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Species diversity and composition of small mammal communities in Goteniška gora (S Slovenia)

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Abstract. Although a considerable improvement in knowledge about small mammal fauna in Slovenia has been noted over the past 30 years, the group is still understudied. Here we present results of the nine-year trapping and information on abundance and community assemblage of small mammals of Goteniška gora, a mountain in southern Slovenia. Trappings were conducted every September from 2002 to 2010. Traps were set in different habitats, ranging from open-space meadows and stony karst areas to dense fir-beech forests (*Abieti-Fagetum dinaricum*). At least 12 different species constituted local communities, mostly resembling central European deciduous and mixed forest communities. Some representatives of Alpine small mammal communities and a Pleistocene relict were also present.

Key words: small mammal community, long term trapping, Goteniška gora, Dinarides

Izvleček. Vrstna pestrost in sestava združb malih sesalcev na Goteniški gori (J Slovenija) – Kljub napredku na področju raziskovanja malih sesalcev Slovenije v zadnjih 30 letih je ta skupina še vedno slabo preučena. V prispevku predstavljamo rezultate devetletnega vzorčenje na območju Goteniške gore na jugu Slovenije in podatke o gostoti in združbah malih sesalcev na tem območju. Vzorčili smo vsak september v letih od vključno 2002 do 2010 v različnih habitatih, od odprtih travnikov in kamnitega kraškega območja do gostih, dinarskih jelovo-bukovih (*Abietum-Fagetum dinaricum*) gozdnih sestojev. Združbo malih sesalcev Goteniške gore sestavlja vsaj 12 različnih vrst malih sesalcev, v glavnem značilnih za srednjeevropske listopadne in mešane gozdove. Poleg teh smo zabeležili tudi predstavnike alpinskih združb malih sesalcev, kot tudi en pleistocenski relikt.

Ključne besede: mali sesalci, združba, večletno vzorčenje, Goteniška gora, Dinaridi

Introduction

According to the literature, there are more than 2,500 species of small mammals present on all continents except Antarctica (Nowak 1999). More than 125 species are known from Europe (Temple & Terry 2007), where the small mammal assemblage consists of two independent evolutionary lineages: Eulipotyphla (some of the families formerly belonging to the order Insectivora) and Rodentia (Barnett & Dutton 1995). In Slovenia, the group is represented by thirty one species; last one added to the list is the garden dormouse *Eliomys quercinus* (Kryštufek 2003). Since small mammals inhabit different niches and participate in nutrient circulation, they are an important part of every terrestrial ecosystem, representing a link between different trophic levels (Stoddart 1979). Small mammals, especially rodents, are known for periodical oscillations in their numbers. At least 20 hypotheses have been formulated to explain this pattern, invoking the effect of specialist predators, food shortage, or intrinsic factors (Smith et al. 2006, Zub et al. 2012).

Thanks to the work carried out by Slovenian biologists at the end of the 20th century and beginning of the 21st century, considerable knowledge about Slovenian theriofauna has been collected; still, the small mammal fauna remains understudied. B. Kryštufek, the author of *Sesalci Slovenije*, a key work of Slovenian mammalogy (Kryštufek, 1991), made major advances in small mammal knowledge from the 1980s onward. Kryštufek (1983, 1987), Remžgar (1990) and Vrček (2002), among others, have already conducted several small mammal studies from the broader vicinity of Kočevje, including Goteniška gora.

In this paper, we analysed data on small mammals collected during the nine-year trapping in Goteniška gora (S Slovenia) and compiled a list of small mammals present in the study region, including some morphometric characteristics and sample-based estimates of total number of expected species.

Materials and methods

Study area

The study was conducted at Goteniška gora, the mountain situated in southern Slovenia. Mountain ridge orientation follows the main Dinaric ridge direction - from northwest to southeast. The highest peak of Goteniška gora is Goteniški Snežnik (1,290 m a.s.l.). Mean annual air temperature is 6-8°C, mean temperatures for January -2–0°C and 18–20°C for July. Goteniška gora has average annual precipitation between 1,600 and 2,600 mm (ARSO 2006). Although the area has one of the highest precipitation rates in Slovenia, the lack of surface waters is obvious due to the permeable karst geology (Gams 2004). Geological substrate is mostly Cretaceous and Jurassic limestone, dolomite and dolomitic limestone combined with Triassic dolomites (Pleničar et al. 2009). Most of the soil is Chromic Cambisol and Rendzina (Mihelič et al. 2000). Phytogeographically, the altitudes below 700 m a.s.l. belong to the

pre-Dinaric region and those above 700–800 to the Dinaric phytogeographic area (Marinček & Zupančič 1977). The latter region, which includes most of Goteniška gora, is mainly covered with dense Dinaric fir-beech forests (*Abieti-Fagetum dinaricum*) in the areas from 900 to 1,300 m a.s.l. (Surina 2002).

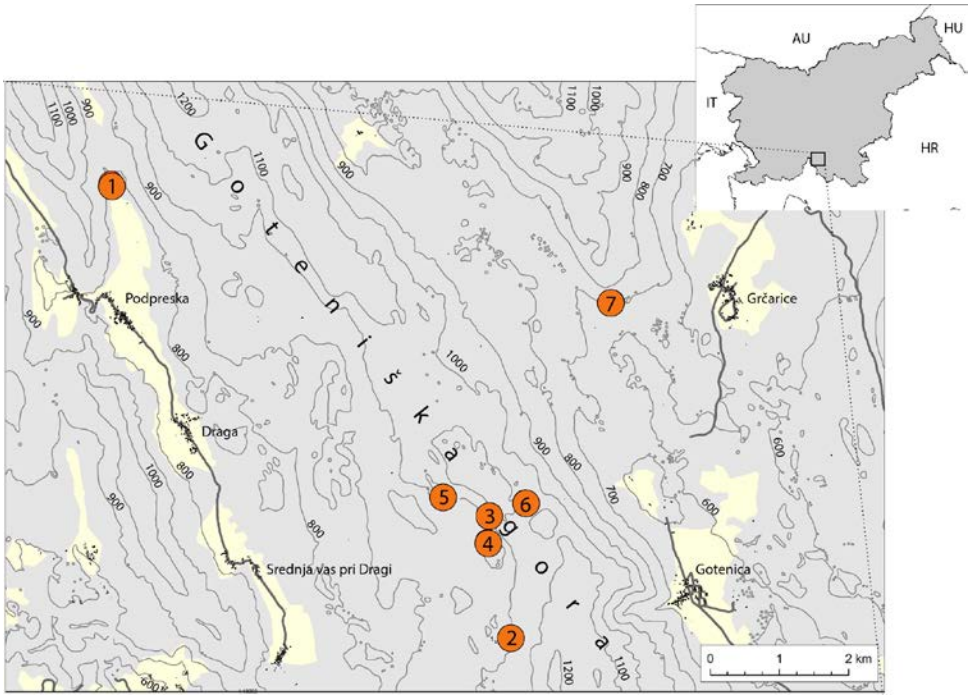

Figure 1. Geographic position of Goteniška gora and sampling sites. Numbers of sampling sites refer to Table 1.
Slika 1. Položaj Goteniške gore in vzorčnih mest. Številke vzorčnih mest se nanašajo na Tabelo 1.

Small mammals were trapped in the second half of September from 2002 to 2010. Trappings were performed at seven different localities (Fig. 1, Tab. 1). Through the years, the trapping method was changed in respect to trap setting and number of traps used (ranged from 45 to 128 traps per sampling site). In general, two traps were used in a pair to avoid snapping of at least one from a pair as a consequence of bad weather conditions (e.g. rain or strong wind) and set at 10 m distance in a grid formation. Traps were set in the places with visible signs of small mammals' activity: in front of animal burrows, on paths, etc. Trap checking was performed twice a day: in the morning and in the evening. Baits were a mix of canned sardines in oil and bread crumbs and were refreshed as needed (dissolved by rain, old or removed by other animals). Trapping sessions lasted from three to seven days. If trapping exceeded three days per year, it was usually performed on two different localities that were at least few hundred meters apart. Details about trapping sites, trapping duration, number of used traps and habitat type are given in Tab. 1.

Table 1. List of sampled sites with Gauss-Krüger coordinates and information on the number of traps, habitat type, etc.
Tabela 1. Seznam vzorčenih mest s koordinatnimi točkami po Gauss-Krüger-ju in informacijami o številu pasti, habitatu itd.

	Year	Date	Sample site	Gauss-Krüger y	Gauss-Krüger x	N (traps)	N (days)	Habitat type
1.	2002a	18.-20.9.	Podpreska	472327	57920	64	2	forest edge
2.	2002b	12.-16.9.	Medvedjak, travnik	478110	51357	64	4	meadow
2.	2003	23.-25.9.	Medvedjak, travnik	478110	51357	64	2	meadow
2.	2004	21.-23.9.	Medvedjak, travnik	478110	51357	128	2	meadow
2.	2005	20.-22.9.	Medvedjak, travnik	478110	51357	112	2	meadow, forest edge
3.	2006	26.-28.9.	Sovja stena	477801	53133	112	2	forest
3.	2007	26.-28.9.	Sovja stena	477801	53133	112	2	forest
4.	2008a	20.-22.9.	Goteniška gora	477767	52747	128	2	forest
5.	2008b	24.-26.9.	Ograda	477137	53385	128	3	forest
3.	2009a	19.-23.9.	Sovja stena 1	477801	53133	70	4	forest
3.	2009b	24.-27.9.	Sovja stena 2	477801	53133	70	3	forest
6.	2010a	18.-24.9.	Hajduk	478313	53319	60	6	forest
7.	2010b	18.-24.9.	Konfin	479569	56205	45	6	forest

Measurements and data analyses

Animals were weighed, measured and sexed; specimens were identified according to Macdonald & Barrett (1993). Weight was measured to 0.5 g accuracy with Pesola 60 g Micro-Line Spring Scale. Snout-vent length, tail length, hind feet and ear measurements were taken with a metal ruler (±1 mm accuracy). Animals were skinned, the skin stretched on cardboards of adequate sizes, and the body residuals preserved in 96% ethyl alcohol for future research.

Based on data collected over the nine years, we calculated abundance per species, abundance per year, sex ratio and daily activity. Since data for daily activity and sex ratio are incomplete, we presented results only for the trapping years with complete information (daily activity) and those individuals whose sex was reliably determined (less 12 individuals). For the six most abundant species we calculated minimum, maximum and mean values for every measurement taken. Additionally, we estimated sample-based total species number for small mammals, and species accumulation curve with EstimateS 8.2.0 (Colwell et al. 2012) for Goteniška gora overall and separately for open and forest habitats (Fig. 5). We used R statistical environment (R Development Core Team, 2012) for data handling and calculation of the parameters. Vegan (Oksanen et al. 2012) and BiodiversityR (Kindt & Coe 2005) packages were used for calculating the expected number of species. Data visualization was done using package ggplot2 (Wickham 2009). The R code is available per request from the authors.

Results

Over a period of 9 years, from 2002 to 2010, we trapped 341 animals, belonging to 12 species of small mammals (nine rodents and three insectivores: the latter referring to species belonging to former Insectivora) (Tab. 2, Fig. 2). The information on trapped individuals overall and in two different habitats is given in Tab. 2.

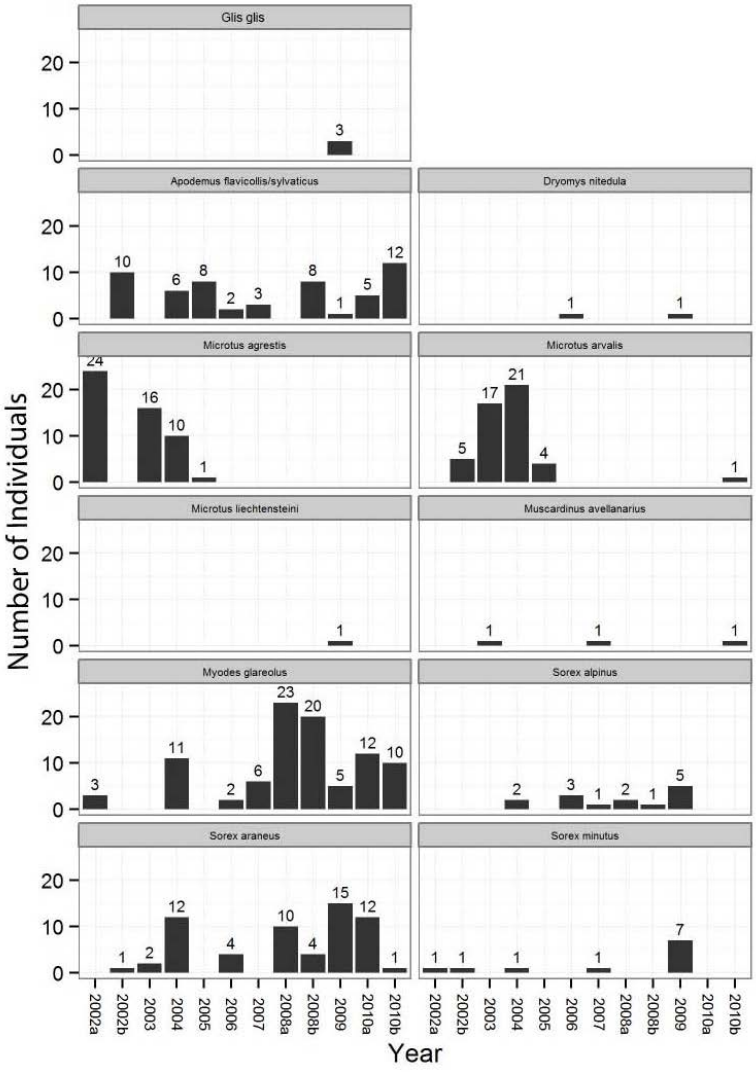

Figure 2. Number of individuals per species through the 2002-2010 period. Years with a and b note stand for two different sampling sites per year.

Slika 2. Število ujetih osebkov za posamezno vrsto skozi leta 2002-2010. Oznaki a in b na letnicah označujeta dve lokaliteti, vzorčeni v istem letu.

Table 2. Species assemblage overall and in two habitats: open and forest habitats. The most abundant species are printed in bold.
Tabela 2. Prikaz vrstne sestave za vsa vzorčenja skupaj ter ločeno po tipu habitata: travniškem in gozdnem. Krepko odtisnjene so najpogosteje ulovljene vrste.

	total number		**open habitat**		**forest habitat**	
Species	**N**	**%**	**N**	**%**	**N**	**%**
Myodes glareolus	**92**	**27.0**	14	10	**78**	**38.8**
Sorex araneus	**61**	**17.9**	14	10	**47**	**23.4**
Apodemus flavicollis/sylvaticus	**55**	**16.1**	14	10	**41**	**20.4**
Microtus agrestis	51	15.0	**51**	**36**		
Microtus arvalis	48	14.0	**42**	**30**	6	3.0
Sorex alpinus	14	4.1	2	1	12	6.0
Sorex minutus	11	3.2	2	1	9	4.5
Glis glis	3	0.8			3	1.5
Muscardinus avellanarius	3	0.8	1	1	2	1.0
Dryomys nitedula	2	0.6			2	1.0
Microtus liechtensteini	1	0.3			1	0.5
total number	**341**	**100%**	**140**	**100%**	**201**	**100%**

The most abundant species of Goteniška gora were bank vole *Myodes glareolus* (27.0%) and common shrew *Sorex araneus* (17.9%), the third most abundant species was yellow-necked/wood mouse *Apodemus flavicollis/sylvaticus* (16.1%) (Tab. 2). The pooled proportion of the remaining species in the community was below 40%. Since morphological features do not always suffice for species determination, data for *A. flavicollis* and *A. sylvaticus* are given together. Due to the habitat type and the biogeographic region itself, our data most likely concern primarily *A. flavicollis*, which is the most abundant small mammal of the Dinaric forests (Kryštufek 1991, Trilar 1991).

If we divide data according to habitat type, open habitat and forest habitat, we can see a notable difference in species composition. In open habitats (meadow above 1,000 m a.s.l.), the most abundant species are field vole *Microtus agrestis* (36%) and common vole *Microtus arvalis* (30%). Composition of the most abundant species in forest habitats resembles overall composition: *M. glareolus* (38.8%), *S. araneus* (23.4%) and *A. flavicollis/sylvaticus* (20.4%). Overall, 140 individuals belonging to at least eight different species were trapped in open habitat and 201 belonging to at least 10 species in forest habitats. Values of body measurements for the six most abundant species are given in Tab. 3.

Table 3. Body measurements for the six most abundant species.
Tabela 3. Vrednosti telesnih velikosti za šest najbolj pogostih vrst.

		Weight [g]			Snout-Vent [mm]			Tail length [mm]			Hind foot [mm]			Ear length [mm]		
	N	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Myodes glareolus	**92**	13	23.9	62	30	96	150	29	45.1	86	12	18.4	28	7	11.9	19
Sorex araneus	**61**	7.5	8.33	9	54	64.7	77	42	46	49	12	12.3	13			
Apodemus flavicollis/sylvaticus	**55**	12	24.3	40	69	90.7	120	35	94.8	113	12	22.8	29	11	16.9	23
Microtus agrestis	**51**	10	24.1	48	71	95.3	123	21	30.1	44	13	17	20	6	10.9	18
Microtus arvalis	**48**	10	22	52	64	89.8	129	16	29.3	43	14	16.4	26	9	11.4	17
Sorex alpinus	**14**	11.3	12.8	14.2	75	75.5	76	68	69	70	15	15.5	16			

Rodents were generally more abundant, irrespective of differences between habitats, except in the years 2006 and 2009.

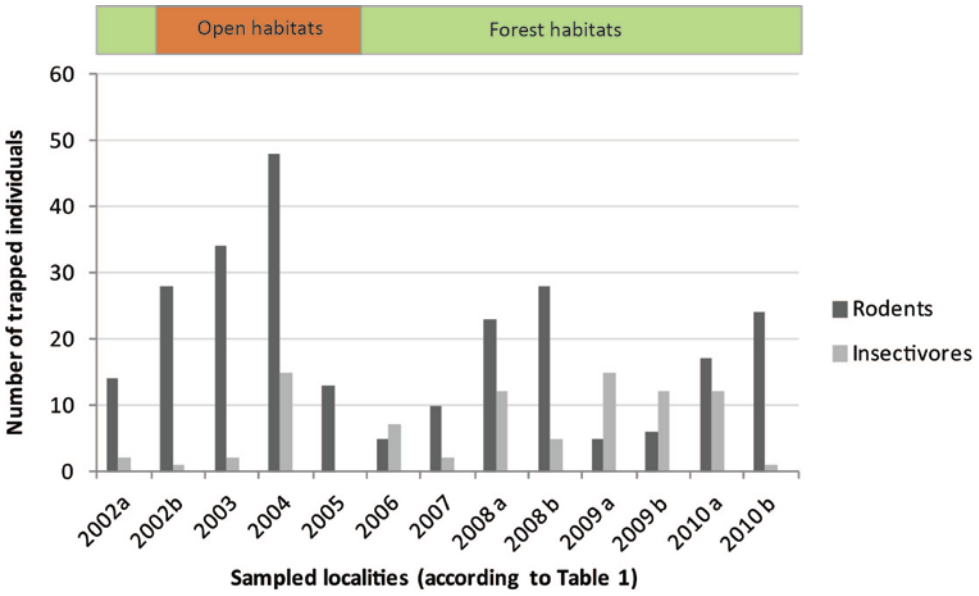

Figure 3. Number of insectivores and rodents trapped according to sampling localities in two different habitat types.
Slika 3. Število ujetih žužkojedov in glodalcev glede na vzorčno mesto v različnih habitatih.

The two methods used to predict total species number of Goteniška gora gave similar results. Sample-based estimation predicted that 11–13 species are present in sampled area of Goteniška gora (10–12 in forest habitats and 8–10 in open habitats); similar results are shown by accumulation curves for open habitats, forest habitats and Goteniška gora overall (Fig. 4).

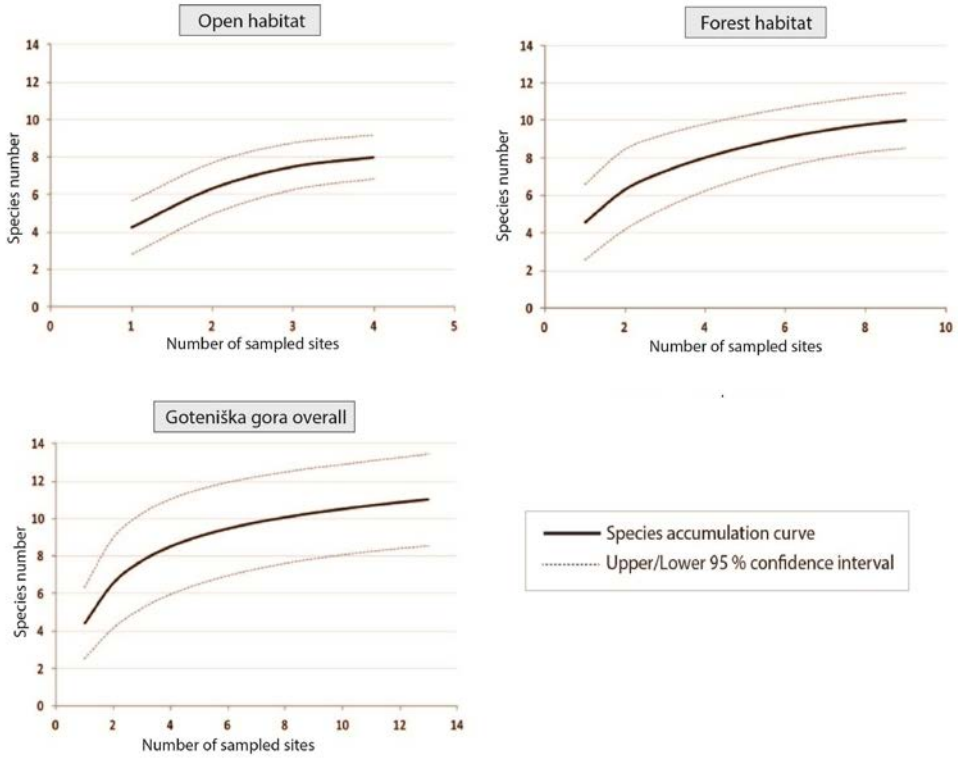

Figure 4. Sample-based species accumulation curves for Goteniška gora overall, open and forest habitats.
Slika 4. Krivulja kopičenja vrst za Goteniško goro, travniške in gozdne habitate, nastala na podlagi vzorčenj.

Table 4. Percentage of males and females per species for Goteniška gora, open and forest habitats.
Tabela 4. Razmerje med spoloma znotraj vrste za Goteniško goro, travniške in gozdne habitate.

	Goteniška gora overall			Open habitats			Forest habitats		
	Total	% ♂	% ♀	Total	% ♂	% ♀	Total	% ♂	% ♀
M. glareolus	**87**	**55**	**45**	14	57	43	**73**	**55**	**45**
S. araneus	**57**	**58**	**42**	14	36	64	**43**	**56**	**44**
A. flavicollis/sylvaticus	**54**	**50**	**50**	14	57	43	**40**	**48**	**53**
M. agrestis	51	30	70	**51**	**30**	**70**			
M. arvalis	47	34	66	**41**	**37**	**63**	6	17	83
S. alpinus	14	50	50	2	0	100	12	58	42
S. minutus	11	73	27	2	50	50	9	78	22
G. glis	3	0	100				3	0	100
D. nitedula	2	100	0				2	100	0
M. avellanarius	2	50	50	1	100	0	1	0	100
M. liechtensteini	1	100	0				1	100	0
Σ =	**329**			**139**			**190**		

Table 5. Ratio of daily and nightly active animals per species for Goteniška gora, open and forest habitats.
Tabela 5. Razmerje med nočno in dnevno aktivnimi živalmi za Goteniško goro, travniške in gozdne habitate.

	Goteniška gora overall			Open habitats			Forest habitats		
	Total	% night	% day	Total	% night	% day	Total	% night	% day
M. glareolus	60	87	13	11	55	45	49	94	6
S. araneus	50	61	39	14	64	36	36	61	39
M. arvalis	43	81	19	42	81	19	1	100	0
A. flavicollis/sylvaticus	41	95	5	14	100	0	27	93	7
M. agrestis	26	62	38	26	61	39			
S. alpinus	11	82	18	2	50	50	9	89	11
S. minutus	8	88	12	1	100	0	7	86	14
G. glis	3	67	33				3	67	33
D. nitedula	2	100	0				2	100	0
M. avellanarius	2	100	0	1	100	0	1	100	0
M. liechtensteini	1	100	0				1	100	0
Σ =	**247**			**111**			**136**		

Discussion

Species assemblage in open and forest habitats highlights duality of small mammal communities according to habitat type. In 2002, 2003, 2004 and 2005, traps were set in open habitats (dry meadows with sufficient but not very tall vegetation). In those years, high proportions of *M. arvalis* and *M. agrestis* were present. Otherwise, these open-habitat species (Niethammer & Krapp 1982, Dienske 1979) were almost absent from forest habitat type. Since *M. arvalis* dispersion is connected to human activities (Kryštufek 1987, Myllymäki 1977), higher population numbers in Medvedjak meadows could be explained by anthropogenic impact (wood industry) within the area in the past. The number of trapped animals switched between two species through years (2002-2005); as the number of *M. agrestis* decreased, the number of *M. arvalis* increased, probably due to the impacts of our trapping on species

assemblage and competition between the two species. As we sampled eight different small mammal species during our four-year trapping in Medvedjak meadows, Vrček (2002) found only *M. agrestis* while trapping at the same site in 2000.

In 2008, higher numbers of *M. glareolus* were trapped at two forest sites, probably due to the high production of beechnut persisting throughout the winter. In mild winters (with no or little snow cover) with enough food resources, spring-born young mature early and breed in the year of their birth, giving another (additional) cohort of young (Gliwicz & Jancewicz 2004, Borkowska & Ratkiewitcz 2004). Similar variations in *M. glareolus* population sizes are known from mount Snežnik in southwestern Slovenia in the 1988–1990 period (Trilar 1991) and other parts of Europe (Ylönen 1988, Zub et al. 2012). Although our data are not directly comparable (since trappings differed among each other in numbers of traps used, trapping days and locations), two independent forest locations with high number of *M. arvalis* trapped in only two days in 2008 strongly suggest that population numbers were high in 2008. Comparing rodents and insectivores, the latter had higher densities only in Sovja stena (2006, 2009a, b).

Most of the trapped individuals (on the species level) were males, except for the most abundant open-habitat species - *M. arvalis* and *M. agrestis* - where females prevailed. Any conclusion concerning population sex structure would be excessive, since localities differ from year to year and trapping methods were inconsistent. Daily activity of small mammals shows that they are mostly nocturnal, but some species show patterns of daily activity. The results show that 18.6% of all *M. arvalis* and 38.5% of all *M. agrestis* were caught during daytime, which could be explained by two-hour activity cycles in day activity pattern in these animals (Daan & Slopseema 1978). High percentage of shrews trapped during the day was expected, since they have high metabolic rate and high activity pattern (Kryštufek 1991). Values of body measurements are in the range of values reported by other authors working in the region and Slovenia (Remžgar 1990, Vrček 2002, Kryštufek 1991), except for several individuals that were either young animals or injured due to trapping.

Besides species that were present through trapping years (depending on trapping site), some rarities were recorded: Liechtenstein's pine vole *Microtus lichtensteini*, forest dormouse *Dryomys nitedula,* hazel dormouse *Muscardinus avellanarius* and common dormouse *Glis glis.* Low number of dormice, only 2.2% of total animals caught, is not surprising since all three members of the family are primarily arboreal species. In Snežnik, less than 10% of all dormice were caught with ground traps (Skok 2011). Additional reason for low number of *G. glis* caught through years is improper (too light) construction of traps used during our research.

In the vicinity of Kočevje (Remžgar 1990), small mammals were snap-trapped on three different locations. Thirteen different species were trapped, three of them absent in our study; bicoloured shrew *Crocidura leucodon,* lesser white-toothed shrew *Crocidura suaveolens* and Miller's water shrew *Neomys anomalus.* We trapped two species that were not present in Remžgar's study (1990): *D. nitedula* and *M. avellanarius.* Although studies were conducted in neighbouring areas, differences between trapped species are expected, since the sampled habitats were different. While Remžgar (1990) laid traps at lower elevations, mostly under 500 m a.s.l. along streams, in forest and in agricultural fields, our study took place in forests and meadows at higher elevations (above 700 m a.s.l.) lacking streams and agricultural fields. In Slovenia, *D. nitedula* is known only from elevations higher than 490 m a.s.l. (Kryštufek 1987, Kryštufek & Vohralik 1994). Beside the habitat differences, *D. nitedula* is an element of

alpine small mammal communities (Trilar 1991), so climate could be an additional reason for their absence at lower altitudes in the vicinity of Kočevje.

Like small mammal communities of Snežnik mountain (Trilar 1991) and the vicinity of Kočevje (Vrček 2002), Goteniška gora small mammal communities also resemble central European deciduous and mixed forest fauna according to Petrov (1985). Apart from central European elements, some other faunal elements are also present in small mammal community of Goteniška gora mountain: alpine shrew *Sorex alpinus*, European snow vole *Chionomys nivalis* and *D. nitedula* as representatives of the alpine communities and *M. liechensteini* as a Pleistocene relict. The above mentioned *C. nivalis* is a rare species for Goteniška gora, caught only twice in Sovja stena before our research begun; one individual was caught on 23. 9. 1998 and one on 26. 9. 1998 (F. Kljun, pers. information).

The estimated number of total species, based on yearly trapped sample, shows that we can expect up to 13 different small mammal species in the sampled areas. Estimated number of species shows that discovery of new species would be a rare event; generally, the surveyed area can be considered well sampled. Curves of species accumulation show a trend similar to the estimation of total number of species. All three habitats (open area habitat, forest habitat and overall sampled sites) share the same trend, approaching the asymptote, which means that most of the species present in the sampling area were trapped. We have to point out that our species number estimates and accumulation curves were sample-based, but Goteniška gora is also inhabited by red squirrel *Sciurus vulgaris,* European mole *Talpa europaea,* and hedgehog *Erinaceus concolor*, which are usually not caught in the kind of traps we used. Additionally, species preferring different habitat types, e.g. anthropophilic species like *Ratus* sp. and *Mus* sp. or lowland species from Remžgar's list (1990), may have been missed.

Unfortunately, owing to the inconsistent sampling methodology and lack of notes about reproductive status, we are unable to make any prediction about population numbers, dynamics, biomasses, reproductive status or age of individuals. The systematic recording of those data should be established in the future, enabling additional analyses and understanding of dynamics of small mammal communities in the region.

Povzetek

Čeprav se je v zadnjih 30 letih poznavanje malih sesalcev v Sloveniji zelo izboljšalo, je o skupini še vedno znanega razmeroma malo. V prispevku smo analizirali rezultate devetletnega vzorčenja malih sesalcev na območju Goteniške gore v južni Sloveniji in podajamo nekaj informacij o razširjenosti in zgradbi združb malih sesalcev na tem območju. Geološko podlago raziskovanega območja sestavljajo večinoma kredski in jurski apnenci ter dolomiti in dolomitski apnenci, pomešani s triasnimi dolomiti. Taka podlaga je primerna za goste dinarsko jelovo-bukove gozdove, ki pokrivajo večino območja. Vzorčili smo vsak september v letih od 2002 do 2010 na sedmih različnih lokacijah Goteniške gore. Vzorčenja so se razlikovala v trajanju (od 2 do 6 dni) in številu uporabljenih pasti (od 45 do 128). Živali smo lovili z mrtvolovkami, ki smo jih nastavljali na določene gozdne ali travniške površine, kjer so bile vidne sledi aktivnosti malih sesalcev (luknje, steze, ...). Ujete živali smo premerili, stehtali ter določili spol, nato pa jih razkožili in kože ter preostanke teles shranili v 96 % etanolu. V 9 letih smo ujeli 12 različnih vrst malih sesalcev, večinoma značilnih za srednjeevropske listopadne in mešane gozdove. Poleg teh smo ujeli tudi

vrste, značilne za alpinske predele ter pleistocenske relikte teh predelov. Izračunali smo glavne značilnosti telesnih dimenzij za ujete vrste; dolžine trupa, repa, stopala, ušesa in telesno maso. Ugotovili smo razlike v vrstni sestavi med gozdnimi in odprtimi, travniškimi habitati. Največji delež ujetih živali je pripadal gozdni voluharici *M. glareolus* (27 %), za njo pa gozdni rovki *S. araneus* (17,9 %) in rumenogrli/navadni belonogi miši *A. flavicollis/sylvaticus* (13,5 %). Izračunali smo oceno pričakovanega števila vrst malih sesalcev na preučevanem območju. Pričakujemo lahko približno 13 vrst, kar nam pove, da je možnost najdbe novih vrst na vzorčenem območju redek dogodek ter da so vzorčna mesta že dobro povzorčena.

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