IMPACT OF SHEEP GRAZING ON SMALL MAMMALS DIVERSITY IN LOWER MOUNTAIN CONIFEROUS FOREST GLADES

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Abstract. Sheep grazing has once been a traditional mode of exploitation of forest as well as alpine zones in the majority of European montane regions. Nowadays, in Tatra Mts, sheep grazing is limited to a number of glades of anthropogenic origin, primarily as a method of protection against overgrowing with trees. Results of the present study demonstrate that sheep grazing causes a decrease in species diversity of small mammals Micromammalia in forest zone glades. The values of biodiversity indicators in sheep-grazed glades are lower than those in the non-managed or mown ones. On sheep-grazed glades, a lower biodiversity of Soricomorpha and a domination of common vole *Microtus arvalis* have been found.
Keywords: *glades management, sheep grazing, micromammals biodiversity, Tatra Mountains*

Introduction

There has always been a controversy over agricultural use of areas located within high nature value lands. Generally, there is a trend to exclude or reduce agricultural activities in protected ecosystems for the purpose of eliminating anthropogenic factors that may distort natural relationships. Cultivation practices in arable grounds, mowing of meadows, and animal grazing always affect the utilized land. Alterations in flora and fauna composition are the most significant effects.

Large herbivorous mammals have a great meaning when it comes to shaping the grassland ecosystems (Hobbs, 1996; Frank, 1998; Frank et al., 2002; Moore et al., 2015). In many regions of Europe, the presence of grazing animals is considered as a method of natural forest succession control, e.g., in high nature value heathland (Newton et al., 2009). Grazing is often considered to be a factor which contributes to vegetation stability. Moreover, it is regarded as a conservation method to protect a unique ecosystem, especially in regions, e.g., the Pyrenees, where animal grazing is a long-time tradition (Casasús et al., 2007; Sebastiá et al., 2008).

It is generally believed that the presence of farm animals, such as sheep or cattle, significantly affects the vegetation. Austrheim and Eriksson (2001) consider grazing as a key process stimulating biodiversity in alpine and subalpine ecosystems in Scandinavia. However, there are differences in vegetation between areas of different grazing intensity (Austrheim et al., 2014). Intensive grazing causes negative changes in the flora of alpine ecosystems (Austrheim et al., 2008; Mysterud, 2008; Lanta et al., 2014). Sheeps demonstrate large diet selectivity preferring herbs over grasslands which are eaten afterwards. Thus they significantly change the flora increasing the share of

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grasslands in the species groups (Bowns and Bagley, 1986; Hülber et al., 2005). Pasture and cutting also influences the structure of the flora. Low density of sheep has no effect on vegetation (Kausrud et al., 2006; Mayer and Huovinen, 2007; Austrheim et al., 2008) but it can affect vegetation when long-term (Mayer et al., 2009).

Changes in vegetation caused by grazing farm animals in natural environment affect wild animals that inhabit these areas. It is especially noticeable in lowland areas. Studies on small mammals population structure show unequivocally that the effect is negative (Schmidt et al., 2005; Torre et al., 2007). Nevertheless, grazed areas are important as feeding grounds for birds (Wheeler, 2008).

In montane ecosystems, studies on the effect of grazing on wild montane animals are relatively rare. In Britain, no effect of sheep grazing on insects was found (Mysterud et al., 2005). However, in central Argentina mountains, negative consequences of grazing was reported in subalpine meadows. Intensive cattle grazing causes a decrease in insect biomass and species diversity (Cagnolo et al., 2002). Extensive use of semi-natural montane meadows causes an increase in species diversity of birds (Rolando et al., 2006). An increase in grazing intensity can hinder that process (Loe, 2007). Negative effect of grazing on the populations of rodents was reported from subalpine zone in Norway (Steen et al., 2005; Austrheim et al., 2007).

The origins of grassland ecosystems in the mountain areas are usually difficult to determine unequivocally. In some cases they were created as a result of uniqe climate conditions and are maintained thanks to large herbivorous animals (Weigl and Knowls, 2014). Tatra glades are the artifacts of human activities in the forest areas. They are located among and surrounded by subalpine forests. The grounds within Tatra Mts have been utilized for pasturage for hundreds of years. The first remarks on the glades appear in written documents as early as in XVIth century. For agricultural purposes, forest areas on mountain slopes were slashed-and-burned. 120 glades were created in that way (Hołub-Pacewiczowa, 1931).

In Polish Tatras, the intensive sheep grazing was continued up to the ‘80 of the 20th century. Sheep grazing was primarily taking place in mountaine forests and on alpine meadows, the areas situated above the upper range of the forest. The pressure of the shepherding on the natural ecosystems resulted in the changes in the natural reach of plant communities in many places, e.g. in the lowering of the upper range of the forest (Skawiński, 1993). Currently, sheep grazing in Polish Tatras is mainly of extensive character and takes place only on selected glades. Sheep grazing above the upper range of the forest is no longer cultivated (Kaźmierczakowa, 1990). The changes in the structure of grazing are connected with restrictions introduced by the Tatra National Park. Tatra glades, once used agriculturally, are now maintained only by a continuous human intervention. Otherwise they would be overgrown by forests in the process of natural succession. The utilization of Tatra glades has resulted in the evolution of endemic meadow association *Gladiolo-Agrostietum* as well as crocuses *Crocus scepusiensis* – on the areas with high intensity of sheep grazing (Kaźmierczakowa, 1990; Piękoś-Mirkowa and Mirek, 1996). The agricultural activities which aim at the maintenance of plant community include mowing and sheep grazing.

There is no information on the effect of various agricultural practices on small mammals populations in montane mid-forest glades. The aim of the study was to evaluate the effect of montane mid-forest glades utilization practices on small mammals communities and assess transformations in glades that were excluded from pasturage.

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Material and methods

Study area

The studies were carried out in mid-forest glades located within Tatra Mts. The range of Tatra Mts is the highest massif within the Carpathians. Tatra are distinctly separated from the surrounding area although the length of the range is only 57 km and its width – 18 km. The height above sea level ranges from 900 m at the foothills up to 2499 m at the top of Rysy that is the highest summit in the Polish part of Tatra. The landscape of Tatra is of alpine type with altitudinal zonation: low mountain zone forests (to 1200 – 1250 m a.s.l.), high mountain zone forests (to 1500 m a.s.l.), subalpine zone (to 1800 m a.s.l.), alpine grasslands (to 2300 m a.s.l.), subnivean zone (from 2300 m a.s.l. up). Polish and Slovak parts of Tatra are protected as national parks and as a Biosphere Reserve of UNESCO.

The study areas were located in mid-forest glades within lower mountain zone forests. The glades were surrounded by silver fir-spruce forest and differed in the utilization mode. Three categories of glades were distinguished: (I) non-managed glades: Brzanówka (B), Dudowa (D), Gronik (G), Wyżnia Rówień Miętusia (WRM), Przysłup Miętusi (PM); (II) glades mowed annually: Huciska Niżne (HN) and Palenica Pańszczykowa (PP); (III): grazed glades: Biały Potok (BP), Huciska Wyżnie (HW), Molkówka (M), Siwa Polana (SP). All glades were situated at elevations ranging from 920 to 1174 m a.s.l. Animal traps were located in the centre of each glade to avoid ecotone effects.

The vegetation of the glades consists of semi-natural meadows (*Tab. 1*). The most common type of vegetation is mesotrophic grassland represented by *Gladiolo-Agrostietum* (association of *Gladiolus imbricatus* and *Agrostis capillaris*). There are also patches of flora belonging to the association of *Hieracio-Nardetum, Festucetum rubrae* as well as *Festuco-Cynosuretum.* Associations of *Cirsietum rivularis, Festuco-Cynosuretum*, and *Rubetum idaei,* as well as ruderal species, patches covered with *Rubus* spp. and scraps with *Deschampsia caespitosa* occur on the non-managed glades. Grazed glades feature associations of *Deschampsietum caespitosae, Festuco-Cynosuretum* as well as degraded association of *Gladiolo-Agrostietum.* Sheep-grazed glades are characterized by the predominance of *Deschampsia caespitosa* as well as ruderal flora with dominance of *Artemisia vulgaris*. *Crocus scepusiensis* occurs with various incidence on the grazed glades.

The plant cover of glades was categorized into four types, depending on vegetation density:

1. strongly grazed vegetation with *Deschampsia caespitosa*; vegetation cover very scarce (M)
2. semi-grazed vegetation with *Deschampsia caespitosa* and *Cirsium rivulare*; vegetation cover relatively scarce (SP, HW, BP),
3. *Deschampsia caespitosa* – dominated meadow with abundance of herbaceous plants; vegetation cover relatively dense (B, PP, HN, G, PM)
4. meadow with *Rubus* spp. and *Aconitum firmum*; vegetation cover very dense (D, WRM).

Sheep grazing occurred from the beginning of May until the end of October. The glades were grazed by herding sheep from one glade to another. The glades Molkówka, Siwa Polana, and Biały Potok were grazed by one flock (300 sheep in 2004, 220 sheep

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in 2005) and Huciska Wyżnie by another flock (190 sheep in 2004 and 170 sheep in 2005). While herded, sheep grazed along central part of the glade. Additionally, in Siwa Polana, some cattle were kept during the vegetation season (7 cattle in 2004 and 8 cattle in 2005).

Table 1. *Forms of exploitation, geographical location and botanic characteristic of the investigated Tatra glades*

Forms of exploitation of a glade	Glade	Geographical location	Area ha	Altitude asl.	Type of flora
Non-managed	B	N 49°17′22″ E 20°05′21″	4	932	wet tall-forb grassland
	D	N 49°14′58″ E 19°49′37″	3	1174	secondary forb communities
	G	N 49°16′28″ E 19°53′39″	3	972	grassland
	WRM	N 49°15′08″ E 19°53′43″	5	1142	wet tall-forb grassland
	PM	N 49°15′47″ E 19°53′22″	9	1147	secondary forb communities
Mown	PP	N 49°17′22″ E 20°05′21″	4	925	grassland with *Deschampsia caespitosa*
	HN	N 49°17′22″ E 20°05′21″	4	985	grassland
Grazed	M	N 49°16′44″ E 19°49′39″	18	991	intensely eaten grass with *Deschampsia caespitosa*
	SP	N 49°16′40″ E 19°50′16″	53	936	poorly eaten grass with *Deschampsia caespitosa*
	HW	N 49°17′22″ E 20°05′21″	2,5	1026	poorly eaten grass with *Deschampsia caespitosa* and *Cirsium rivulare*
	BP	N 49°16′42″ E 19°50′55″	30	920	poorly eaten grass with *Deschampsia caespitosa* and *Cirsium rivulare*

Methods

Trapping of mammals was carried out at the turn of July and August of 2004 and 2005. The research was conducted in all glades in the same time period in 2004 and repeated in 2005. Micromammalia were caught using 45 cm high cone traps. 20 traps were placed in each study area (10 traps in 2 rows). The distance between traps and rows was 10 m. All traps were located in the central part of a glade. CMR (capture/mark/recapture) method was applied (Gurnell and Flowerdew, 1994). Trapped animals were marked by cutting a small fragment of fur on their dorsal side. Trapping was conducted during 5 consecutive nights (2200 trapnights). Traps were emptied four times per day (6.00 a.m., 8.00 a.m., 5.00 p.m., and 8.00 p.m.). If it was raining, the traps were visited more frequently or the traps were blocked.

The structure of mammal communities in Tatra glades was characterized using several parameters that depict species diversity: dominance coefficient D and Shannon-Wiener diversity index *H'* (log base 2).

The numbers of caught mammals in 2004 and 2005 were compared using Pearson's χ^2 test. The differences in abundance of individual species were also analysed. The effect of sheep herding on small mammals communities was determined using Pearson's

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χ^2 test with Yates' continuity correction. Chi-squared test was applied to establish the relationship between the number of small mammals and the year of study.

The areas of study were of the same size. It has been assumed that population density is the number of mammals per one study area. It has been assumed that the average density of mammals on a trapping area matches the number of trapped individuals on a 1 ha area.

Multivariate analysis of variance (MANOVA) was carried out to determine which factor (year of study, mode of utilization, density of vegetation cover, sheep herding) has the most significant effect on population density. In all analyses, the significance level was set to 0.05.

Results

The study on the small mammals populations show that there are differences in species composition and population number between the glades that differed in the mode of use. The richest in species were non-managed glades (13 species of small mammals). In mown glades, there were 11 species and in grazed glades – 7 species (*Tab. 2, Fig. 1*).

Table 2. *The effect of the exploitation of the Tatra glades on the species diversity of small mammals (Micromammalia)*

Parameter	Non-managed glades				Mown glades		Grazed glades				
	G	WRM	PM	D	B	PP	HN	M	SP	HW	BP
Number of species	7	7	7	7	7	9	6	2	6	3	4
Number of individuals	32	89	68	71	30	41	19	5	69	10	20
Proportion of shrews %	37.5	33.7	23.5	36.6	23.3	36.6	36.8	-	5.8	20	10
Proportion of rodents %	62.5	66.3	76.5	63.4	76.7	63.4	63.2	100	94.2	80	90
Trapping success (per 100 trap-nights)	1.6	4.45	3.4	3.55	1.5	2.05	0.95	0.25	3.45	0.5	1.0
Shannon-Wiener index *H'*	2.02	2.12	2.24	2.08	2.53	2.77	2.18	0.72	0.77	1.16	1.32

The highest number of small mammals occurred in non-managed glades (on average, 58 individuals/glade). The mean number of individuals in mown glades was 30, and in the grazed glades – 26. The relatively high mean number of mammals in grazed glades was associated with the high number of common vole *Microtus arvalis* that occurred in extensively used Siwa Polana. Significant differences in the number of mammals caught in different years occurred in mown glades (HN, PP), non-managed glades (G, PM, WRM), and grazed glades (SP). Significant decrease in the number of caught mammals occurred in 2005 in comparison to 2004 ($\chi^2 = 12.72$, df = 1, $p = 0.0003$) (*Tab. 3*).

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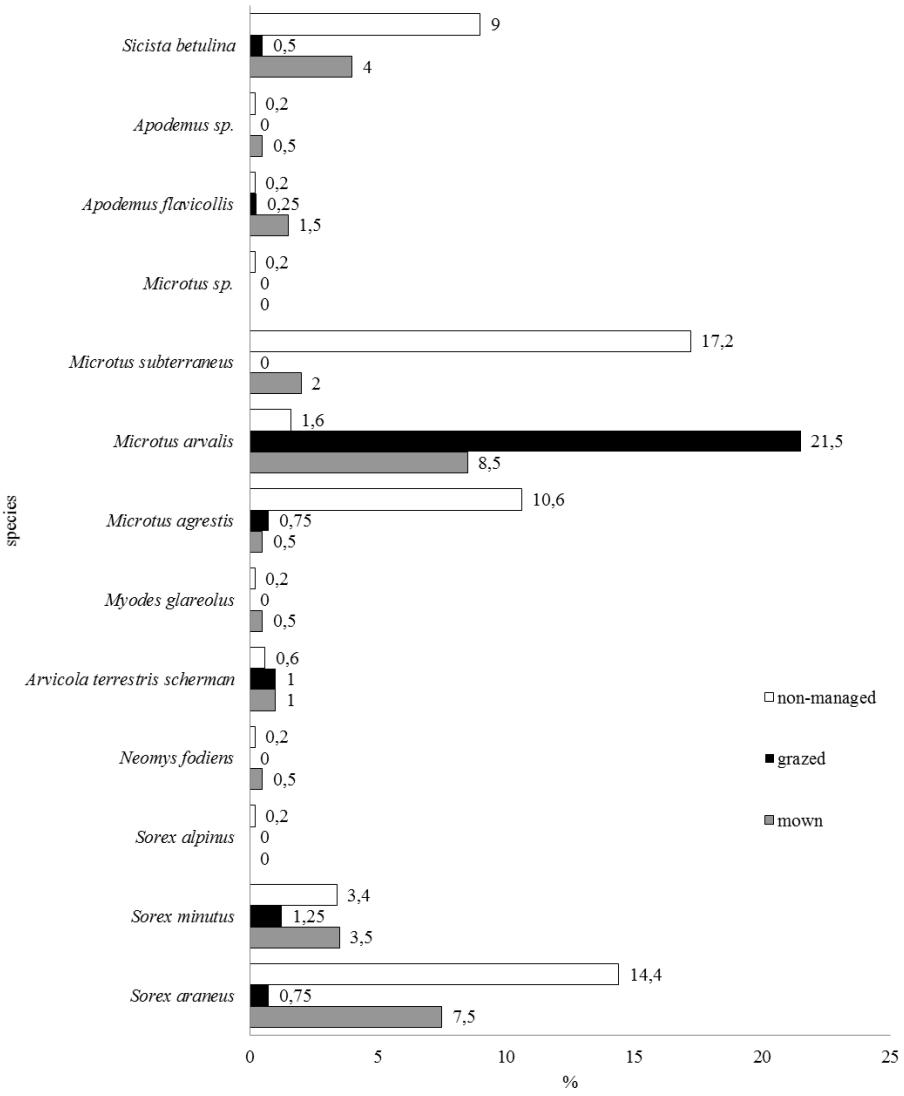

Figure 1. *Structure of small mammals communities on non-managed, mown and grazed Tatra glades in 2004-05*

Table 3. *Differences in the number of caught mammals (Micromammalia) on the Tatra glades in the years 2004 and 2005 (Pearson's χ^2 test)*

Forms of exploitation of a glade	Glade	Number of individuals N		*p*
		2004	2005	
Mown	HN	15	4	0.0116
	PP	27	14	0.0423
Non-managed	B	20	10	0.0679
	D	29	42	0.1229
	G	25	7	0.0015
	PM	48	20	0.0007
	WRM	62	27	0.0002
Grazed	BP	9	11	0.6547
	HW	8	2	0.0578
	M	4	1	0.1797
	SP	18	51	0.0001

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Within all small mammals that were caught in all types of glades, rodents Rodentia were the predominating group. Their number in non-managed and mown glades was comparable: 62-77% of all small mammals. In grazed glades, the number of rodents was very high and reached 80-100% of all small mammals, depending on a glade. In grazed glades, Soricomorpha were scarce: the maximum number of individuals of that group amounted to 20% of all small mammals and one species – common vole (70%) – clearly predominated (*Tab. 2*). The highest density of common vole occurred in grazed glades with a relatively low density of sheep (ca. 5-9 sheep/ha). The density of common vole is distinctly lower in glades where more sheep 15-28 sheep/ha) are grazing. This result shows that grazed glades are the worst environment for Soricomorpha. In other types of glades, no clear predominance of any of species occurred. In non-managed and mown glades, a high number of other vole species was found: field vole *Microtus agrestis*, common pine vole *Microtus subterraneus*, and of other rodents – birch mice *Sicista betulina*. In non-managed glades, common shrew *Sorex araneus* and pygmy shrew *Sorex minutus* were co-dominating (*Fig. 2*). The number of individuals of several species differed in different years of study and the difference was significant (*Tab. 4*). Differences in the value of Shannon-Wiener Index on a grazed glades, cut glades and non-managed glades were statistically significant (χ^2 = 10.2657, df = 2, p = 0.0059). The post-hoc test revealed that the differences occurred between grazed and non-managed glades (non-managed vs. mown p = 0.343; grazed vs. mown p = 0.162, grazed vs. non-managed p = 0.007).

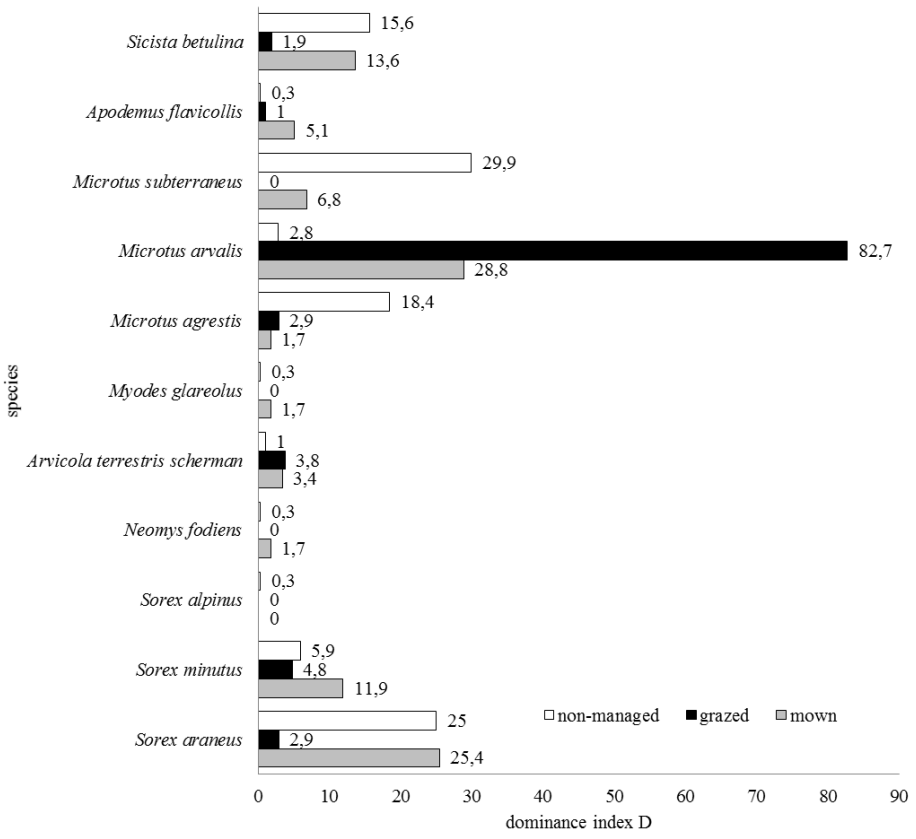

Figure 2. *The values of the dominance index (D) on non managed, mown and grazed Tatra glades in 2004-05*

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Table 4. *Differences in the total number of caught mammal species (Micromammalia) on the Tatra glades in the years 2004 and 2005 (Pearson's χ^2 test)*

Species	Number of individuals N		*p*
	2004	**2005**	
Sorex araneus	68	22	0.0000
Sorex minutus	22	7	0.0053
Sorex alpinus	1	0	-
Neomys fodiens	1	1	1.0000
Arvicola terrestris scherman	8	1	0.0196
Myodes glareolus	0	2	-
Microtus agrestis	45	12	0.0000
Microtus arvalis	31	80	0.0000
Microtus subterraneus	56	34	0.0204
Microtus sp.	0	1	-
Apodemus flavicollis	5	0	-
Apodemus sp.	2	0	-
Sicista betulina	26	29	0.6858

The mode of exploitation of mid-forest glades affects the species diversity as well as the number of individuals. The most important factor is the grazing of sheep and the differences observed were mainly due to the intensity of grazing. Of the grazed glades, the lowest biodiversity occurred in the glades at Molkówka (intensive grazing: 17 sheep/ha in 2004 and 12 sheep/ha in 2005) and the highest in Siwa Polana (species spectrum comparable to non-managed glades; extensive grazing: 6 sheep/ha in 2004 and 4 sheep/ha in 2005). The limited grazing in Siwa Polana allowed higher number of species and higher number of individuals than in other grazed glades (*Tab. 2*).

The MANOVA showed that the density of vegetation and type of exploitation in glades have significant impact on the density of small mammals (p = 0.002 and p = 0.004, respectively). The remaining factors analyzed, year of study and herding of sheep did not affect the density of mammals (p = 0.7455 and p = 0.6688, respectively).

Discussion

Presence of large herbivorous mammals strongly impacts local populations of small mammals causing the increase of one species' population and decrease of other species' population (Keesing, 1998). Negative influence is demonstrated by the decrease of shelters' accessibility, reduction of nutritional base abundance and greater risk of predator's attack (Flowerdew, 2001). Diversity and number of small mammals that are particularly tied to grassland ecosystems is greater on the areas protected from livestock (Pedo et al., 2010).

In Polish Tatra, sheep grazing is of extensive character and occurs only in selected glades within forest zone. The exploitation of the forest zone glades affects the small mammals population structure, depending on the mode of use. Environmental preferences of small mammals are diversified depending on the species. Glades' use is favourable for some species while for others it may be negative (*Tab. 5*). The most important result associated with sheep grazing is the appearance of common vole. In grazed glades, this species predominates. However, it prefers meadows that are exploited extensively, that is where the density of sheep is low. Common vole is a

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species characteristic of agricultural land. It is likely that in Tatra, it follows the herded sheep because it does not occur in other than the glades, habitats. In Slovak parts of Tatra, the common vole was found only in the areas where sheep grazed (Kratochvíl and Pelikán, 1955; Rosický and Kratochvíl, 1955). In the 1950s, after the national park had been erected, the sheep grazing was abandoned. Twenty years later, no common voles were found in the areas where sheep grazing occurred and where common vole occurred (Zima et al., 1984). Single individuals of that species occurred only in deforested and partly urbanized areas at low altitudes (Štollmann and Dudich, 1985). At the same time, a high proportion (87-100%) of common vole in small mammals populations was reported from the neighbouring mountain range Gorce, where intensive sheep grazing occurred (Białas et al., 1989).

Table 5. *Habitat preferences of mammal species (Micromammalia) found on the Tatra glades in the years 2004-2005*

Species	Preferred habitats	
Sorex araneus	cool habitats with dense vegetation cover	Anděra, 1999
Sorex minutus	damp areas with dense vegetation including swamps, grasslands, heaths, sand dunes, woodland edge, rocky areas, scrubland, and montane forests	Hutterer, 1999
Sorex alpinus	cool and humid environment, densely vegetated	Spitzenberger, 1999
Neomys fodiens	wetland habitats, damp grasslands, humid woodlands	Spitzenberger, 1999
Arvicola terrestris scherman	dry or mesic grasslands, meadows pastures and occasionally in wooded areas	Saucy, 1999
Myodes glareolus	all kinds of woodlands	Spitzenberger, 1999
Microtus agrestis	moist habitats with rich grass cover, woodlands, marshes, wet meadows	Zima, 1999
Microtus arvalis	open cultivated agricultural land, grazed pastures, meadows	Zima, 1999
Microtus subterraneus	a variety of meadows habitats and pastures	Kryštufek, 1999
Apodemus flavicollis	a variety of woodland habitats, open scrublands and secondary habitats	Juškaitis, 2002
Sicista betulina	a variety of habitats including boreal and montane forests, subalpine meadows, wet meadow habitats	Pucek, 1999

In the grazed areas, the number of field vole decreases. This phenomenon was described by Steen et al. (2005) who found a negative correlation between an increase of grazing sheep and field vole population number. In the present study, the frequency of common vole in traps decreased drastically in mown and extensively grazed glades. Sheep grazing causes a decrease in the availability of food for the rodents, which may affect their population number (Austrheim et al., 2007).

Moser and Witmer (2000) showed that in the montane meadows, cattle grazing and red deer *Cervus elaphus* grazing caused a decrease in species diversity and number of small mammals and an elimination of shrews. Similar results were found in the present study. The sheep grazing caused a decrease in the number of caught shrews. It is interesting though, that mowing does not affect shrews.

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In grazed glades, the decrease in number of birch mouse, field vole, common pine vole, and common shrew coincides with the increase of number of common vole. The change in species composition and species domination structure (prevalence of common vole) does not affect the overall number of small mammals in grazed glades, which was confirmed using MANOVA.

The distinctive character of sheep grazing is that the animals do not exploit the whole glade at one time. Therefore, the species spectrum and population number may be different in different parts of a glade. At the same time, species diversity of small mammals in montane deforested areas may be affected by the size of a glade. In small glades, the diversity indices are close to those of the surrounding forests (Bryja et al., 2002). In the present study, biodiversity indices of non-managed or mown glades were higher than the indices calculated for the forests in lower as well as upper mountain forest zones by Juchiewicz et al. (1986).

The high numbers of birch mouse in non-managed and mown glades is associated with the occurrence of plants that grow high that are preferred by this species. Changes in exploitation mode of glades affect the stability of these plant populations. Birch mouse is less frequent in grazed glades where the vegetation structure is changed due to grazing. Individual glades are isolated from each other by compact forest areas. Therefore, grass mowing causes a complete destruction of the birch mouse habitat. Birch mouse may occur in montane forests (Bobretsov et al., 2005), but spruce forests that surrounded Tatra glades studied do not have grass undergrowth, so they are not a good habitat for this species.

In the montane-zone glades studied, a distinct negative effect of grazing on biodiversity of small mammals occurred. Sheep grazing in relatively small glades changes habitat conditions profoundly. It is grazing as well as trotting that have an influence. The changes include also a shift in domination structure: one species (common vole) becomes a dominant one. The influence is particularly negative in the cases of common pine vole, field vole, birch mouse, and shrews. Even the extensive grazing may change vegetation structure in a negative way for mammals that occur there. The abundance of common vole may also be connected with the presence of sheep (Kratochvíl and Pelikán, 1955; Rosický and Kratochvíl, 1955). The occurrence of that species in the areas distant from agricultural lands is not likely.

Mowing or the abandonment of exploitation has a positive impact on the biodiversity of montane-forest zone glades. Nevertheless, the lack of human activity and natural succession will promote the appearance of typical forest fauna.

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