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Characteristics of centipede (Chilopoda) assemblies in Dinaric frost hollows in Velika gora (Slovenia)

Značilnosti združbe strig (Chilopoda) v dinarskih mraziščih na Veliki gori (Slovenija)

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Abstract: Current study is preliminary research of centipedes (Chilopoda) assemblies in Slovenian frost hollows. With two sampling methods in three series (June, August and November) in year 2010, 834 individuals were caught and indentified to 30 species. Most collected species had middle Europe distribution, 6 species were endemic for southeast Alps and northwest Balkan region, 3 of them are probably new for science. Five species had paleartic distribution. Maximum number of species found in one location was 28. Average density of centipedes was from 218 ind./m^2 to 552 ind./m^2. The alfa diversity of the centipede assemblies is medium compared to other locations in Dinaric part of Slovenia and evidently higher compare to other European forest. The same applies for average density and species richness. Overall centipede assemblies were more similar in one location during the season than to assemblies from different locations in the same month.

Keywords: Chilopoda, frost hollow, assemblies, seasonal characteristic, Dinaric region

Izvleček: Preučevali smo sezonsko dinamiko strig v nekaterih mraziščih na Veliki gori, J Slovenija. Z dvema vzorčevalnima metodama v treh vzorčenjih (junija, avgusta in novembra) v letu 2010 smo dobili 834 osebkov, ki smo jih uvrstili v 30 vrst. Največ vrst je imelo srednje evropsko razširjenost, kar 6 vrst je bilo endemnih za območje jugovzhodnih Alp ali severozahodnega Balkana, od tega so 3 vrste najverjetneje nove za znanost. Največje število dobljenih vrst v enem mrazišču je bilo 28. Povprečna gostota osebkov na posameznem vzorčenju je bila od 218 os./m^2 do 552 os./m^2. Glede na alfa diverziteto združbi strig v mraziščih sodita med srednje bogate na območju Slovenije in med zelo bogate v primerjavi z drugimi evropskimi gozdnimi združbami. Enako velja za vrstno bogastvo in povprečno gostoto. Združbe strig so si bile bolj podobne na posamezni lokaciji skozi sezono, kot združbe različnih lokacij v istem mesecu.

Ključne besede: strige, mrazišče, združba, sezonske značilnosti, dinarsko območje

Introduction

According final revision of data (Ravnjak 2012) there are 98 species of Chilopoda known in Slovenia, more than one third of them (35 species) being endemic in southeast Alps or northwest Balkan (Kos 2001). But Slovenia area is not evenly studied. We have still very little information for the southeast and northeast part of Slovenia, part of the southwest and surroundings of the Ljubljana basin (Ravnjak 2012).

One of unique characteristic of Slovenia is also karst terrain and karst phenomena such as frost hollows. In Slovenia frost hollows are present in the Julian Alps, Karavanke and all Dinaric area. There were many topological and geological studies conducted in the hollows (Gams 1972, 1974, Trošt 2008, Stepišnik 2006, 2010), but few biological studies. Authors who made studies of vegetation in frost hollows in Slovenia were Martinčič (1977), Zupančič (1980, 1999), Wraber M. (1969), Wraber T. (1963) and Zavadlav (1974). There were only few studies of the fauna in frost hollows, confined to the particular animal groups: Collembola (Červek 1967, 1968), Gastropoda (Bole 1976) and Acarina (Tarman 1975). Chilopoda in frost hollows have been only partially sampled (Kos et al. unpublished) and collected data have not yet been analyzed. This survey is therefore first preliminary study of centipedes' assemblies in frost hollows in Slovenia. Our expectations were as follows: (i) rare or new species for centipede fauna of Slovenia will be found, (ii) the majority of species found will be species with middle European and paleartic distribution, iii) species with boreal and alpine character will be present, iv) there will be season differences in densities of centipedes, v) individual species will have different densities during the season.

Materials and methods

Sampling took place in Velika gora hills in Dinaric region in southern of Slovenia, west of city Ribnica (Fig. 1). Bedrock in this area is mostly calcareous, dominated by limestone and dolomites of different ages. Area is mountainous but does not reach great heights, while the terrain is very diverse due to karst phenomena (Bole and Slapnik 1997). Dominant natural vegetation in the area is the fir – beech forest (*Omphalodes - fagetum*) (Bole and Zupančič 1992). First selected frost hollow was **Smrekov žleb** (GKX: 5061900, GKY: 5476404). Most numerous tree species in the valley are common spruce (*Picea abies*) and fir (*Abies alba*). The topmost layer of the soil in the frost hollow was acidic and covered with rich undergrowth. Second frost hollow was near **Kragulovec** (GKX: 5062821, GKY: 5474681). Common spruce was also most present tree species there, ground were also covered with rich, acidophilic undergrowth.

Sampling took place on the 1st of June, 17th of July and 17th of November in year 2010, between 8 am and 15 pm. Nine (9) soil sample units (SU), representing one sample, on each location were collected with metal cylinder. The sample units dimensions was Ø21cm x 15cm (appr. 5.2 dm^3 of soil). Both organic (litter) as well as the fermentation horizon were covered. Samples were taken randomly in single location, but minimum 10 m apart. Samples were then placed on Tullgren funnels, modified so that the lower parts of fun-

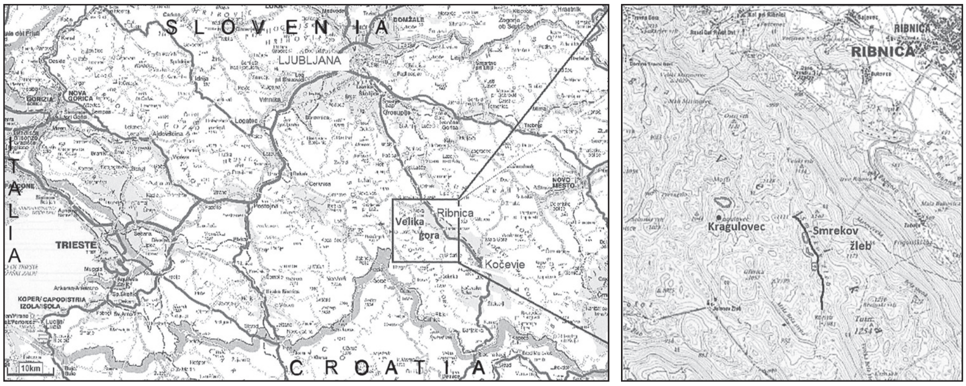

Figure 1: Left: The location of Velika gora plateau in south of Slovenia. Right: Frost hollows Kragulovec and Smrekov žleb.

Slika 1: Levo: Položaj planote Velika gora v Sloveniji. Desno: Mrazišči Kragulovec in Smrekov žleb.

nels were in the dark and cooled. Animals were intercepted in vessels filled with ethylene glycol. The extraction lasted 20-30 days, depended of the humidity of the sample. We also collected animals under the dead wood plants material and stones. In single location we have searched for 20 – 30 min in all area. Captured animals were directly put in 70% alcohol.

All statistical analysis was made following Krebs (1989). For estimation of species richness we used Jackknife for diversity Shanon-Wiener index and Evenness index. For calculation of similarity among centipede assemblies Percentage similarity (Renkonen index) was used (Krebs 1989, p.304). For this we used only relative share of species (without juvenile lithobids and undetermined individuals) from each soil sampling. Dendrogram of similarity was made with program PAST (http://folk.uio.no/ohammer/past/) using minimum-linkage method of clustering. Centipedes were determined following published literature by Eason (1964), Koren (1986, 1992), Matic (1966, 1972), Verhoef (1931, 1937) and other. All collected material is kept in Biotehnical faculty in Department of biology.

Results

Review of the species

Order Geophilomorpha was recently fully reviewed and amended by Bonato and Minelli (2014). New species names are therefore used in the article, but to allow comparison with earlier data, the previous valid names and/or names that were used in past Slovenian literature are given in parentheses in list 1. For general distribution of species we followed Stoev (1997), Kos (2012) and data from Fauna europaea and Chilobase.

List 1: A list of all taxa collected with hand sampling (*) and with soil sampling method (+) in both locations. Currently known distribution (C.D.): pa – paleartic, il – Illyric, en – endemic, Ev – european, miE - middle european, sE - south european, seE- southeast european, eE – east european, Me –Mediterranean

Seznam 1: Seznam vseh taksonov. Vrste, ki smo jih dobili pri ročnem pobiranju * in vrste, ki smo jih dobili pri talnem vzorčenju +. Splošna razširjenost (C.D.): pa – palearktična, il – ilirska, en – endemit, Ev – evropska, miE – srednjeevropska, sE – južnoevropska, seE - jugovzhodnoevropska, eE – vzhodno evropska, Me – mediteranska

C.D	o. GEOPHILOMORPHA	
	f. Geophilidae Leach, 1815	
ili	*Clinopodes carinthiacus* (Latzel, 1880) +	(*Clinopodes trebevicensis* (Verfoeff, 1898))
En	*Eurygeophilus pinguis* (Brölemann, 1898) +	(*Chalandea scherpeltzi* Attems, 1952)
miE	*Geophilus alpinus* Meinert, 1870 +	(*Geophilus (Orinophilus) insculptus* Attems, 1895)
En	*Geophilus n.*sp. +	(*Geophilus* (*Orinophilus)* n.sp.)
sE	*Stenotenia sorrentina* (Attems, 1903) +	
	f.Linotaeniidae Cook, 1899	
Ev	*Strigamia acuminata* (Leach, 1815) +	
miE	*Strigamia transsilvanica* (Verhoeff, 1928) + *	
	f. Mecistocephalidae Bollman, 1893	
ili	*Dicellophilus carniolensis* (C.L.Koch), 1847 + *	
	f. Schendylidae Cook, 1896	
Al-ka	*Schendyla tyrolensis* (Meinert, 1870) + *	(*Schendyla montana* Attems, 1895)
Ili	*Schendyla carniolensis* (Verhoef, 1902) +	
Pa	*Schendyla nemorensis* (C. L. Koch, 1837) +	

	o. LITHOBIOMORPHA	
	f. Lithobiidae	
sE	*Eupolybothrus (Leptopolybothrus) tridentinus* (Fanzago, 1874) *	
En	*Harpolithobius* cf. *gottscheensis* (Verhoeff, 1937) +	
	Harpolithobius sp. + *	
	Lithobius juv + *	
	Lithobius sp. +	
Pa	*Lithobus borealis* Meinert, 1868 *	
Me	*Lithobius castaneus* Newport, 1844 +	
Pa	*Lithobius forficatus* (Linnaeus, 1758) *	
miE	*Lithobius latro* Meinert, 1872 +	
miE	*Lithobius nodulipes* Latzel, 1880 + *	
miE	*Lithobius pelidnus* Haase, 1880 +	
miE	*Lithobius pygmaeus* Latzel, 1880 +	
Ev	*Lithobius tenebrosus* Meinert, 1872 + *	
miE	*Lithobius punctulatus* C.L. Koch, 1847 + *	(*Lithobius validus* Meinert, 1872)
miE	*L. (Monotarsobius) aeruginosus C.* L. Koch, 1862 +	
En ?	*L. (M.)* n.sp. + *	
En	*L. (Sigibius) burzenlandicus carinthiacus* (Koren, 1992) + *	
En ?	*L. (Sigibius)* n. sp. «anici« +	
	o. SCOLOPENDROMORPHA	
	f. Cryptopidae	
Pa	*Cryptops anomalans* Newport, 1844 *	
Pa	*Cryptos hortensis* Leach, 1815 +	
Ev	*Cryptos parisi* Brolemann, 1920 + *	
seE	*Cryptos rucneri* Matic & Teodoreanu, 1966 +	

All species that were found in this study have been already found in area of Slovenia. Four species were found only by hand collecting method, 17 species only with soil sampling method. Nine species were found with both sampling methods (List 1). Most collected species had middle European distribution (8), followed by endemic species (6) and paleartic species (5). We found 3 Illiric species and 3 species with european distribution (List 1). One Mediterranean (*Lithobius castaneus*), one alpine-karpatian (*Schendyla tyrolensis*) and one species with southeast distribution (*Cryptops rucneri*) were also found.

Table 1: N- number of centipedes collected with hand collecting method.
Tabela 1: N- število ulovljenih osebkov pri ročnem nabiranju. Vrste označene "odebeljeno", so bile najdene le s to metodo

	Sampling date	1. 6. 2010		17. 8. 2010		17. 11. 2010	
o.	Species/Vrste	Kragulovec	Smrekov žleb	Kragulovec	Smrekov žleb	Kragulovec	Smrekov žleb
geo	*D. carniolensis*		3		5		
geo	*S. tyrolensis*	1					
geo	*S. transsilvanica*			1		1	
lit	***E. tridentinus***	**1**			**5**		
lit	***L. borealis***					**4**	
lit	*L. burzenlandicus carinthiacus*				1		
lit	*L. castaneus*			1	1		
lit	***L. forficatus***		**1**				
lit	*L. nodulipes*				1		
lit	*L. pelidnus*					1	
lit	*L. punctulatus*			1	1	1	
lit	*L. tenebrosus*	1	2	1	1	1	17
lit	*L. (M.)* n.sp.				1		
sco	***C. anomalans***			**3**	**1**		
sco	*C. parisi*			6	1	2	
lit	*Harpolithobius*.sp.				1		
lit	*Lithobius* juv			1			
	N	3	6	14	19	10	17

Average density and species richness

Juvenile Lithobiidae had the highest density in location **Kragulovec** in summer and autumn followed by species *Lithobius pygmaeus, Clinopodes carinthiacus* and *Cryptops parisi*. The last two had highest densities in the spring and then progressively lower. *Schendyla carniolensis*, *S. tyrolensis* and *Stenotaenia sorerentina* on the other hand had the lowest densities in the summer and the highest in the autumn.

In **Smrekov žleb** species with very high density in all three samplings were *Lithobius (Sigibius*) n.sp. »anici«, followed by L. *pygmaeus* and again *C. parisi*. Juvenile Lithobiidae also had very high density, but lower than in Kragulovec. In this location *L. pygmaeus, Cryptops hortensis* and *C. parisi* had highest densities in the summer. Opposite had *Eurygeophilus pinguis*, *Lithobius (Monotarsobius*) n. sp. and *L. (S*.) n. sp. "anici" lowest densities in the summer.

Average density of centipedes was from 218 ind./m^2 to 552 ind./m^2 (Tab. 2,Tab. 3). In location **Smrekov žleb** the density was higher in all three samplings comparing to samplings in location **Kragulovec**. The number of species caught with square soil sampling method at one sampling was between 12 in 20 (Tab. 2,Tab. 3). Total number of species (soil sampling and hand collecting method in all three samplings) was 22 in location Kragulovec and 28 in location Smrekov žleb.

Diversity index, evenness and Similarity of the assemblies

Shannon – Wiener diversity index was between 1.9 and 2.47 and the Evenness index was between 0.77 and 0.86 (Tab. 2, Tab. 3). In both locations the highest S-W index and Evenness was in August.

Calculation of percentage similarity (Renkonen index) showed the greatest similarity between the centipedes assemblies in June and August on loca-

Table 2: Location Kragulovec, soil sampling method. n – the number of collected centipedes belonging to single species, D - dominance, ind/m^2 (min, max) - density estimation with 95% confidence. N- the number of all individuals in one sampling, densities (ind/m^2) on each location, Jackknife – species richness (max. number estimation), S-W -Shannon-Wiener diversity index, E - Evenness.

Tabela 2: Lokacija Kragulovec, talon vzorčenje. n -Število ulovljenih osebkov določene vrste pri posameznem vzorčenju, D - dominanca, ind/m^2 - povprečna gostota osebkov z 95% intervalom zaupanja, N –celotno število osebkov pri posameznem vzorčenju, average.ind/m^2 - povprečna gostota osebkov na posamezni lokaciji, Jackknife – ocena vrstnega bogastva, S-W - Shannon-Wiener indeks, (E) - parameter stalnosti.

	Sampling date	1.6.2010					17.8.2010					17.11.2010				
o.	Species (vrste)	n	D (%)	ind/m^2	min	max	n	D (%)	ind/m^2	min	max	n	D (%)	ind/m^2	min	max
geo	*C. carinthiacus*	34	24.8	109.1	17.1	135.7	7	10.3	22.5	9.9	35.0	1	0.8	3.2	0.0	7.4
geo	*E. pinguis*	3	2.2	9.6	0.2	19.1	2	2.9	6.4	0.0	12.6					
geo	*G. (O.)* n.sp.											1	0.8	3.2	0.0	7.4
geo	*S. carniolensis*	8	5.8	25.7	1.8	38.6	6	8.8	19.3	0.0	29.3	28	22.8	89.9	25.6	154.1
geo	*S. nemorensis*						1	1.5	3.2	0.0	7.4	1	0.8	3.2	0.0	7.4
geo	*S. tyrolensis*	7	5.1	22.5	1.8	43.1						8	6.5	25.7	5.8	45.6
geo	*S. sorrentina*	2	1.5	6.4	0.0	12.3	1	1.5	3.2	0.0	7.4	13	10.6	41.7	14.8	68.6
geo	*S. acuminata*	2	1.5	6.4	0.0	12.6	3	4.4	9.6	0.0	17.1	3	2.4	9.6	0.2	19.1
geo	*S. transsilvanica*	2	1.5	6.4	0.0	12.3	1	1.5	3.2	0.0	7.4	3	2.4	9.6	0.2	19.1
lit	*L. burzenlandicus carinthiacus*	3	2.2	9.6	0.2	19.1										
lit	*L. castaneus*	1	0.7	3.2	0.0	7.4										
Lit	*L. latro*	4	2.9	12.8	0.0	26.5	2	2.9	6.4	0.0	12.3	1	0.8	3.2	0.0	7.4
lit	*L. nodulipes*						4	5.9	12.8	0.0	21.7	2	1.6	6.4	0.0	12.3
lit	*L. pelidnus*	1	0.7	3.2	0.0	7.4										
lit	*L. pygmaeus*	22	16.1	70.6	29.4	111.8	13	19.1	41.7	7.6	75.9	15	12.2	48.1	11.6	84.7
lit	*L. (M.)* n.sp.	1	0.7	3.2	0.0	7.4										
sco	*C. hortensis*	1	0.7	3.2	0.0	7.4	1	1.5	3.2	0.0	7.4					
sco	*C. parisi*	13	9.5	41.7	7.6	75.9	6	8.8	19.3	2.9	35.6	3	2.4	9.6	0.2	19.1
sco	*C. rucneri*	3	2.2	9.6	0.0	17.1										
lit	*Harpolithobius* sp.											3	2.4			
lit	*Lithobius* juv	27	19.7	89.9	36.1	143.6	19	27.9	61.0	20.5	101.5	41	33.3	131.6	34.4	228.7
lit	*Lithobius* sp.	3	2.2				2	2.9								
N		137					68					123				
Aver. ind./m^2 (min-max)		343,4 (158,4-528,6)					218.3 (100.6-332.6)					394.8 (257.3-532.1)				
Species No.		16					12					12				
Jackknife		20 (17-24)					16 (12-21)					16 (12-19)				
S – W		2.14					2.15					1.89				
E		0.77					0.86					0.76				

Table 3: Location Smrekov žleb, soil sampling method. n – the number of collected centipedes belonging to single species, D - dominance, ind/m² (min, max) - density estimation with 95% confidence. N- the number of all individuals in one sampling, densities (ind/m²) on each location, Jackknife – species richness (max.number estimation), S - W – Shanon-wiener indeks, E – parameter stalnosti

Tabela 3: Lokacija Smrekov žleb, talno vzorčenje. n -Število ulovljenih osebkov določene vrste pri posameznem vzorčenju, D - dominanca, ind/m² - povprečna gostota osebkov z 95% intervalom zaupanja, *N*–celotno število osebkov pri posameznem vzorčenju, average.ind/m² - povprečna gostota osebkov na posamezni lokaciji, Jackknife – ocena vrstnega bogastva, S - W – Shannon-wiener diversity index, E – Evenness

	Sampling date	1.6.2010					17.8.2010					17.11.2010				
	Species (vrsta)	n	D (%)	ind/m²	min	max	n	D (%)	ind/m²	min	max	n	D (%)	ind/m²	min	max
geo	*C. carinthiacus*	4	2.5	12.8	0.0	21.2	5	4.8	16.0	2.3	29.8					
geo	*D. carniolensis*	2	1.3	6.4	0.0	12.3	4	3.8	12.8	0.0	21.2					
geo	*E. pinguis*	11	6.9	35.3	4.3	66.3	5	4.8	16.0	6.1	26.0	7	4.1	22.5	0.0	32.7
geo	*G. (O.)alpinus*						3	2.9	9.6	0.0	17.1	6	3.5	19.3	2.9	35.6
geo	*G. (O.)* n.sp.	4	2.5	12.8	0.0	20.2	1	1.0	3.2	0.0	7.4	7	4.1	6.4	0.0	32.4
geo	*S. carniolensis*	6	3.8	19.3	0.0	25.9	1	1.0	3.2	0.0	7.4	13	7.6	41.7	8.9	74.5
geo	*S. tyrolensis*	3	1.9	9.6	0.2	19.1						21	12.2	67.4	29.9	93.2
geo	*S. sorrentina*	4	2.5	12.8	0.0	26.5	1	1.0	3.2	0.0	7.4					
geo	*S. acuminata*	2	1.3	6.4	0.0	12.3	2	1.9	6.4	0.0	12.3	3	1.7	9.6	0.0	17.1
geo	*S. transsilvanica*	1	0.6	3.2	0.0	7.4	1	1.0	3.2	0.0	7.4	1	0.6	3.2	0.0	7.4
lit	*H. gottscheensis*											1	0.6	3.2	0.0	7.4
lit	*L. burzenlandicus carinthiacus*	4	2.5	12.8	0.0	21.7	3	2.9	9.6	0.0	17.1	3	1.7	9.6	0.2	19.1
lit	*L. castaneus*	2	1.3	6.4	0.0	12.3										
lit	*L. latro*	2	1.3	6.4	0.0	12.3	1	1.0	3.2	0.0	7.4	2	1.2	6.4	0.0	12.3
lit	*L. nodulipes*						1	1.0	3.2	0.0	7.4					
lit	*L. pelidnus*						2	1.9	6.4	0.0	12.6					
lit	*L. pygmaeus*	9	5.6	28.9	3.9	53.8	22	21.0	70.6	21.5	119.7	14	8.1	44.9	13.5	76.4
lit	*L. punctulatus*						1	1.0	3.2	0.0	7.4					
lit	*L. tenebrosus*	2	1.3	6.4	0.0	12.6						1	0.6	3.2	0.0	7.4
lit	*L.(M.)aeruginosus*											1	0.6	3.2	0.0	7.4
lit	*L. (M.)* n.sp.	14	8.8	44.9	9.5	80.4	1	1.0	3.2	0.0	7.4	6	3.5	19.3	0.4	38.1
lit	*L. (S.)* n.sp.*"anici"*	49	30.6	157.3	52.6	261.9	12	11.4	38.5	4.8	54.9	23	13.4	134.8	24.1	105.2
sco	*C. hortensis*	5	3.1	16.0	2.3	29.8	10	9.5	32.1	3.1	61.1	3	1.7	9.6	0.0	17.1
sco	*C. parisi*	16	10.0	51.4	24.9	70.8	10	9.5	32.1	1.9	46.6	13	7.6	41.7	18.4	65.0
sco	*C. rucneri*	5	3.1	16.0	2.3	29.8	2	1.9	6.4	0.0	12.3	3	1.7	9.6	0.2	19.1
lit	*Harpolithobius* sp.	1	0.6													
lit	*Lithobius* juv	12	7.5	41.7	18.4	65.0	17	16.2	54.6	20.0	89.1	42	24.4	134.8	38.0	192.0
lit	*Lithobius* sp.	2	1.3									2	1.2			
N		160					105					172				
Average. ind./m² (min-max)		513.5 (335.7-691.1)					337.0 (267.6-406.3)					552.1 (427.7-676.2)				
Species No.		19					20					18				
Jackknife		22 (19 - 25)					28 (21-34)					22 (18 - 26)				
S - W		2.37					2.47					2.45				
E		0.81					0.83					0.85				

tion Kragulovec (68.2%), followed by assemblies in Smrekov žleb in June and November (64.7%) (Tab.4). Overall centipede assemblies were more similar in one location during the season than assemblies from different locations in the same month (Fig. 2).

Table 4: Matrix of similarity coefficients (Renkonen index) for all samples. K1 - Kragulovec 1.6.2010, K2 - Kragulovec 17.8.2010, K3 – Kragulovec 17.11.2010; SmZ1 – Smrekov žleb 1.6.2010, SmZ2 – Smrekov žleb 17.8.2010, SmZ3 – Smrekov žleb 17.11.2010

Tabela 4: Matrica podobnosti (Rankonenov indeks) med posameznimi vzorčenji. K1 – Kragulovec 1.6.2010, K2 - Kragulovec 17.8.2010, K3 – Kragulovec 17.11.2010; SmZ1 – Smrekov žleb 1.6.2010, SmZ2 – Smrekov žleb 17.8.2010, SmZ3 – Smrekov žleb 17.11.2010

	K1	K2	K3	SmZ1	SmZ2	SmZ3
K1						
K2	0,682					
K3	0,449	0,499				
SmZ1	0,427	0,361	0,248			
SmZ2	0,547	0,564	0,331	0,569		
SmZ3	0,487	0,423	0,407	0,647	0,582	

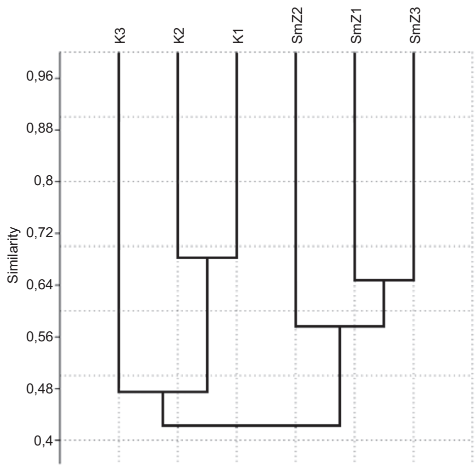

Figure 2: Dendrogram of similarity using Renkonen index of similarity) between locations (soil sampling method). Key: K1 - Kragulovec 1.6.2010, K2 - Kragulovec 17.8.2010, K3 – Kragulovec 17.11.2010; SmZ1 – Smrekov žleb 1.6.2010, SmZ2 – Smrekov žleb 17.8.2010, SmZ3 – Smrekov žleb 17.11.2010

Slika 2: Dendrogram podobnosti med posameznimi lokacijami (talni vzorci) po Renkonenovemu indeksu podobnosti. Legenda: K1 – Kragulovec 1.6.2010, K2 - Kragulovec 17.8.2010, K3 – Kragulovec 17.11.2010; SmZ1 – Smrekov žleb 1.6.2010, SmZ2 – Smrekov žleb 17.8.2010, SmZ3 – Smrekov žleb 17.11.2010

Discussion

Presentation of species

Many studies was made stating that for most representative faunistic studies combination of quantitative and qualitative sampling methods should be used (Kos, 1988a, Fründ et al. 1997, Leśniewska 2000, Grgič 2005). Much smaller number of individuals obtained with hand collecting method is the result of lower effort compared with soil sampling method. Nevertheless according to the given estimation of species richness repeated sampling would result in 2 (in location Kragulovec) to 6 (location Smrekov žleb) additional species at most. We can therefore conclude that our sampling was sufficiently intense and that most of the species present in frost hollows were captured. Below are in more detail presented 4 species which are endemic to the southeast Alps or/and the northwest Balkan region, one species with alpine character and two species with boreal character (in alphabetical order).

Eurygeophilus pinguis Brolemann, 1898

In Slovenia there were 36 individuals found in the Dinaric and alpine region (Kos 1988a, Kos unpublished) and 28 more individuals in frost hollows (Vode & Kos this research). They were first determined as *Chalandea scheerpeltzi* Attems, 1952, following Attems (1952) and Koren (1986) with reference to their physical characteristics and number of legs. All male individuals had 33 and all female indivividuals had 35 pairs of leg namely. After the revision (Bonato et al. 2006) *C. scheerpeltzi* was put in the synonimics with *E. pinguis*.

Individuals of ***Geophilus ("Orinophilus") n. sp.*** were found in Kočevska reka (Kos and Praprotnik 2000), Mala gora near Kočevje (Grgič 2002), near Ribnica (Kos 1988a) in the valley Iška (Grgič 2005), in Cerkno (Pagon 2006) and in the frost hollows near Velika gora (Vode & Kos, this research). Altogether 60 individuals were found and identification key for thee potentially new species is in preparation.

We found one individual of the species ***Harpolithobius gottscheensis*** Verhoef, 1937. Till now several individuals were found in the Karst Edge (Kos 1990), Kočevski Rog (Kos & Grgič 2001), valley Iška (Grgič 2005) and Boč plateau (Ravnjak 2006). According to current knowledge this species is rare in Slovenia and it is considered endemic in northern Dinarides and southeast Alps (Kos, 2012).

Lithobius borealis Meinert, 1868 is paleartic species, common in boreal forests in northern Eurasian area. It was found sparsely in Slovenian Alps (Kos et al. 2000), valley Iška (Grgič 2005) and Dinaric region (Kos 1988a, 1995a, b; Vode & Kos this research). Altogether there have been only 17 individuals found in Slovenia so far.

Lithobius tenebrosus Meinert, 1872 is widespread in boreal forests in Northern and Central Europe and the Carpathian Mountains (Chilobase, Kos 1995b). With its unique metabolism it is adapted to the environments with low temperature (Kos unpublished). It was found in alpine, sub alpine and Dinaric region of Slovenia (Kos 1988b, Kos et al. 2000, Pagon 2006, Grgič 2002, 2005, respectively) almost exclusively with hand collecting method. Its colder preferences were confirmed with this study as it was most abundant species found in frost hollows with hand collecting method.

There were 38 individuals of the species ***Lithobius* (*Monotarsobius*) n. sp.** found in Kočevski Rog (Kos 1995b), Kočevje area (Kos and Praprotnik 2000), the valley Iška (Grgič 2005), Cerkno (Pagon 2006) and Kras (Kos et al. unpublished). In this study 23 more individuals were found, which is noticeable contribution to facilitate the description of this potentially new species.

***Lithobius (Sigibius*) n. sp. "anici"** is new species for science and was fist found in Kočevje area, where it was one of the most abundant species (Kos 1988a). Later it was also found in Bosnia (Kos 1992), Slovenian Karst (Kos 1995a), in the valley Iška (Grgič 2005), Kočevje area (Kos in Praprotnik 2000, Vode & Kos this research). Altogether there were almost 800 individuals found which makes this species one of the most numerous species of Dinaric region in Slovenia.

Centipede assemblies' characteristics

Comparing to other locations in Dinaric region in Slovenia (where densities and species number were as high as 44 species and 892 ind./m^2 (Grgič 2005)) average density of centipedes from 218 ind./m^2 to 552 ind./m^2 and number of species 22 to 28 defines centipede assemblies in frost hollows as medium rich. But when comparing to forest assemblies in Europe can be defined as (very) rich. In Poland for instance Leśniewska (2000) found up to 19 species with average density 181 ind./m^2 in *Querco-Carpinetum* forest with two sampling methods. Tuf (2000) found 2 - 9 species (max. aver. density 250 ind./m^2 with soil sampling method) in different successional stages of *Querco-Ulmetum* association and Wytwer (2000) found 6 – 9 species (max. aver. density 40 ind/m^2 with Barber'pitfall traps) in 5 different forests types. Studies made in Germany by Albert (1982) and Fründ (1987) also reviled smaller numbers of species (4 – 9) and lower densities (up to 171 ind/m^2) as have studies in England (Roberts 1957: 7 species, 150 ind./m^2) and in Hungary (Loksa, 1979: 7-9 species, up to 234 ind./m^2). Jet we must point out that all densities made by Slovenian authors were determined on the basis of sampling the unoccupied ("free") surface. The data are therefore not fully compatible with other authors who used different combination of sampling methods and statistical analysis.

Seasonal depended centipede assemblies changes

According to the temperature of the soil and air in the frost hollows made in previous studies (see "Introduction") we presume that evaporation in the frost hollows is smaller and soil retains more moisture than in the surroundings. Knowing that centipedes actively choose the most optimal locations available (Grgič and Kos 2001) and that they are capable of relatively long distance migration (referring to larger epidaphic species) (Kos 1995a, Grgič 2005) we were anticipating there will be seasonal migration to frost hollows from the surrounding area in the summer, meaning that centipede densities in the frost hollows would be higher in the summer months. Our results reject this theory as the average centipede density was in the summer in both locations lower than in spring or in autumn. Our presumptions are therefore that in summer months when the temperatures were higher, larger more mobile species migrated out of frost hollows, while smaller less mobile species moved deeper in the soil. The disclosure of reasons for this migration as well as the confirmation of our migrational theory still have to be done.

Diversity, evenness and similarity

Although the average densities were in the summer the lowest, the S – W diversity index and the evenness index were in the summer the highest in both frost hollows. Interpretation of the dominance tells us why. In every sampling 2 - 3 species and juvenile Lithobiidae had very high dominance. In location Kragulovec they were presenting 57 – 77% of all captured individuals. In spring species *Clinopodes carinthiacus* had 24.8% dominance. Increased evenness rate in summer in Kragulovec can be attributed to more balanced proportions of species present while *C. carinthiacus* dominance declined to 10.3%. Again lower evenness rate and S – W index in autumn are due to the increased dominance of *Schendyla carniolensis, Stenotaenia sorrentina* and *Lithobius pygmaeus*. In location Smrekov žleb S – W diversity index and evenness rate were higher comparing to Kragulovec as three most dominant taxa represent “only” 48 – 49% of all species found. In this location *Lithobius (Sigibius)* n.sp. “anici” was most dominant species in all samplings followed by one more species (*C. parisi* in the spring, *L. pygmaeus* in the summer and *S. tyrolensis* in the autumn) and juvenile Lithobiidae. Whereas the total dominance of the 3 most dominant species did not change during the season so did not the S – W and evenness index.

Dendrogram of similarity show distinct difference between frost hollows. The assemblies were more similar in the same location during the season, than to assemblies in the same month in other location. We assume that species composition of centipede assembly therefore depends more with respect to the surroundings rather than by environmental conditions in the frost hollows.

Conclusions

According to results we can confirm all hypotheses. We found 6 species that are endemic for northeren Dinarides or southeasteren Alps, 3 of them are probably new to science. Species with middle European distribution were far most numerous frost hollows, followed by species with palearctic distribution. We found *Eurygeophilus pinguis* which is alpine species and two species with boreal character: *Lithobius borealis* and *Lithobius tenebrosus*, last being the most numerous species obtained with hand collecting method. There were statistical differences in species composition and densities during the season. From the results we predict that there is an active season migration between frost hollows and surroundings. We assume that frost hollows in Dinaric region are “refugia” of local populations of certain species thus having an important role when concerning maintaining population viability and biodiversity of the area. Due to this features we believe that frost hollows are suitable sampling sites for monitoring of impact of climatic changes on centipedes. To confirm our theories more comprehensive seasonal sampling with additional sampling methods should be carried out.

Povzetek

Namen raziskave je bil ugotoviti vrstno sestavo in gostoto strig v mraziščih, ter kako se tekom vegetacijske sezone spreminjata. Predvidevali smo, da bomo našli redke ali nove vrste za slovensko favno strig, da bomo poleg vrst s srednjeevropskim in palearktičnim arealom razširjenosti našli vrste z alpskim in borealnim značajem, kar smo potrdili. Našli smo 6 endemnih vrst, od katerega so 3 najverjetneje nove za znanost, vrsto *Eurygeophilus pinguis*,ki ima alpski značaj in dve vrsti z borealnim značajem, *Lithobius tenebrosus* in *Lithobius borealis*. Skupno smo dobili 22 in 28 vrst v posameznem mrazišču, povprečna gostota

je bila od 218 os./m^2 do 552 os./m^2, kar uvršča združbo strig v mraziščih med srednje bogate združbe v primerjavi z drugimi lokacijami v slovenski dinarski regiji oziroma med zelo bogate v primerjavi z drugimi evropskimi gozdnimi lokacijami. Povprečna gostota je bila poleti na obeh lokacijah najmanjša, kar je v nasprotju z našimi predvidevanji, da strige poleti migrirajo v mrazišča zaradi nižjih temperatur in posledično večje vlažnosti. Zato predvidevamo, da se strige poleti ali umaknejo ven iz mrazišč ali pa se pomaknejo globlje v tla, kar pa s to študijo nismo uspeli potrditi. Prav tako ostaja nepojasnjeno, kateri parametri so glavni razlog za sezonske spremembe v združbi strig v mraziščih, saj temperatura sama očitno nima glavnega vpliva. Vrstna pestrost v izbranih mraziščih je primerljiva z vrstno pestrostjo dinarskih bukovo-jelovih gozdov in je višja od mezofilnih gozdov srednje in severne Evrope. V obeh mraziščih sta bila vrednost Shannon – Wienerjevega indeksa ter indeksa stalnosti najvišja v avgustovskem vzorčenju. To lahko razložimo s stopnjo dominance treh najštevilčnejših taksonov. Poleti so bile vrste bolj enakomerno zastopane kot spomladi ali jeseni, ko so dominirali juvenilni litobidi in vrste *Clinopodes carinthiacus, Lithobius pygmeus, Schendyla carniolensis* in *Stenoteania sorrentina* v lokaciji Kragulovec, oziroma juvenilni litobidi in vrste *Schendyla tyrolensis*, *Lithobius (Sigibius)* n.sp. »anici« in *Cryptops parisi* v lokaciji Smrekov žleb. Ocena podobnosti po Renkonenu je pokazala, da so bile združbe strig v posameznem mrazišču tekom sezone bolj podobne med sabo, kot z združbo v drugem mrazišču vzorčeno v istem obdobju, kar pomeni, da je vrstna sestava združbe strig bolj odvisna od vrstne sestave okolice, kot od okoljskih značilnosti mrazišča. Ta preliminarna raziskava združb strig v mraziščih utemeljuje potrebo po sezonskem vzorčenju z dodatnimi metodami, da bomo lahko potrdili naše domneve glede sezonske migracije strig med mraziščem in okolico in o refugialnem pomenu mrazišč za določene vrste. Že sedaj pa lahko predvidevamo, da so mrazišča primerna vzorčna mesta za spremljanje vplivov klimatskih sprememb na združbe strig.

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