterised and distinctions from other scree stands are usually not questionable. Recently, a comprehensive study of the snow-bed vegetation in the Northern Calcareous Alps (Englisch, 1999) resulted in the recognition of three floristically and ecologically well defined alliances in the Alps, including the *Arabidion caeruleae, Salici herbaceae-Arabidion caeruleae* and *Soldanello alpinae-Salicion retusae*. However, although this study also included some of the relevés from the South-eastern Calcareous Alps, no similar treatise of syntaxa from *Arabidetalia* in the South-eastern Alps has yet been provided. The aim of the paper is thus to study, on the basis of a comprehensive synoptic table and cluster analyses, the ecology and syntaxonomy of the order, with an emphasis on the phytogeographic peculiarities of the area, as well as to summarise current knowledge on the phytosociology and ecology of syntaxa of *Arabidetalia* in the South and South-eastern Alps.

The phytogeographic peculiarities of the flora and vegetation of the South-eastern (Calcareous) Alps (Fig. 1) have been recognised for a long time. In comparison to other Alpine regions, they are characterised by a significant number of conservative, progressive, absolute and relative endemics, southern-, south-eastern – Alpine, north – Illyrian and Illyrian (Illyricoid) species (Engler, 1901; Mayer, 1960a, 1960b; Wraber, 1995; Tribsch & Schönswetter, 2003; Surina, 2004a). According to Pawlowski (1970), the South-eastern Calcareous Alps are floristically the second richest region of the Alps. The particularity of its flora and vegetation are due to their specific origin as a result of the historical, geographical and ecological peculiarities of the area.

The first phytosociological studies in the area on frigiphilous and hygrophilous scree vegetation were performed by Aichinger (1933: columns 1, 2, 14 in Table 1) in the Karavanke Mts. Further research in the South-eastern Calcareous Alps (Julian Alps, Kamnik Alps and the Karavanke Mts.) was implemented by Wraber (1972: 7, 8, 15) and Surina (2004c: 4, 12, 13) in the Julian Alps and by Haderlapp (1982: 14) in the Kamnik Alps. Poldini & Martini (1993: 17) studied the calcareous hygrophilous and frigiphilous snow-bed and talus slope vegetation in the Carnic Alps, Wikus (1959: 3, 9, 10) in the Dolomites of Lienz, and Lasen (1983: 18) in the Dolomites of Belluno, while Gerdol & Piccoli (1982: 18) engaged in its research in Monte Baldo. Pignatti & Pignatti (1983) studied the vegetation of Vette di Feltre (Dolomites of Belluno) and with two unpublished relevés identified the association *Salicetum retuso-reticulatae*. The same phytosociologists published an analysis and overview of the calcareous scree vegetation (*Thlaspietalia rotundifolii*) in the South-eastern Alps (Pignatti & Pignatti, 1984), while Wraber (1970) published a paper on vegetation of the SE Alps.

In comparison to the SE Alps, the snow-bed vegetation on calcareous soils in the Northern Calcareous Alps has been studied by many phytosociologists. The results were summarised by Englisch *et al.* (1993) and lately by Englisch (1999).

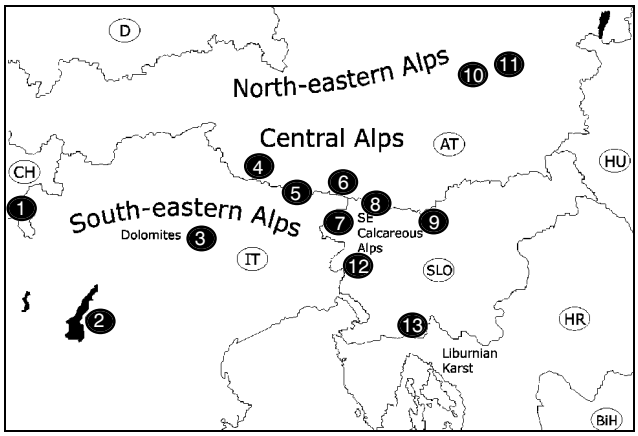

Fig. 1: Research area. 1 – Bernina; 2 – Monte Baldo; 3 – Dolomites of Belluno; 4 – Dolomites of Lienz; 5 – Carnic Alps; 6 – Mt. Dobrač; 7 – Julian Alps; 8 – Karavanke Mts.; 9 – Kamnik Alps; 10 – Gesäuse; 11 – Hochschwab; 12 – Trnovski gozd plateau; 13 – Mt. Snežnik.
Sl. 1: Raziskovano območje. 1 – Bernina; 2 – Monte Baldo; 3 – Bellunški Dolomiti; 4 – Lienški Dolomiti; 5 – Karnijske Alpe; 6 – Dobrač; 7 – Julijske Alpe; 8 – Karavanke; 9 – Kamniške Alpe; 10 – Gesäuse; 11 – Hochschwab; 12 – Trnovski gozd; 13 – Snežnik.

MATERIAL AND METHODS

Phytosociological research of calcareous scree vegetation of *Arabidetalia* was conducted by applying the sigmatistic method (Braun-Blanquet, 1964; Westhoff & Maarel, 1973; Dierschke, 1994). Altogether, 232 relevés from the SE Alps (between Monte Baldo and the Kamnik Alps) and NE Alps were used in the analysis (see the Appendix). With the aid of SYN-TAX 2000 computer programme (Podani, 2001) and a synoptic phytosociological table (Tab. 1), comparisons between stands were made after the transformation of cover-abundance values according to van der Maarel (1979) had been performed. The measure of dissimilarity was the complement of the "Similarity Ratio" coefficient. We used the Furthest Neighbour – Complete Linkage clustering

method (CL) and the Principal Coordinates Analysis (PCoA) ordination method. Coverage index ($D_{\%}$, see Surina, 2004b, 2005) was calculated for each taxon separately. Groups of diagnostic species were formed on the basis of our own criteria, but with regard to numerous authors. Three floristically and/or ecologically similar syntaxa were included in the analyses, *i.e. Saxifragetum hohenwartii (Thlaspion rotundifolii)* from the *Karavanke Mts., Poo supinae-Cerastietum cerastoidis (Salicion herbaceae, Salicetalia herbaceae)* from the Dolomites of Lienz, and *Drepanoclado uncinati-Heliospermetum pusilli* from the Liburnian Karst (*sensu* Beck, 1901) in the Dinaric Mts. Nomenclature of the syntaxa follows Englisch *et al.* (1993), Theurillat *et al.* (1995), Englisch (1999), and Aeschimann *et al.* (2004b); the list is given in the Appendix. Plant names and chorological groups are in agreement with the Flora alpina (Aeschimann *et al.*, 2004a) and the Register of the Flora of Slovenia (Trpin & Vreš, 1995).

Tab. 1: Synoptic table of syntaxa from the order *Arabidetalia caeruleae* ***s. lat. in the South-eastern and North-eastern Alps. 1, 2 –*** *Saxifragetum hohenwartii****; 3 –*** *Saxifragetum stellaro-sedoidis* ***var. geogr.*** *Achillea oxyloba****; 4 –*** *Saxifragetum stellaro-sedoidis* ***var. geogr.*** *Ranunculus traunfellneri****; 5, 6 –*** *Saxifragetum stellaro-sedoidis* ***var. geogr.*** *Campanula pulla****; 7, 8 –*** *Ranunculo traunfellneri-Festucetum nitidae****; 9 –*** *Poo supinae-Cerastietum cerastoidis****; 10 –*** *Salici herbaceae-Arabidetum coeruleae****; 11 -*** *Drepanoclado uncinati-Heliospermetum pusilli****; 12 –*** *Salici retusae-Geranietum argentei****; 13, 14 –*** *Homogyno discoloris-Salicetum retusae****; 15–17 –*** *Salicetum retuso-reticulatae****; 18, 19 –*** *Potentillo brauneanae-Homogynetum discoloris****.***

Tab. 1: Sinoptična tabela sintaksonov iz reda *Arabidetalia coeruleae* ***s. lat. v jugovzhodnih in severovzhodnih Alpah. 1, 2 –*** *Saxifragetum hohenwartii****; 3 –*** *Saxifragetum stellaro-sedoidis* ***var. geogr.*** *Achillea oxyloba****; 4 –*** *Saxifragetum stellaro-sedoidis* ***var. geogr.*** *Ranunculus traunfellneri****; 5, 6 –*** *Saxifragetum stellaro-sedoidis* ***var. geogr.*** *Campanula pulla****; 7, 8 –*** *Ranunculo traunfellneri-Festucetum nitidae****; 9 –*** *Poo supinae-Cerastietum cerastoidis****; 10 –*** *Salici herbaceae-Arabidetum coeruleae****; 11 –*** *Drepanoclado uncinati-Heliospermetum pusilli****; 12 –*** *Salici retusae-Geranietum argentei****; 13, 14 –*** *Homogyno discoloris-Salicetum retusae****; 15–17 –*** *Salicetum retuso-reticulatae****; 18, 19 –*** *Potentillo brauneanae-Homogynetum discoloris****.***

	Successive number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
	Syntaxa	Arabidion caeruleae s. lat.											Soldanello-Salicion retusae							
	No. of relevés	6	10	16	11	22	17	8	18	3	12	24	16	13	9	18	7	5	8	9
	No. of species	**26**	**33**	**39**	**42**	**39**	**47**	**41**	**72**	**22**	**54**	**58**	**88**	**86**	**65**	**97**	**56**	**42**	**66**	**39**
	Characteristic and differential (d) species																			
	Arabidion caeruleae (AC_3)																			
	Soldanella minima**	50	90	63	9				33		67		31	23	11	33	29		13	67
	Saxifraga androsacea	17	60	13	9	55	94	50	22	33	92			15	33	44		20	38	
	Saxifraga sedoides			100	100	100	100	75	39	67	33			15		17	43			
	Gnaphalium hoppeanum						6	38	28	100	100				11	33		80	25	100
	Hutchinsia alpina ssp. austroalpina*	83	90	75	64			75	33						11		14			11
	Hutchinsia alpina ssp. brevicaulis					100	88			100	33					33		20		
	Potentilla brauneana							38	56		83				11				88	100
	Thlaspi alpestre*		20			5	18						6	8		17				
	Arabis caerulea*						29	88	6	100	92									
	Saxifraga hohenwartii*	100	100	6											11					
	Rumex nivalis				18			63	89											
	Geographical differential species																			
TR_2	Achillea oxyloba*			75						100	83			8		33	43			
AC_2	Ranunculus traunfellneri**	83	40	6	64			63	72				25	62	44				38	
TR_2	Achillea clusiana*					5	29													
AC_3	Campanula pulla*					45	76									22				
ES	Viola calcarata ssp. calcarata**																	100		
SS	Soldanella alpina								44		42	4	56	38	44	44	29	100	50	44
	Soldanello alpinae-Salicion retusae (SS)																			
	Salix retusa		70	6		5	41	13	56		58		81	100	100	100	100	80	88	100
	Salix reticulata						24				33				11	78	100	40		

	Arabidetalia caeruleae (AC_2)																			
	Veronica aphylla		50	25	36	9		25	44		17		13	15	33	22		20	50	33
	Arabis alpina ssp. alpina	83	80	63	82	95	35	38	22			17		8	11					
	Carex atrata ssp. atrata				9		6					8	6	23	56	6	29	80		
	Carex parviflora				9		65	25	11				6	38		61	29		88	
	Carex ornithopodoides			6				13	6		58			15	11	6			75	
	Festuca nitida				55			38	100			4	50	38					50	
	Ranunculus alpestris				9	50	82				8					61	100	60		
	Anemone baldensis				10				33		8			15	33	11				
	Galium noricum**						41	38	17						11	39			63	
	Soldanella austriaca*					50	71									28				
	Doronicum glaciale ssp. calcareum*						18													
	Festuca rupicaprina*					9														
	Thlaspion rotundifolii (TR_3)																			
	Thlaspi rotundifolium ssp. rotundifolium*			56	9	5		50	33											
	Leontodon montanus ssp. montanus			19		5					25					11				
	Papaver aurantiacum			38				13												
	Papaver ernesti-mayeri							13	17											
	Alyssum ovirense							13												
	Minuartia austriaca**			13																
	Petasition paradoxi (PP)																			
	Silene quadrifida**	17	30		9		6		17			4	44	15					13	67
	Adenostyles glabra			6	18	5	6		6			8	13	8						
	Polystichum lonchitis							13	11			8								
	Rumex scutatus			25										8						
	Aconitum angustifolium*												13							
	Athamanta cretensis												6							
	Cystopteris montana											8								
	Dryopteris villarii											4								
	Gypsophila repens												6							
	Thlaspietalia rotundifolii (TR_8)																			
	Achillea atrata**	50	90	19	9	9	65	100	94				6	15	78	22		40	38	67
	Taraxacum alpinum agg.	17	40	31			18	88	83	100	75		6	23	11	28	57		25	78
	Moehringia ciliata	83	70	88	36	45	82	88	83	33	42		6	15	11	17				
	Poa minor			75		18	53		11						11	17	43			11
	Sedum atratum ssp. atratum					9	12	25	17				6		11			20		
	Cerastium carinthiacum ssp. carinthiacum*					9										11	43			
	Doronicum grandiflorum								17					8						
	Trisetum argenteum												6							
	Androsacetalia alpinae (AA)																			
	Veronica alpina		50		9	23	24	75	83	100	75				11	17		100	75	44
	Gentiana bavarica*						6				50					39		60		
	Oxyria digyna				36			13												
	Trifolium pallescens												94						13	
	Epilobium anagallidifolium										8									
	Geum reptans															6				
	Gymnocarpium dryopteris											33								
	Saxifraga seguieri*															6				
	Drabetalia hoppeanae (DH)																			
	Doronicum glaciale ssp. glaciale*			25	18								6	15		22				
	Sesleria ovata*					18	35									17				
	Thlaspietea rotundifolii (TR_1)																			
	Campanula cochleariifolia	33	60	6	27	5		25	50			8	25	31	11	22	29		13	
	Minuartia sedoides			6			6		28		8		44	15		17	14		100	
	Armeria alpina					5	24	13	22				13	8		33	14			
	Biscutella laevigata ssp. laevigata						12		17		8			8	22	17			13	
	Leontodon hispidus								6				25	8		17		20		
	Linaria alpina ssp. alpina					5		13	28											

	Saxifraga oppositifolia ssp. oppositifolia			13				25								6				
	Rhodiola rosea												6	15						
	Salicetea herbaceae (SH)																			
	Sagina saginoides					5	24	38	11	100	58				11	17			50	56
	Alchemilla fissa										50			15	11	17		6		56
	Salix herbacea									100	67						14	80		
	Sibbaldia procumbens							13									14	20		33
	Gnaphalium supinum							13											13	22
	Cerastium cerastoides									100	8									
	Soldanella pusilla															11			13	
	Asplenietea trichomanis (AT)																			
dAC_2	Silene pusilla			6	9	45	24					100				11				
dAC_3	Arabis bellidifolia ssp. stellulata	17	10	38	18	5	59		6		50				44	22			13	
dAC_3	Valeriana elongata**	50	80	31	9	9	18		11						11	17				
dAC_3	Cystopteris regia	33	40		27	14			33			13		8						
	Phyteuma sieberi*		10		9				11				19	23	33		14		25	
	Saxifraga paniculata				9		12	13	6				6	8		6				
	Paederota lutea			6					17				13	15	11					
	Asplenium viride			6								50	19	15						
	Cystopteris fragilis											46	6	8			29			
	Saxifraga crustata				9								38	8			14			
	Cerastium subtriflorum**								6				38	8						
	Valeriana saxatilis				18								6		11					
	Petrocallis pyrenaica														11				13	
	Primula clusiana*						6									6				
	Elyno-Seslerietea (ES)																			
dAC_2	Aster bellidiastrum	33	40	6	18	9	6	25	67	33	50	21	81	69	78	67	43		75	33
dAC_2	Silene acaulis				9	14	41	75	39		58		50	15	44	78	86	80	100	
dSS	Carex firma			6		5	47	50	33		33	4	38	31	78	61	14		38	
dSS	Campanula scheuchzeri					5	12		39		58	8	56	8	11	11		100	100	67
dSS	Homogyne discolor		30				6	13	11		25		31	31	89	56	14		100	78
dSS	Euphrasia salisburgensis					5		25	17				75	23	22	6		20	50	78
dSS	Bartsia alpina		20	6					17			4	13		67	44	29	40		
dSS	Carex sempervirens						6				8		88	4	11	56	57	80	38	
dSS	Dryas octopetala					5			6			4	6	8	22	39	14		25	
dSS	Potentilla crantzii								11			4	63	23	11	17	43		63	
dSS	Ranunculus carinthiacus											38	38		33	11	14		38	67
dSS	Homogyne alpina												19	15		17	29	100		
dSS	Salix serpillifolia												13		22			40		
dSS	Geranium argenteum												100	23						
	Poa alpina	50	100	38	100	73	71	100	100		83	42	69	54	78	72	57	20	100	89
	Myosotis alpestris		50		45	5	18	50	78		58	8	56	15	33	61	86	80	38	
	Carex ferruginea ssp. ferruginea						6		33		17	13	6		22	17		100	25	11
	Galium anisophyllum		10				6		56		8	29		77	56	6			38	78
	Juncus monanthos				18		6				8		88	23	33	17	14		13	
	Sesleria caerulea			6	9		6		11				38		78	44		100	63	
	Cerastium carinthiacum ssp. austroalpinum*	33	50	6	27			50	89				6	4						
	Gentiana pumila*						12	13	17					8	67	17			100	33
	Pedicularis verticillata						12		11				69	8	11	6		20	13	
	Festuca quadriflora			6	9	5	24									44		40	38	
	Arabis vochinensis							38	94					15	33				63	11
	Gentiana anisodonta							13					75	15	11				38	56
	Gentiana verna ssp. verna								6				25		22	28	14		38	
	Pedicularis rostratocapitata						6		17				6	31	11	17				
	Ranunculus montanus					5			11		50					44	43	100		
	Salix alpina			13					17				19	31		17	14			
	Achillea clavenae								17				63	24		17	14			
	Agrostis alpina								6		50			8		17			88	
	Festuca norica*	50	50	13	9															44

	Saxifraga caesia			13							8				11	6	29			
	Thymus praecox ssp. polytrichus								22				38	15		6				33
	Crepis aurea								22							6			38	78
	Draba aizoides ssp. aizoides				10			25			17							40		
	Erigeron glabratus											4	63	8		6				
	Gentiana clusii												25		11	6			38	
	Ligusticum mutellina						12				75					11		100		
	Anthyllis vulneraria ssp. alpestris										8		13		22					
	Astrantia bavarica**								11				31		11					
	Carex ornithopoda												19	8					13	
	Cerastium arvense ssp. strictum								6				13			6				
	Elyna myosuroides										8					11			25	
	Festuca violacea agg.											67			22			100		
	Gentiana orbicularis										50			8		17				
	Gentiana terglouensis*				9			25	17											
	Helianthemum alpestre												75	8					13	
	Hieracium bifidum											8		8			14			
	Hieracium villosum												56	8		6				
	Phyteuma orbiculare											13	6			6				
	Ranunculus hybridus								6					8	11					
	Sesleria sphaerocephala*			19				13											13	
	Juncetea trifidi (JT)																			
	Potentilla aurea															33	14	80	13	78
	Euphrasia minima										42		6			6	29			
	Luzula spicata ssp. spicata														11	11		20	38	
	Agrostis rupestris													8	11				13	
	Botrychium lunaria																14		13	
	Primula minima										8					28				
	Veronica bellidioides															6	14			
	Nardetea strictae (N)																			
	Coeloglossum viride										8		6	8		11				
	Luzula multiflora ssp. multiflora												6	8						
	Nardus stricta																14			22
	Loiseleurio-Vaccinietea (LV)																			
	Rhodothamnus chamaecistus**												25	8		6				
	Vaccinium gaultherioides												13			6			38	
	Juniperus communis ssp. alpina											8					14			
	Montio-Cardaminetea (MC)																			
dAC_2	Saxifraga aizoides	67	40	19	55	9	12		22		17		19	23	44	17	14		13	
dAC_3	Saxifraga stellaris			31	9	91	88	75	44	100	8			8		11				
	Scheuchzerio-Caricetea fuscae (SC)																			
	Selaginella selaginoides										33		56	8	67	50		80	63	67
	Carex capillaris										8	71	19	15	33	11			63	
	Parnassia palustris											67	88	46	11		14		13	
	Pinguicula alpina											13			22	17				
	Tofieldia calyculata													15	11	11				
	Molinio-Arrhenatheretea (M-Ar)																			
	Lotus corniculatus								6		8		31			6	29			
	Anthoxanthum odoratum												69	8		17				
	Trifolium pratense ssp. pratense								6				38			6				
	Trifolium repens ssp. repens											4		8						
	Trollius europaeus											4				11				
	Mulgedio-Aconitetea (MA)																			
dAC_2	Viola biflora	17	60		27	9			44		8	88	13	38			43		38	78
	Salix waldsteiniana											8	6	23		22	14			
	Veratrum album ssp. lobelianum								22				19	15		6				
	Aconitum lycoctonum ssp. neapolitanum								11			4	6							
	Adenostyles alliariae								6			29								
	Geranium sylvaticum								6			4								
	Salix appendiculata											71		8						

	Saxifraga rotundifolia L.		20								4								
	Erico-Pinetea (EP)																		
	Rhododendron hirsutum**										38	19	8			14			
	Pinus mugo ssp. mugo										8		8						
	Rubus saxatilis										42		8						
	Querco-Fagetea (QF)																		
	Luzula sylvatica							6			8				6	14			
	Daphne mezereum							6				6	8						
	Solidago virgaurea (incl. minuta)										4	6							
	Vaccinio-Piceetea (VP)																		
	Huperzia selago										21	6	8		6				
	Vaccinium vitis-idaea										71	13	15		6				
	Picea abies			6							58								
	Other species																		
	Polygonum viviparum		90	31	18	23	29	50	56		83	63	88	85	89	94	86	100	100	78

RESULTS AND DISCUSSION

An extensive analytical table was provided and analyses were performed applying hierarchical classification methods. Two distinct groups of relevés were recognised in the cluster analysis: stands from *Arabidion* s. lat. and *Salicion* s. lat. (Fig. 4). Within the "*Arabidion*" group, seven distinct clusters were recognised (Fig. 2): A – *Saxifragetum hohenwartii (Thlaspion, Thlaspietalia)* from the Karavanke Mts. (Tab. 1: columns 1, 2), B – *Ranunculo traunfellneri-Festucetum nitidae* from the Julian Alps (7, 8), C – *Poo-Cerastietum (Salicetea herbaceae*; 9) and *Salici herbaceae-Arabidetum caeruleae (Salici-Arabidion*; 10) from the Dolomites of Lienz, D – *Saxifragetum stellaro-sedoidis* var. geogr. *Achillea oxyloba* (3) from the Dolomites of Lienz, E –from the Julian Alps (var. geogr. *Ranunculus traunfellneri*; 4), F – from Hochschwab and Gesäuseberge (5), and G from the Hochschwab only (F-G var. geogr. *Campanula pulla*; 6).

The "*Salicion*" group consisted of nine clusters (Fig. 3): A – *Drepanoclado-Heliospermetum* from the Liburnian Karst, B – *Salici retusae-Geranietum argentei* from the Julian Alps (12), C – *Homogyno discoloris-Salicetum retusae* from the Krn Mts. (Julian Alps) and Carnic Alps (13), and D – from the Karavanke Mts. and the Kamnik Alps (14), E – *Salicetum retuso-reticulatae* from the Dolomites of Lienz and Carnic Alps (15), F – from the Monte Baldo and Dolomites of Belluno (16) and G – from Bernina (Unter-Engadin, above Val Cluoza; 17), H – *Potentillo brauneanae-Homogynetum discoloris* from the Julian Alps (18) and I – from the Karavanke Mts. (19).

Stands of *Drepanoclado-Heliospermetum* were grouped within the "*Salicion*" cluster, but several floristical, phytogeographical as well as ecological distinctions were recognised. Due to the lower altitude, such stands were inhabited by many forest *(Querco-Fagetea, Vaccinio-Piceetea, Erico-Pinetea)* and tall-herb *(Mulgedio-Aconitetea)* species (Tabs. 1–4). The presence of Illyrian species in stands, such as *Gentiana liburnica, Polygala croatica* and *Thymus balcanus* (Tab. 1) as well as *Arabis scopoliana, Scabiosa silenifolia, Carex kitaibeliana* etc. (*Seslerion juncifoliae, Seslerietalia juncifoliae, Elyno-Seslerietea*) were of phytogeographical importance (Surina & Vreš, 2004). In comparison to other syntaxa, Alpine geoelements in the broadest sense occurred more sporadically, while Eurosiberian and Eurosiberian/N-American geoelements prevailed (Tab. 2).

Secondly, a synoptic table (Tab. 1) was provided with the aid of cluster analysis (Fig. 4) and on the basis of previous results obtained within both groups of relevés.

Distinction between the *Arabidion* and the *Soldanello-Salicion* were evident and delimitation of *Arabidion* according to Englisch (1999) into at least two alliances was not questionable (Tabs. 1–4). Scree stability, aspect and talus slope may be the three most important environmental factors that determine the floristic composition and differentiation of the alliances: *Arabidion* prefers shady and slightly less stabilised scree with no or very little accumulation of soils and perhaps steeper slopes in comparison to the *Soldanello-Salicion*. The coverage indices and number of species of the *Thlaspion* and the *Androsacetalia alpinae*, which prefer less stabilised screes, were also much higher. The *Poo-Cerastietum* and *Salici-Arabidetum* were grouped together in the cluster analysis, but within the "*Arabidion*" cluster (Fig. 2: cluster C; Fig. 4: clusters 9, 10). The later syntaxon was placed into the *Salici-Arabidion* (Englisch, 1999), which was separated from *Salicion herbaceae* due to floristical and ecological differences derived from the fact that the newly proposed alliance embraces the snow-bed vegetation on humus rich calcareous screes. The number and coverage indices of acidophilous and hygrophilous species of *Salicetea herbaceae, Androsacetalia alpinae, Juncetea trifidi, Nardetea, Vaccinio-Piceetea* and *Scheuchzerio-Caricetea fuscae* (Tabs. 1, 3, 4) proved the unique syntaxonomic position of *Salici-Arabidetum* (between *Salicion herbaceae* and *Arabidion caeruleae*) and the aforementioned classification of syntaxa.

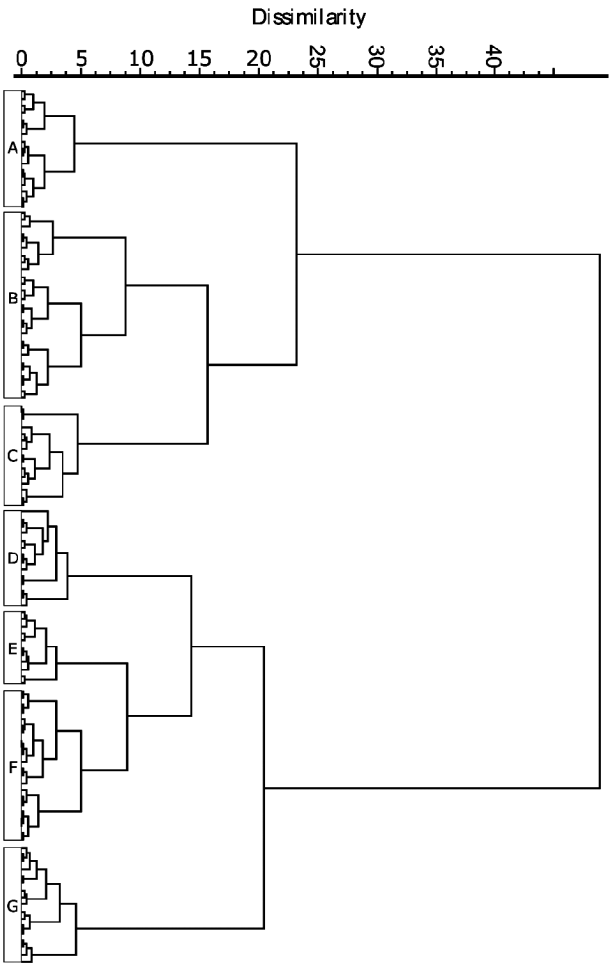

Fig. 2: Dendrogram based on species frequency in the syntaxa of *Arabidetalia caeruleae* ***s. lat. in the South-eastern and North-eastern Calcareous Alps. A –*** *Saxifragetum hohenwartii****; B –*** *Ranunculo traunfellneri-Festucetum nitidae****; C –*** *Poo supinae-Cerastietum cerastoidis* ***&*** *Salici herbaceae-Arabidetum caeruleae****; D –*** *Saxifragetum stellaro-sedoidis* ***var. geogr.*** *Achillea oxyloba****; E –*** ***var. geogr.*** *Ranunculus traunfellneri****; F–G –*** ***var. geogr.*** *Campanula pulla****.***

Sl. 2: Dendrogram, izdelan na osnovi pogostosti vrst v sintaksonu *Arabidetalia caeruleae* ***s. lat. v jugovzhodnih in severovzhodnih Apneniških Alpah. A –*** *Saxifragetum hohenwartii****; B –*** *Ranunculo traunfellneri-Festucetum nitidae****; C –*** *Poo supinae-Cerastietum cerastoidis* ***&*** *Salici herbaceae-Arabidetum caeruleae****; D –*** *Saxifragetum stellaro-sedoidis* ***var. geogr.*** *Achillea oxyloba****; E –*** ***var. geogr.*** *Ranunculus traunfellneri****; F–G –*** ***var. geogr.*** *Campanula pulla****.***

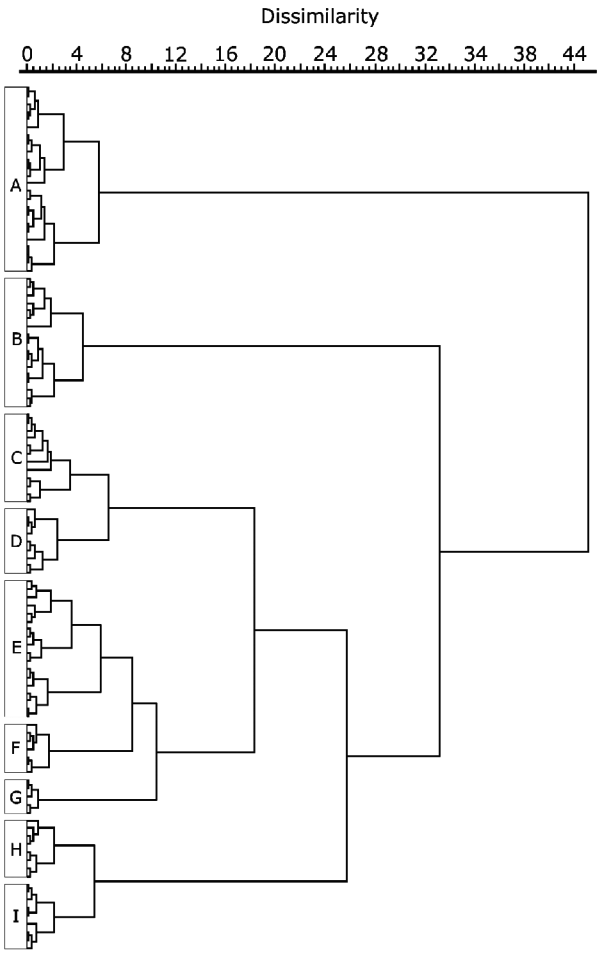

Fig. 3: Dendrogram based on species frequency in the syntaxa of *Soldanello alpinae-Salicion retusae* ***s. lat. in the South-eastern and North-eastern Calcareous Alps. A –*** *Drepanoclado uncinati-Heliospermetum pusilli****; B –*** *Salici retusae-Geranietum argentei****; C, D –*** *Homogyno discoloris-Salicetum retusae****; E–G –*** *Salicetum retuso-reticulatae****; H–I –*** *Potentillo brauneanae-Homogynetum discoloris****.***

Sl. 3: Dendrogram, izdelan na osnovi pogostosti vrst v sintaksonu *Soldanello alpinae-Salicion retusae* ***s. lat. v jugovzhodnih in severovzhodnih Apneniških Alpah. A –*** *Drepanoclado uncinati-Heliospermetum pusilli****; B –*** *Salici retusae-Geranietum argentei****; C, D –*** *Homogyno discoloris-Salicetum retusae****; E–G –*** *Salicetum retuso-reticulatae****; H–I –*** *Potentillo brauneanae-Homogynetum discoloris****.***

Tab. 2: Chorological groups (geoelements) of syntaxa of *Arabidetalia caeruleae* ***in the SE Alps (* endemic, ** subendemic species).***
Tab. 2: Horološke skupine (geoelementi) sintaksonov *Arabidetalia caeruleae* ***v JV Alpah (* endemične, ** subendemične vrste).***

Geoelement / No. of spec.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
S-Eur.-Mont.	3	8	12	11	16	18	14	31	3	26	23	30	31	27	27	18	45	23	18
Arct./Alp.	3	6	6	8	9	9	19	12	5	12	7	13	12	13	14	6	21	10	10
SE-Europ.-Mont.	1	1	4	3	3	5	4	6	2	5	8	10	8	7	6	2	9	3	3
E-Alp.**	4	4	5	4	2	4	3	9		1	2	9	6	6	4	2	6	2	1
Eurosib./N-Am.	1	1	2	1	1	1	2	2		5	13	8	8	4	4	2	6	3	2
E-Alp.*	4	6	6	5	7	10	5	6	1	1		7	6	5	3	2	14	4	
Euroasiat.	1	1	1	1	1	1	1	1	2	1	2	1	2	1	2		6		1
E-Alp./Illyr.		1	1	2		1	4	7		1	3	7	7	4	2	2	4	5	
Europ.	1	1	2	2	1	2		4			6	8	5	2	2		6	2	2
Alp.*	1	1	2	2	2		1	3		3		1		1	1		3	1	1
E-Alp./Apen.			1	2	1	1	1	1	1	1		1	1	1	1		1	1	
Europ-/N-Am.				2		2	1	1		1		3	3	1	1		2	1	
Alp.					1	2	2	3		3		1			2		3	1	1
Europ./Mont.			1			1		3		1	1	3	1		3		1	1	
Other							1	4			5	2	3		3		3	1	1
NE-Alp./Illyr.**	1			1		1		1			2	1	1		1	1			
N-Europ.-Alp.				1		1					1	1	1	1			1	1	1
Eurosib.								4			10	3	4	1		1	3	1	
Alp./Apen.						1	1	1	1	1		1	1				1		
Cosmop.											2	1	1		1	1		2	
E-Alp/Carpat			1					2				1	1				1	1	
Alp./Illyr.			1				1					1		1					1
Eurasiat./Afr.								1		1		1					1	1	
Europ./W-Asiat.								1			2	2	2						
Euroasiat./N-Am.										1	3	1					1		
Eurasiat./Am.											1	1	1				1		
S-Europ.					1		1	1									1		
W-Alp.*											1			1					1

Accumulation of soil and formation of tiny horizons, slow decomposition of dead plant material, and subsequent acidification of soils are well suited to species of the *Juncetea trifidi, Nardetea, Loiseleurio-Vaccinietea, Scheuchzerio-Caricetea fuscae*, and *Vaccinio-Piceetea* (Tabs. 3, 4), which were significantly more abundant and achieved higher coverage indices in syntaxa of the *Soldanello-Salicion*. Associations of *Soldanello-Salicion*, restricted mainly to shallow depressions with long lasting snow, were less frigiphilous (Braun-Blanquet, 1926; Englisch *et al.*, 1993) and were species richer, which was mainly due to the occurrence of the *Elyno-Seslerietea* species (Fig. 5). They also achieved relatively high coverage indices. The high share of species of subalpine and alpine calcareous grasslands in the *Salicetum retuso-reticulatae* was already mentioned by Pignatti & Pignatti (1983), while the *Diantho alpinae-Salicetum retusae,* the *Homogyno-Salicetum* and the *Salici-Geranietum* are transitional to the *Elyno-Seslerietea* (mainly the *Caricion firmae*; see Englisch, 1999; Surina, 2004c) and play an important role in the subsequent succession of calcareous scree vegetation towards subalpine and alpine calcareous grasslands.

Our study revealed phytogeographical differentiation of stands of *Saxifragetum stellaro-sedoidis* (Englisch *et al.*, 1993; Englisch, 1999) and several geographical variants or races based on the floristical peculiarities of the area could be distinguished (Tab. 1, Figs. 2, 4).

This was mainly owing to disjunctions of the distribution area of closely related endemic taxa (Tabs. 1, 2), which vicariate in a SE-NE direction (NE-Calcareous Alps – SE-Calcareous Alps), *e.g. Saxifraga sedoides – S. hohenwartii*, *Soldanella austriaca – S. minima*, *Ranunculus alpestris – R. traunfellneri*, *Cerastium carinthiacum* subsp. *carinthiacum – C. c.* subsp. *austroalpinum* etc. (see Hörandl, 1993). As geographical differential species we chose *Achillea clusiana, Soldanella austriaca* and *Campanula pulla* for the NE Calcareous Alps, *Ranuncu-*

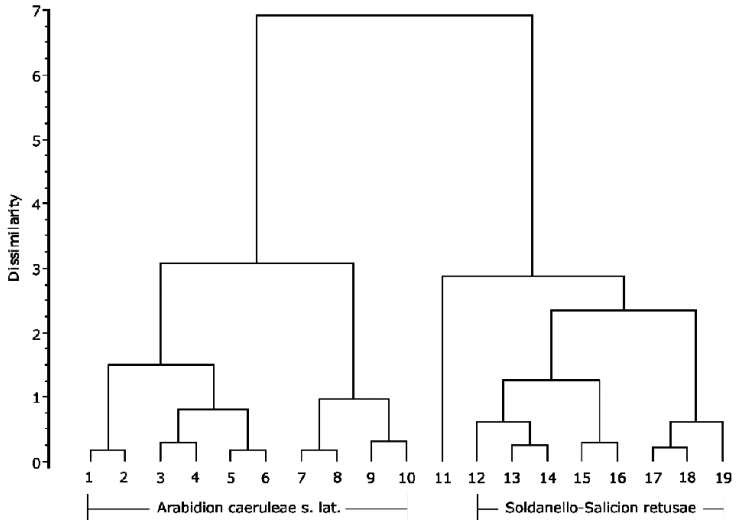

Fig. 4: Dendrogram based on species frequency in the syntaxa of** Arabidetalia caeruleae **s. lat. in the South-eastern and North-eastern Calcareous Alps. 1, 2 –** Saxifragetum hohenwartii**; 3 –** Saxifragetum stellaro-sedoidis **var. geogr.** Achillea oxyloba**; 4 –** Saxifragetum stellaro-sedoidis **var. geogr.** Ranunculus traunfellneri**; 5, 6 –** Saxifragetum stellaro-sedoidis **var. geogr.** Campanula pulla**; 7, 8 –** Ranunculo traunfellneri-Festucetum nitidae**; 9 –** Poo supinae-Cerastietum cerastoidis**; 10 –** Salici herbaceae-Arabidetum coeruleae**; 11 –** Drepanoclado uncinati-Heliospermetum pusilli**; 12 –** Salici retusae-Geranietum argentei**; 13, 14 –** Homogyno discoloris-Salicetum retusae**; 15–17 –** Salicetum retuso-reticulatae**; 18, 19 –** Potentillo brauneanae-Homogynetum discoloris **(numbers correspond with Table 1).

Sl. 4: Dendrogram, izdelan na osnovi pogostosti vrst v sintaksonu Arabidetalia caerule s. lat. v jugovzhodnih in severovzhodnih Apneniških Alpah. 1, 2 –** Saxifragetum hohenwartii**; 3 –** Saxifragetum stellaro-sedoidis **var. geogr.** Achillea oxyloba**; 4 –** Saxifragetum stellaro-sedoidis **var. geogr.** Ranunculus traunfellneri**; 5, 6 –** Saxifragetum stellaro-sedoidis **var. geogr.** Campanula pulla**; 7, 8 –** Ranunculo traunfellneri-Festucetum nitidae**; 9 –** Poo supinae-Cerastietum cerastoidis**; 10 –** Salici herbaceae-Arabidetum coeruleae**; 11 –** Drepanoclado uncinati-Heliospermetum pusilli**; 12 –** Salici retusae-Geranietum argentei**; 13, 14 –** Homogyno discoloris-Salicetum retusae**; 15–17 –** Salicetum retuso-reticulatae**; 18, 19 –** Potentillo brauneanae-Homogynetum discoloris **(številke se ujemajo s tistimi v Tabeli 1).

lus traunfellneri for the SE Calcareous Alps and *Achillea oxyloba* for Mt. Baldo, the Dolomites of Lienz and Belluno, and the Carnic Alps. It has recently been established that *Saxifraga sedoides* from the Dolomites of Lienz was wrongly identified as *S. hohenwartii* by Wikus (Wikus, 1959: Tab. 7), since the species is restricted to the Karavanke Mts. and the Kamnik Alps. We thus treated selective stands (Dirnböck *et al.*, 1999: Tab. 12, rel. 8) as the *Saxifragetum stellaro-sedoidis* var. geogr. *Achillea oxyloba*.

Lectotypes:

- *Saxifragetum stellaro-sedoidis* Englisch 1999 var. geogr. *Campanula pulla* var. geogr. nova: Dirnböck *et al.* (1999: Tab. 12, rel. 8) – Hochschwab, *lectotypus hoc loco*.
- *Saxifragetum stellaro-sedoidis* Englisch 1999 var. geogr. *Ranunculus traunfellneri* var. geogr. nova: Surina (2004c: Tab. 1, rel. 2) – Julian Alps, *lectotypus hoc loco*.
- *Saxifragetum stellaro-sedoidis* Englisch 1999 var. geogr. *Achillea oxyloba* var. geogr. nova: Wikus (1959: Tab. 7, rel. 5) – Dolomites of Lienz, *lectotypus hoc loco*.

Stands of the *Saxifragetum hohenwartii*, in line with recent syntaxonomical literature on calcareous scree vegetation (Englisch *et al.*, 1993; Englisch, 1999), were placed into *Thlaspion rotundifolii* as earlier proposed by Wikus (1959), Zollitsch (1967) and Wraber (1970). Although stands with predominating *Saxifraga hohenwartii* were transitional between the *Thlaspion* and the *Arabidion*, our views on the syntaxonomy of the *Saxifragetum hohenwartii* was in agreement with the author of the unit (Aichinger, 1933), who placed this association into the *Arabidion*. We considered those associations to be a phytogeographical vicariant (in the Karavanke Mts. and Kamnik Alps) to the *Saxifragetum stellaro-sedoidis* s. lat.

Within the *Soldanello-Salicion* (Fig. 3), four associations were clearly identified, such as the *Salici-Geranietum*, the *Homogyno-Salicetum*, the *Salicetum retuso-reticulatae*, and the *Potentillo-Homogynetum*. Floristical distinctions between the *Homogyno-Salicetum* and the *Salicetum retuso-reticulatae* were not only due to the presence or absence of *Salix reticulata*, *Carex ferruginea* and *Homogyne discolor* (*e.g.* Englisch, 1999), but also owing to the significantly higher coverage indices and number of acidophilous species of the *Androsacetalia al-*

pinae, the *Salicetea herbaceae* and the *Juncetea trifidi* (Tabs. 1, 3, 4). Stands with predominating *Salix retusa* showed certain phytogeographical and ecological differentiation. Several vicariant syntaxa were therefore described: the *Homogyno-Salicetum* and the *Salici-Geranietum* for the SE Calcareous Alps, and the *Diantho-Salicetum* and the *Selaginello selaginoidis-Salicetum reticulatae* for the NE Calcareous Alps. In contrast to stands of the *Homogyno-Salicetum* and the *Salicetum retuso-reticulatae*, stands of the *Salici-Geranietum* and the *Diantho-Salicetum* were transitional to stands of alpine calcareous grasslands (the *Caricion firmae*), and stands of *Potentillo-Homogynetum* transitional to stands of *Loiseleurio-Vaccinietea*. Several succession stages of *Salicetum retusae* s. lat. were observed: in the SE Calcareous Alps towards stands of *Gentiano terglouensis-Caricetum firmae* and *Dryadetum octopetalae* s. lat., and in the NE Calcareous Alps towards stands of *Caricetum firmae* (Wendelberger, 1971; Englisch *et al.*, 1993; Englisch, 1999; Surina, 2004b). For a more detailed description of the ecology, chorology and syntaxonomy of snow-bed vegetation, see previously cited references.

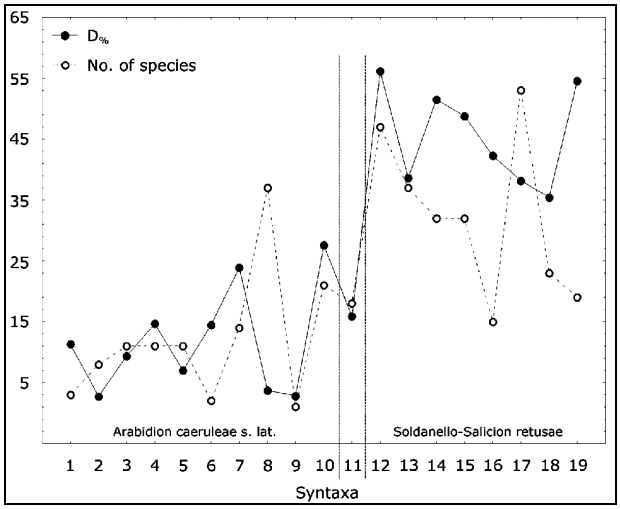

Fig. 5: Coverage index ($D_{‰}$) and number of alpine and subalpine calcareous grasslands species *(Elyno-Seslerietea)* ***in syntaxa of*** *Arabidetalia caeruleae* ***in SE Alps.***
Sl. 5: Indeks pokrivnosti ($D_{‰}$) ter število alpinskih in subalpinskih apneniških traviščnih vrst (Elyno-Seslerietea) ***v sintaksonih*** *Arabidetalia caeruleae* ***v JV Alpah.***

Tab. 3: Phytosociological groups of syntaxa of *Arabidetalia caeruleae* ***in the SE Alps.***
Tab. 3: Fitosociološke skupine sintaksonov *Arabidetalia caeruleae* ***v JV Alpah.***

Syntaxa / No. of spec.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Me**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**Me**
Arabidion caeruleae	5	6	6	7	6	8	7	9	3	7	**6.5**		3	5	8	7	3	9	3	3	**4.0**
Soldanello-Salicion		1	1		1	2	1	2		3	**1.0**	1	2	2	3	2	2	3	3	3	**2.5**
Arabidetalia caeruleae	1	2	3	6	3	5	5	6	1	4	**3.5**	2	4	6	5	4	2	7	3	3	**4.0**
Thlaspion rotundifolii			4	1	3		4	2		1	**1.0**							1			**0.0**
Petasition paradoxi	1	1	2	2	1	2	1	3			**1.0**	5	5	3		1	1				**0.5**
Thlaspietalia rotundifolii	3	3	6	2	6	6	4	6	3	3	**3.5**		6	5	5	2	3	6	4	2	**4.5**
Androsacetalia alpinae		1		2	1	2	2	1	1	3	**1.0**	1	1		1	2	1	4		2	**1.0**
Drabetalia hoppeanae			2	1	1	2		1		1	**1.0**		2	2		1		3	1		**1.0**
Thlaspietea rotundifolii	2	2	3	2	4	3	5	6		1	**2.5**	2	4	6	3	2		5	2	1	**2.5**
Salicetea herbaceae					1	1	3	1	3	4	**1.0**			1	2	3	4	4	2	3	**2.5**
Asplenietea trichomanis	2	3	4	7	3	5	2	8	1	1	**3.0**	6	12	8	5	3		4	3		**3.5**
Elyno-Seslerietea	3	8	11	11	11	2	14	37	1	21	**11.0**	18	47	37	32	32	15	53	23	19	**32.0**
Vaccinio-Piceetea			1					1		1	**0.0**	1	3	4				3	1	1	**1.0**
Scheuczerio-Caricetea fuscae										3	**0.0**	3	5	4	5	3	1	6	1	1	**3.5**
Juncetea trifidi										2	**0.0**			1	2	6	1	11	4	2	**2.0**
Nardetea										1	**0.0**		2	4			1	1	1		**1.0**
Loiseleurio-Vaccinietea											**0.0**	1	3	1		1		3	1		**1.0**
Molinio-Arrhenatheretea	1	1	1	1	1	1	1	4	1	2	**1.0**	5	7	3	1	1	2	6	2	1	**2.0**
Montio-Cardaminetea	1	1	2	2	2	2	1	2	1	2	**2.0**	1	1	2	1	1		2	1		**1.0**
Mulgedio-Aconitetea	1	2		1	1			8		1	**1.0**	7	4	4	1	1	1	2	5		**1.5**
Erico-Pinetea											**0.0**	6	1	3	2				1		**0.5**
Querco-Fagetea								3			**0.0**	20	3	2				2	1		**0.5**
Artemisietea vulgaris							1	1		1	**0.0**					1		1			**0.0**
Festuco-Brometea						1					**0.0**		1	1		1					**0.0**
Trifolio-Geranietea											**0.0**		1					1			**0.0**
Seslerion juncifoliae											**0.0**	3									**0.0**
Epilobietea angustifolii											**0.0**	2									**0.0**
Other species							1	4			**0.0**	5	2	3		3		3	1	1	**1.5**

CONCLUSIONS

1. Delimitation among the alliances *Arabidion, Salici-Arabidion* and *Soldanello-Salicion*, based on floristic composition and the phytogeographical peculiarities of the area as well as the specific ecology of stands, was distinct and several phytogeographical and/or ecological vicariant syntaxa were recognised. Within the *Arabidion*, three associations were recognised in the study area, such as the *Ranunculo-Festucetum* (an endemic association in the Julian Alps), the *Saxifragetum hohenwartii* (restricted to the Karavanke Mts. and the Kamnik Alps), and the *Saxifragetum stellaro-sedoidis* (distributed throughout the Eastern Alps). The latter was subdivided into three geographical variants, such as variants of *Achillea oxyloba* (western part of the SE Alps: Monte Baldo, Dolomites, Carnic Alps), of *Ranunculus traunfellneri* (mainly SE Calcareous Alps), and of *Campanula pulla* (NE Alps).

2. The *Salici-Arabidetum* was placed into the *Salici-Arabidion* and our analysis partly confirmed its unique syntaxonomic position between the *Arabidion* and the *Salicion herbaceae*. This association is distributed in the Northern, Central and Southern Alps.

3. Within the *Soldanello-Salicion*, four associations were clearly recognised, such as the *Homogyno-Salicetum*, the *Salicetum retuso-reticulatae*, the *Salici-Geranietum*, and the *Potentillo-Homogynetum*. The distribution area of the *Salicetum retuso-reticulatae* is restricted mainly to the NE, SE and Central Alps, and is replaced by the *Homogyno-Salicetum* in the SE Calcareous Alps. To date, stands of the *Salici-Geranietum* have only been documented in the Julian Alps and constitute somewhat transitional unit of the *Elyno-Seslerietea (Caricion firmae).*

4. Our study confirmed the placement of the *Drepanoclado-Heliospermetum* from the Liburnian Karst into the Dinaric alliance *Salicion retusae*. Since no synoptic treatment of Dinaric syntaxa has yet been provided, syntaxonomical and geographical delimitations of the *Soldanello-Salicion* and the *Salicion retusae* have remained unresolved. Nevertheless, stands from the Trnovski gozd plateau (NW Dinaric Mts., Slovenia) resembled those of Mt. Snežnik and are probably situated in the north-westernmost part of the distribution area of the *Salicion retusae*.

Tab. 4: Index of coverage ($D_{\%}$) of phytosociological groups of syntaxa of *Arabidetalia caeruleae* ***in the SE Alps.***
Tab. 4: Indeks pokrivnosti ($D_{\%}$) fitosocioloških skupin sintaksonov *Arabidetalia caeruleae* ***v JV Alpah.***

Syntaxa / $D_{\%}$	1	2	3	4	5	6	7	8	9	10	Me	11	12	13	14	15	16	17	18	19	Me
Arabidion caeruleae	33.78	27.59	27.69	27.56	16.93	34.45	19.28	15.66	2.00	19.17	23.42		1.57	7.94	6.70	8.33	17.76	1.29	1.36	5.59	6.14
Soldanello-Salicion		3.24	0.40		0.27	2.94	0.53	4.59		6.35	0.46	0.18	7.28	16.99	14.67	5.58	7.19	15.45	19.58	13.47	14.07
Arabidetalia caeruleae	9.00	7.29	7.38	13.35	15.49	13.95	8.43	11.54	8.18	4.47	8.71	0.67	2.21	7.96	6.64	8.00	1.26	5.96	3.28	4.46	5.21
Thlaspion rotundifolii			9.56	0.85	1.64		4.32	1.30		1.15	1.00							0.79			0
Petasition paradoxi	1.32	1.37	4.58	1.75	0.27	0.45	0.53	0.97			0.75	1.78	2.63	1.37		0.28	2.72				0.14
Thlaspietalia rotundifolii	12.58	12.13	22.80	3.50	8.98	14.28	18.52	11.74	13.64	9.23	12.36		1.76	3.42	4.39	1.76	6.98	4.98	1.36	2.23	2.82
Drabetalia hoppeanae			2.19	2.56	1.92	2.95		0.72		0.43	0.58		1.58	1.54		2.41		1.66	0.60		1.07
Androsacetalia alpinae		2.29		3.50	1.64	1.25	4.52	2.59	1.82	5.19	2.05	0.98	3.30		0.35	2.26	1.88	1.98		5.39	1.93
Thlaspietea rotundifolii	9.93	8.89	5.78	8.87	9.64	3.24	5.68	3.81		0.29	5.73	1.36	1.87	3.43	1.76	0.56		3.65	1.79	0.67	1.77
Salicetea herbaceae					0.42	1.13	3.54	0.36	28.75	1.43	0.39			0.75	0.73	2.68	8.37	2.27	1.19	5.59	1.73
Asplenietea trichomanis	9.93	8.47	3.79	6.68	5.48	4.38	5.30	2.59	6.36	4.32	5.39	7.67	4.62	4.29	3.17	1.13		1.34	2.39		1.86
Elyno-Seslerietea	11.29	2.73	9.37	14.65	6.98	14.49	23.88	3.72	2.82	27.55	10.33	15.88	56.13	38.66	51.54	48.78	42.26	38.19	35.44	54.55	45.52
Vaccinio-Piceetea			0.60					0.22		0.29	0	9.50	1.15	3.13				0.95	1.19	3.37	1.05
Scheuczerio-Caricetea fuscae										5.98	0	5.42	5.74	3.59	5.32	3.53	2.72	2.92	0.60	2.69	3.22
Juncetea trifidi										1.87	0			0.38	0.73	2.82	3.35	4.82	2.99	3.37	2.91
Nardetea										0.29	0		0.29	1.58			0.84	0.32	0.60		0.30
Loiseleurio-Vaccinietea											0	0.24	1.81	0.38		0.99		0.64	0.60		0.49
Molinio-Arrhenatheretea	3.97	5.26	2.59	8.87	6.16	3.29	6.32	4.64	13.51	3.75	4.95	3.73	7.00	3.52	3.34	4.66	5.23	3.78	4.18	0.67	3.98
Montio-Cardaminetea	7.95	2.59	4.38	7.12	8.43	5.90	3.77	1.80	7.27	0.86	5.14	3.47	0.43	1.30	1.58	0.28		0.79	0.60		0.52
Mulgedio-Aconitetea	1.32	3.89		2.85	0.55			3.88		0.72	0.64	9.15	1.86	4.97	1.23	1.41	3.14	1.29	4.18		1.63
Erico-Pinetea											0	5.22	0.52	1.22	1.23				0.60		0.26
Querco-Fagetea								0.54			0	7.92	0.87	0.75				0.39	1.00		0.20
Festuco-Brometea						0.23					0		0.29	0.38		0.42					0
Trifolio-Geranietea											0		0.43					0.16			0
Artemisietea vulgaris							1.53	4.89		0.43	0					0.28		0.32			0
Seslerion juncifoliae											0	0.36									0
Epilobietea angustifolii											0	0.82									0
Other species							0.53	1.44			0	13.37	3.12	1.13		5.96		0.47	1.19	0.67	0.90

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FITOGEOGRAFSKA IN SINTAKSONOMSKA ANALIZA VEGETACIJE SNEŽNIH DOLINIC NA KARBONATNI PODLAGI V JUGOVZHODNIH ALPAH: NUMERIČNI PRISTOP

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POVZETEK

*Avtor v prispevku s pomočjo klastrske analize in opirajoč se na fitogeografske posebnosti območja podaja pregled vegetacije snežnih dolinic na karbonatni podlagi v Jugovzhodnih Alpah (*Arabidetalia caeruleae, Thlaspietea rotundifolii*). Obravnava osem asociacij, ki se dobro razlikujejo ekološko in fitogeografsko, te pa združuje v tri zveze. Asociacije* Saxifragetum stellaro-sedoidis, Saxifragetum hohenwartii *in* Ranunculo traunfellneri-Festucetum nitidae *pripadajo zvezi* Arabidion caeruleae*, asociacija* Salici herbaceae-Arabidetum caeruleae*, ki je v sintaksonomskem oziroma ekološkem oziru sorodna s sintaksoni snežnih dolinic na silikatni podlagi iz razreda* Salicetea herbaceae*, pa zvezi* Salici herbaceae-Arabidion caeruleae*. Asociacija* Saxifragetum stellaro-sedoidis *se fitogeografsko dobro diferencira v tri nove geografske variante, in sicer* Achillea oxyloba *v Lienških Dolomitih,* Ranunculus traunfellneri *v Jugovzhodnih Apneniških Alpah ter* Campanula pulla *v Severovzhodnih Apneniških Alpah.*

Analiza je nadalje potrdila smiselnost obravnavanja sestojev, v katerih prevladujeta vrbi Salix retusa *in* S. reticulata *v okviru samostojne zveze* Soldanello alpinae-Salicion retusae*. Na območju Jugovzhodnih Alp pripadajo tej zvezi štiri asociacije:* Salicetum retuso-reticulatae, Homogyno discoloris-Salicetum retusae, Salici retusae-Geranietum argentei *in* Potentillo brauneanae-Homogynetum discoloris*. Asociacija* Drepanoclado uncinati-Heliospermetum pusilli*, ki jo poznamo z Liburnijskega krasa (severozahodni Dinaridi), se floristično, fitogeografsko in ekološko zelo dobro loči od sintaksonov vzhodno-alpske zveze* Soldanello-Salicion retusae *in jih uvrščamo v dinarsko zvezo* Salicion retusae.

Ključne besede: biogeografija, sintaksonomija, endemiti, klastrska analiza, vegetacija snežnih dolinic, *Arabidetalia caeruleae, Thlaspietea rotundifolii*

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APPENDIX

List of relevés considered in the analysis (Tab. 1)

1 – *Saxifragetum hohenwartii*, Aichinger (1933): Tab. 9, relevés 1, 4, 11, 14–16; **2** – *Saxifragetum hohenwartii*, Aichinger (1933): Tab. 9, relevé 2, 3, 5–10, 12, 13; **3** – *Saxifragetum stellaro-sedoidis* var. geogr. *Achillea oxyloba*, Wikus (1959): Tab. 7, relevé 1–12, 14 (sub nom. *Saxifragetum hohenwartii),* Englisch (1999): Tab. G, relevé 45; Hörandl (1993) in Englisch (1999): Tab. G.: 35, 36, **4** – *Saxifragetum stellaro-sedoidis* var. geogr. *Ranunculus traunfellneri*, Wraber (1972): Tab. 9, relevés 1 (sub nom. *Saxifrago sedoidi-Arabidetum caeruleae),* Surina (2004b): Tab. 9, Wikus (1959): Tab. 7, relevé 13 (sub nom. *Saxifragetum hohenwartii),* Englisch (1999): Tab. G, relevés 22, 38; **5** – *Saxifragetum stellaro-sedoidis* var. geogr. *Campanula pulla*, Dirnböck *et al.* (1999): Tab. 12, relevés 12, 19, 20, Englisch (1999): Tab. G, relevés 20, 21, 25–34, 39–42; **6** – *Saxifragetum stellaro-sedoidis* var. geogr. *Campanula pulla*, Dirnböck *et al.* (1999): Tab. 12, relevés 8-11, 13–17, Englisch (1999): Tab. G, relevé 13, 14, 15, 16, 17, 18, 19, 23; **7** – *Ranunculo traunfellneri-Festucetum nitidae*, Wraber (1972): Tab. 9, relevés 3, 4, 6-9, 11, 12 (sub nom. *Saxifrago sedoidi-Arabidetum caeruleae*); **8** – *Ranunculo traunfellneri-Festucetum nitidae*, Wraber (1972): Tab. 9, relevés 5, 10, 13 sub nom. *Saxifrago-Arabidetum*, Tab. 10 (sub nom. *Festuco violaceae-Rumicetum nivalis);* **9** – *Poo supinae-Cerastietum cerastoidis*, Wikus (1959): Tab. 10, relevés 1–3 (sub nom. *Arabidetum caeruleae poetosum supinae);* **10** – *Salici herbaceae-Arabidetum caeruleae*, Wikus (1959): Tab. 10, relevés 4–15 (sub nom. *Arabidetum caeruleae*); **11** – *Drepanoclado uncinati-Heliospermetum pusilli*, Surina & Vreš (2004): Tab. 1; **12** – *Salici retusae-Geranietum argentei*, Surina (2004c): Tab. 11; **13** – *Homogyno discoloris-Salicetum retusae*, Surina (2004c): Tab. 12, Poldini & Martini (1993): Tab. 1, relevés 1, 2, 7 (sub nom. *Salicetum retuso-reticulatae),* Aichinger (1933): Tab. 10, relevé 6; **14** – *Homogyno discoloris-Salicetum retusae*, Aichinger (1933): Tab. 10, relevés 1–5, Haderlapp (1982): Tab. 1, relevés 62–64; **15** – *Salicetum retuso-reticulatae*, Gerdol & Piccoli (1982): Tab. 4, relevé 4, Poldini & Martini (1993): Tab. 1, relevés 3–6, 8–13, Dirnböck *et al.* (1999): Tab. 12, relevés 1–7; **16** – *Salicetum retuso-reticulatae*, Gerdol & Piccoli (1982): Tab. 4, relevés 1–3, 5, Lasen (1983): relevé 19–21; **17** – *Salicetum retuso-reticulatae*, Braun-Blanquet (1926): Tab. 4. **18** – *Potentillo brauneanae-Homogynetum discoloris*, Wraber (1972): Tab. 10; **19** – *Potentillo brauneanae-Homogynetum discoloris*, Aichinger (1933): Tab. 12.

Species with lower frequencies in the Table 1 (*/** endemic and subendemic species in the SE Alps)

Artemisietea – *Cirsium spinosissimum* 25 (7), 89 (8), 8 (10), 13 (15), 11 (17); **AT** – *Campanula cespitosa*** 6 (8), *C. justiniana* 25 (11), *Moehringia muscosa* 8 (11), *Festuca stenantha* 13 (12), *Saxifraga hostii / hostii*** 19 (12), *S. squarrosa*** 19 (12), *Potentilla nitida* 13 (15); **ES** – *Anemone narcissiflora* 31 (12), 5 (15), *Arenaria ciliata* 8 (13), *Carex mucronata* 6 (2), 4 (11), *Chamorchis alpina* 8 (13), 6 (17), *Erigeron uniflorus* 8 (13), 60 (19), *Festuca brachystachys* ssp. *brachystachys*** 12 (6), 6 (17), *Festuca melanopsis** 6 (17), 43 (18), *Galium baldense** 6 (17)m 57 (18), *Gentiana nivalis* 31 (12), 31 (13), *Helianthemum nummularium* ssp. *grandiflorum* 6 (12), 6 (17), *Koeleria eriostachya* 33 (11), 50 (12), *Leontopodium alpinum* 19 (12), 29 (18), *Luzula glabrata** 6 (6), 6 (17), *Minuartia verna* ssp. *verna* 17 (8), 38 (15), *Oxytropis jacquinii* 13 (12), 13 (15), *Pedicularis rosea* ssp. *rosea*** 6 (8), 6 (17), *Pimpinella alpina* 38 (12), 8 (13), *Polygala alpestris* 8 (10), 15 (13), *Stachys alopecuros / alopecuros* 6 (8), 13 (12), *Trifolium thalii* 22 (16), 29 (18), *Androsace chamaejasme* 11 (17), *Aster alpinus* 13 (12), *Callianthemum coriandrifolium* 100 (19), *Carduus defloratus* agg. 6 (6), *Dianthus alpinus** 6 (17), *Festuca calva** 6 (13), *Gentiana froelichii* ssp. *froelichii** 11 (14), *G. liburnica** 4 (11), *Globularia nudicaulis* 4 (11), *Hedysarum hedysaroides* ssp. *hedysaroides* 6 (17), *Helictotrichon parlatorei** 13 (12), *Heracleum austriacum* ssp. *siifolium** 6 (8), *Horminum pyrenaicum* 17 (17), *Laserpitium peucedanoides* 6 (8), *Leucanthemum atratum* ssp. *atratum** 6 (17), *L. a.* ssp. *lithopolitanicum** 11 (14), *Linum alpinum* 8 (13), *Lloydia serotina* 25 (15), *Plantago atrata* ssp. *atrata* 8 (10), *Polygala croatica* 1 (11), *Pulsatilla alpina* ssp. *alpina* 6 (17), *Rhinanthus glacialis* 19 (12), *Saussurea pygmea* 6 (8), *Saxifraga exarata* ssp. *atropurpurea** 19 (12), *S. e.* ssp. *moschata* 5 (5), *Scabiosa lucida* ssp. *lucida* 6 (17), *Thymus balcanus** 8 (11), *Viola calcarata* ssp. *calcarata*** 100 (19); **EP** – *Calamagrostis varia* 33 (11), *Cirsium erisithales* 4 (11), *Erica carnea* 11 (14), *Galium austriacum* 22 (14), *Rosa pendulina* 4 (11); ***Epilobietea angustifolii*** **–** *Fragaria vesca* 21 (11), *Senecio ovatus* ssp. *ovatus* 4 (11); **FB** – *Asperula aristata* 13 (12), *Carex caryophyllea* 13 (15), *Gentiana germanica* 6 (6), *Polygala amarella* 8 (13); **JT** – *Carex curvula* ssp. *curvula* 13 (15), *Carex fuliginosa* 13 (15), *Festuca nigrescens* 6 (17), *Juncus jacquinii* 6 (17), *J. trifidus* 6 (17), *Leontodon helveticus* 22 (17), *Oreochloa disticha* 11 (17), *Veronica fruticans* 6 (17); **LV** – *Arctostaphylos alpina* 13 (12), *Loiseleuria procumbens* 11 (17); **M-Ar** – *Astrantia major* ssp. *major* 6 (8), *Deschampsia cespitosa* 46 (11), *Euphrasia picta* ssp. *picta* 13 (12), *Helictotrichon versicolor* 6 (17), *Poa annua* 11 (16), *P. supina* 100 (9), *Ranunculus tuberosus* 6 (12), *Senecio ovirensis* ssp. *gaudinii* 8 (11), *Vicia sepium* 6 (12); **MC** – *Chrysosplenium alternifolium* 63 (11); **MA** – *Aconitum*

napellus ssp. *tauricum* 14 (18), *Chaerophyllum hirsutum* 6 (8), *Cortusa matthioli* 14 (18), *Hypericum richeri* ssp. *grisebachii* 8 (11), *Pedicularis recutita** 6 (8), *Rumex alpestris* 6 (8), *Salix glabra* 14 (18), *S. hastata* 33 (14); **N** – *Antennaria dioica* 8 (13), *Carex leporina* 8 (13); **QF** – *Adoxa moschatellina* 8 (11), *Anemone nemorosa* 8 (11), *Aquilegia nigricans* 4 (11), *Athyrium filix-femina* 4 (11), *Cardamine enneaphyllos* 4 (11), *Cardamine trifolia* 4 (11), *Carex digitata* 29 (11), *Fagus sylvaticae* 4 (11), *Festuca altissima* 13 (11), *Hieracium murorum* 38 (11), *Homogyne sylvestris* 42 (11), *Lamium orvala* 4 (11), *Luzula luzuloides* ssp. *luzuloides* 25 (12), *Maianthemum bifolium* 17 (11), *Paris quadrifolia* 4 (11), *Phegopteris connectilis* 4 (11), *Poa nemoralis* 29 (11), *Primula elatior* 6 (8), *Salix alba* ssp. *alba* 6 (17), *Stellaria nemorum* ssp. *montana* 4 (11); **SH** – *Luzula alpinopilosa* ssp. *alpinopilosa* 22 (17); **SC** – *Carex nigra* 92 (10), *Gentiana utriculosa* 6 (12), *Luzula sudetica* 31 (12), *Phleum alpinum* 6 (17), *Pinguicula vulgaris* 6 (17); **TG** – *Seseli libanotis* 19 (12), *Veronica chamaedrys* agg. 6 (17); **VP** – *Aposeris foetida* 6 (8), *Clematis alpina* 25 (11), *Drypteris dilatata* 4 (11), *Lonicera caerulea* 46 (11), *Pyrola minor* 4 (11), *P. rotundifolia* 8 (10), *Rhododendron ferrugineum* 15 (13), *Vaccinium myrtillus* 50 (11), *Valeriana tripteris* 8 (11), *Veronica urticifolia* 4 (11); **Other species** – *Alchemilla* sp. 17 (8), 8 (11), 38 (15), 20 (19), *A. flabellata* 56 (12), 8 (13), *Festuca* sp. 44 (12), 8 (13), *Thymus* sp. 22 (8), 75 (15), *Alchemilla anisiaca* 6 (17), *A. sericoneura* 8 (13), *A. subcrenata* 6 (17), *A. vallesiaca* 29 (18), *Campanula* sp. 6 (8), *Erigeron* sp. 6 (17), *Hieracium* sp. 6 (8).

Less frequent geoelements to Table 2

E-Alp./Apenn. – 7, 8; Europ./SW-Asiat. – 3, 13; SW-Europ.-Mont. – 17; Illyr. – 11; N-Europ./Am. – 11; E-Europ. – 14; Europ./Mont. – 12; SE-Europ-Mont./NE-Europ. – 18; Medit.-Mont. – 1; E-Europ. – 11: 1; W-Alp.** – 19: 1; W-Europ. – 11.

List of syntaxa mentioned referred to in the text and Table 1

Thlaspietea rotundifolii Br.-Bl. 1948
Androsacetalia alpinae Br.-Bl. in Br.-Bl. & Jenny 1926
Drabetalia hoppeanae Zollitsch 1968
Thlaspietalia rotundifolii Br.-Bl. in Br.-Bl. & Jenny 1926
Thlaspion rotundifolii Jenny-Lips 1930
Petasition paradoxi Zollitsch ex Lippert 1966
Arabidetalia caeruleae Rübel ex Br.-Bl. 1949
Arabidion caeruleae Br.-Bl. in Br.-Bl. & Jenny 1926 em. Englisch 1999
Ranunculo traunfellneri-Festucetum nitidae (Wraber 1972) Englisch 1999
Saxifragetum stellaro-sedoidis Englisch 1999
var. geogr. *Achillea oxyloba* Surina 2005
var. geogr. *Ranunculus traunfellneri* Surina 2005
var. geogr. *Campanula pulla* Surina 2005
Saxifragetum hohenwartii Aichinger 1933
Salici herbaceae-Arabidion caeruleae Englisch 1999
Salici herbaceae-Arabidetum caeruleae Englisch 1999
Soldanello alpinae-Salicion retusae Englisch 1999
Salicetum retuso-reticulatae Br.-Bl. in Br.-Bl. & Jenny 1926
Homogyno discoloris-Salicetum retusae Aichinger 1933
Diantho alpinae-Salicetum retusae Englisch 1999
Selaginello selaginoidis-Salicetum reticulatae Englisch 1999
Salici retusae-Geranietum argentei Surina 2005
Potentillo brauneanae-Homogynetum discoloris Aichinger 1933
Salicion retusae Horvat 1949
Drepanoclado uncinati-Heliospermetum pusilli Surina & Vreš 2004
Elyno-Seslerietea Br.-Bl. 1948, *Seslerietalia juncifoliae* Horvat 1930, *Seslerion juncifoliae* 1930, *Caricion firmae* Gams 1936, *Gentiano terglouensis-Caricetum firmae* T. Wraber 1970, *Caricetum firmae* Rübel 1911, *Dryadetum octopetalae* Rübel 1911, *Salicetea herbaceae* Br.-Bl. 1948, *Salicion herbaceae* Br.-Bl. in Br.-Bl. & Jenny 1926, *Poo supinae-Cerastietum cerastoidis* Söyrinki ex Oberd. 1957, *Asplenietea trichomanis* (Br.-Bl. in Meier & Br.-Bl. 1926) Oberd. 1957, *Juncetea trifidi* Hadač in Hadač & Klika 1944, *Nardetea strictae* Rivas Goday & Borja Carbonell 1961, *Loiseleurio-Vaccinietea* Eggler 1952, *Montio-Cardaminetea* Br.-Bl. & Tüxen ex Klika & Hadač 1944 em. Zechmeister 1993, *Mulgedio-Aconitetea* Hadač & Klika in Klika & Hadač 1944, *Epilobietea angustifolii* Tüxen & Preising ex von Rochow 1951, *Scheuchzerio-Caricetea fuscae* Tüxen 1937, *Molinio-Arrhenatheretea* Tüxen 1937, *Festuco-Brometea* Br.-Bl. & Tüxen 1943, *Trifolio-Geranietea* Müller 1962, *Artemisietea vulgaris* Lohmeyer, Preising & Tüxen ex von Rochow 1951, *Erico-Pinetea* Horvat 1959, *Querco-Fagetea* Br.-Bl. & Vlieg. 1937, *Vaccinio-Piceetea* Br.-Bl. 1930 em. Zupančič 1976.