

THE IMPACT OF THE LESSER BLIND MOLE RAT [*NANNOSPALAX* (SUPERSPECIES *LEUCODON*)] ON THE SPECIES COMPOSITION AND DIVERSITY OF A LOESS STEPPE IN HUNGARY

ZITA ZIMMERMANN^{1*} - GÁBOR SZABÓ¹ - ANDRÁS ISTVÁN CSATHÓ² - JUDIT SALLAINÉ
KAPOCSI³ - SZILÁRD SZENTES² - MELINDA JUHÁSZ¹ - JUDIT HÁZI¹ - CECÍLIA KOMOLY¹ - KLÁRA
VIRÁGH¹ - HARKÁNYINÉ SZÉKELY ZSUZSANNA² - LAMPERT RITA¹ - ZSUZSANNA SUTYINSZKI² -
SÁNDOR BARTHA¹

¹*Institute of Ecology and Botany, MTA Centre for Ecological Research, H-2163 Vácrátót,
Alkotmány Str. 2-4., Hungary
(phone: +36-30-360-122; fax: + 36-28-360-110)*

²*Szent István University, Institute of Botany and Plant Ecophysiology, H-2100 Gödöllő, Páter
K. Str. 1., Hungary
(phone: + 36-28-522-000; + 36-28-410-804)*

³*Körös-Maros National Park Directorate, H-5540 Szarvas, Anna-liget 1., Hungary
(phone: + 36-66-313-855; fax: +36-66-311-658)*

**Corresponding author
e-mail: zimmermann.zita@okologia.mta.hu*

(Received 22nd Apr 2014 ; accepted 22nd July 2014)

Abstract. Our aim was to investigate the species richness and diversity of a loess grassland influenced by the digging of the lesser blind mole rat [*Nannospalax* (superspecies *leucodon*)] and to study the effect of this disturbance to diversity. The study was conducted in the Külső-gulya loess grassland (Körös-Maros National Park), which is unique in Hungary due to its excellent soil quality and the large spatial extent of natural loess meadow steppe.

We recorded the cover of species in 50x50 cm plots. Altogether 12 plots were sampled on mounds of mole rat and 12 plots as a control in the area with no mounds. Differences in species richness, Shannon-diversity, evenness and total cover between disturbed and control plots were tested by One-Way ANOVA. There were no significant difference neither in the number of species, nor in the Shannon-diversity and evenness. There were differences in the species composition detected by PCO ordination. We can conclude that the presence and disturbance of the mole rat influence the composition of the grassland significantly but it does not cause a difference in the species richness, diversity and total cover. Our results suggest that this grassland has adapted to these natural disturbances.

Keywords: *loess grassland, diversity, disturbance, subterranean rodents, Nannospalax (superspecies leucodon)*

Introduction

Grasslands in Europe are among the most diverse ecosystems (Habel et al., 2013). Dry grasslands can be emphasized within this group (Janišová et al., 2011) because of their high importance in biodiversity conservation in Hungary (Kun, 1998; Valkó et al., 2013a). Grasslands evolved with herbivores, burrowing animals and experienced recurrent fire and adapted to natural disturbances by various life forms and plant behavioural types (Knapp et al., 1998; Strauss and Agrawal, 1999; Gibson, 2009; Valkó et al., 2013b). Several studies concluded that high diversity of grasslands is positively related to the complexity of the disturbance regime (e.g. Collins and Barber, 1986;

Collins, 1987; Belsky, 1992; Noy-Meir, 1995; Savadogo et al., 2008). The most diverse semi-natural grasslands have been found in Europe in traditionally landscapes with complex and patchy pattern of grazing, mowing and burning (Bartha, 2007; Wilson et al., 2012).

To maintain the high diversity of dry grasslands, in particular loess steppes, it is essential to ensure proper management mainly by grazing and mowing (Illyés and Bölöni, 2007; Kiss et al., 2011). Grazing and other natural disturbances help for sustaining high diversity (Olff and Ritchie, 1998; Hickman et al., 2004). Several studies reported degradative vegetation changes in the absence of such natural disturbances (Virágh and Bartha, 1996; Somodi et al., 2004; Enyedi et al., 2008). Recently Hungarian grasslands are strongly affected by the abandonment of traditional grazing management due to the decreasing number of sheep and cattle since the 1960s (KSH, 2012).

The strictly protected Külső-gulya loess grassland (also known as Kis-gulya, Tompapusztai-lőszgyep) is one of the largest ancient loess grasslands remained in Hungary. Its unique nature conservation value has been reported by several botanical and zoological studies (Csathó, 1985, 1986, 2005; Csathó and Csathó, 2007, 2009; Csathó and Jakab, 2012; Herczeg et al., 2011; Kertész, 1996; Molnár, 1997; Molnár et al., 2007). The area is covered by loess steppe grassland community (*Salvia nemorosae-Festucetum rupicolae* Zólyomi ex Soó 1964) characterised by high species diversity and structural richness (Bartha et al., 2011a). The published flora list (Csathó and Csathó, 2009) contains 272 vascular plant species. Based on former studies in dry grasslands we assumed that the extraordinary diversity developed at Külső-gulya loess steppe is a consequence of the complex land-use history of this site (McNaughton, 1985; Collins, 1986; Knapp et al., 1998; Bartha, 2007). It was revealed that the site was managed by low intensity cattle grazing and regular mowing (Bartha et al., 2011b; Bartha et al., 2012). Nowadays only the regular mowing once a year has been continued. However it was revealed that this management not enough to maintain high diversity.

The presence of the lesser blind mole rat (mole rat hereafter) and its mounds are characteristic to the area (Németh et al., 2009). Both its mowing activity and mounds might contribute to preserve diversity and patch dynamics in loess grasslands. Mole rats are considered as serious pests for agriculture in the Mediterranean region due to their foraging of underground organs of vegetables (Moran, 1998). However, no information about the magnitude of such damage has been reported for the natural vegetation.

Ecosystem engineers are organisms which modify, maintain or create habitats for other species (Jones et al., 1994). Subterranean rodents like mole rats also belong to this group (Huntly and Inouye, 1988; Reichman and Seabloom, 2002; Zhang et al., 2003; Hagenah and Bennett, 2013). These species can modify vegetation composition (Ellison and Aldous, 1952; Foster and Stubbendieck, 1980; Reichman and Smith, 1985; Huntly and Reichman, 1994; Nosal et al., 2010; Case et al., 2013), microtopographical features of the soil (Inouye et al., 1997) and bulk density (Kerley et al., 2004). Furthermore they can also change the structure, organic matter and moisture contents of the soil (Mielke, 1977), and they can even reduce the proportion of available soil nitrogen (Inouye et al. 1987).

The *Spalacinae* subfamily (which has two genus, the small *Nannospalax* and the gross *Spalax*) consists of several populations with different chromosome numbers (Nevo, 1961; Savić and Soldatovic, 1984; Savić and Nevo, 1990; Nevo et al., 2001; Hadid et al., 2012). In Hungary four endemic forms exist (Németh et al., 2009) that

belong to the lesser blind mole rat species complex [*Nannospalax* (superspecies *leucodon*)]. The study area is inhabited by the Hungarian blind mole rat (*Nannospalax* (*leucodon*) *hungaricus*) (Németh et al., 2009, Németh, 2011). This species leads a subterranean lifestyle (Watson, 1961) with excavating burrows (Heth, 1989).

Very scarce research (in particular about Asian and African mole rat species) focused on the effects of mole rat mounds on the vegetation (but see Cox and Gakahu, 1985; Reichman and Jarvis, 1989; Hongo et al., 1993). There are some other subterranean rodents with similar way of living, which can be used as reference and can help to understand the disturbing impact caused by the mole rats. For example prairie dogs (*Cynomys* spp.) change the species composition of their habitats (Agnew et al., 1986; Whicker and Detling, 1988). Pocket gophers (*Geomys* spp.) also alter some vegetation characteristics like species composition (Inouye et al., 1987; Huntly and Inouye, 1988). Bartha (2001) detected a negative relationship between the mound of pocket gophers and the amount of litter and dominant grass species in regenerated grasslands. Williams et al. (1986) and Martinsen et al. (1990) detected higher diversity on pocket gopher mounds than in their surroundings. Hagenah and Bennet (2013) also found that the presence of the mole rats enhanced species diversity.

Our aim was to study the species richness and diversity of the grassland influenced by the mound forming of the lesser blind mole rat and study the effect of this disturbance to the diversity.

Our hypotheses were the followings:

- (i) The species composition of the mounds differs from the control area.
- (ii) Diversity is higher on the mounds than in the control areas.

Material and methods

Description and land-use history of the study site

The research was done in Külső-gulya loess steppe which is located in the south-eastern part of Hungary, in Battonya-Tompapuszta (46°21'N, 20°58'E). The 20.9-ha-sized area is characterised by a continental climate with 600 mm mean annual precipitation and 10.6°C mean annual temperature and with a high number of sunny hours (2000 hours/year). The soil type is chernozem developed on loess bedrock (Barczy et al., 2011).

The map of the first military survey shows Külső-gulya loess steppe as a grassland (Anon., 1785). The area was marked as a part of a large pasture in the map of the second military survey (Anon., 1869). The third military survey showed Külső-gulya grassland in its current size, as it can be seen that it was still used as a pasture (Anon., 1887). The Külső-gulya grassland in Battonya-Tompapuszta has been a nature conservation area since 1989, and its status changed to strictly protected in 1997. It is the part of the Körös-Maros National Park.

Sampling methods and data analysis

The sampling was made in 50×50 cm quadrats where the cover scores of species were recorded on the basis of the modified method of Braun-Blanquet (1964) using cover scores estimated by a percentage (%) scale. In determining quadrat size the extent of the mounds of a mole rat was taken into consideration. This size reflects the inner heterogeneity of the community (Virágh and Bartha, 1996). Altogether 12 plots were

made on mounds (disturbed) and 12 plots in the area with no mounds (control).

The scores of Shannon-diversity and evenness were calculated as well as the total cover and the number of species in each of the plots. Rank-abundance curves based on the relative abundance of the species were also calculated. To compare the community parameters (total cover, diversity, evenness, number of species) between disturbed and control plots One-Way ANOVA and Tukey-test were used. These analyses were made in the R statistical environment (R Development Core Team, 2008). Species composition was analysed with PCO ordination with SYNTAX 5.0 program package (Podani, 1993) using Bray-Curtis similarity.

Results

The mean number of species ($p=0.163$) and the mean total cover ($p=0.487$) did not showed significant differences between the disturbed and the control sites (*Fig. 1, Table I.*).

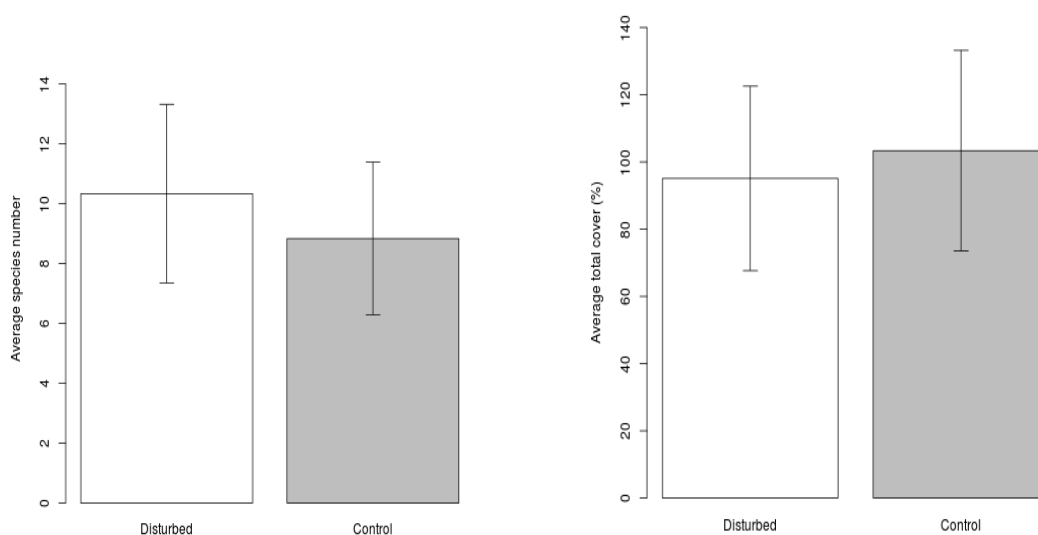


Figure 1. The average number of species and the average cover values on the disturbed and control sites (mean $\pm$ SE)

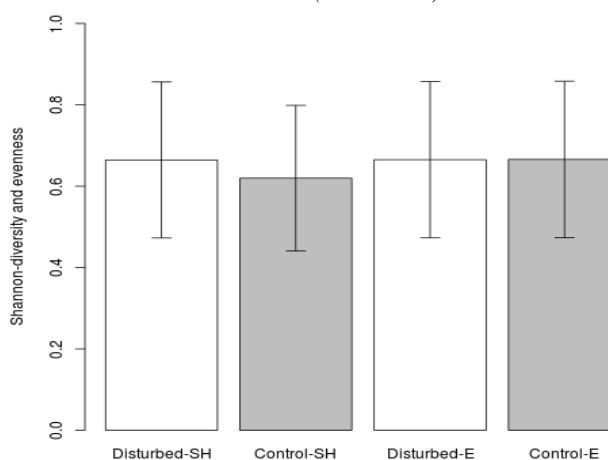


Figure 2. The Shannon-diversity (SH) and evenness (E) on the disturbed and control sites (mean $\pm$ SE)

There was also no significant difference (*Fig. 2.*, *Table 1.*) neither in the Shannon-diversity ($p=0.373$) nor in the evenness ($p=0.44$).

Table 1. Results of the One-Way ANOVA of the species number, total cover, Shannon-diversity, evenness and the cover of grass species, legumes, litter and *Teucrium chamaedrys*

Source	Df	MS	F	P
Species number	1	13.5	2.0867	0.1627
Total cover	1	416.67	0.4989	0.4874
Shannon-diversity	1	0.011989	0.8263	0.3732
Evenness	1	0.0086398	0.6184	0.44
Grasses	1	12553.8	41.405	1.788e-06 ***
Legumes	1	119.707	3.0464	0.09487 .
<i>Teucrium chamaedrys</i>	1	6337.5	12	0.002206 **
Litter	1	5787.7	8.6561	0.007538 **

The comparison of the rank-abundance curves did not reveal distinctions between the sites (*Fig. 3.*).

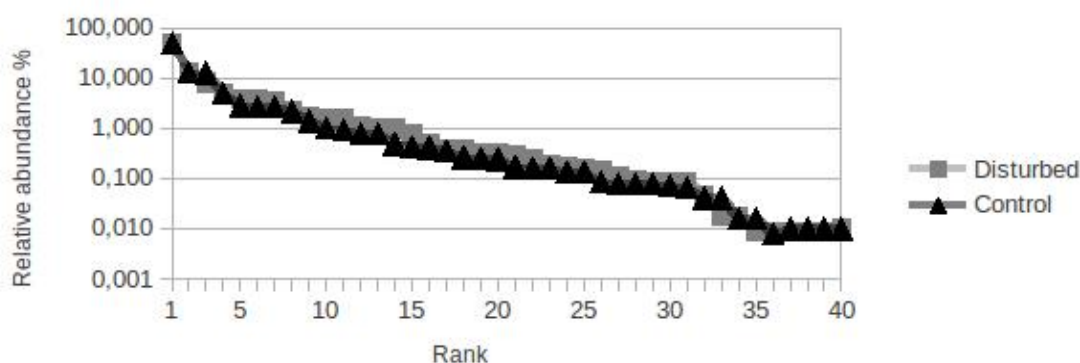


Figure 3. Rank-abundance curves based on the relative abundance of the species

The control and disturbed plots differ significantly based on the the PCO ordination (*Fig. 4.*). But if we have a closer look at the proportion of certain species groups (legume species, grasses) and the litter, the difference is remarkable (*Fig. 5.*). Legume species (*Astragalus cicer*, *Genista tinctoria*, *Lathyrus pratensis*, *Lathyrus tuberosus*, *Vicia angustifolia*) characterised the mounds ($p=0.095$) whilst the cover of the grasses (*Festuca valesiaca*, *Poa angustifolia*, *Carex praecox*) were much higher on the control sites ($p=1.788e-06$). The accumulation of the litter was more pronounced on the control sites as well ($p=0.0075$). Some dicots (*Teucrium chamaedrys* – $p=0.0022$, *Galium verum*, *Fragaria viridis*, *Thymus glabrescens*) occurred in higher cover on the mounds.

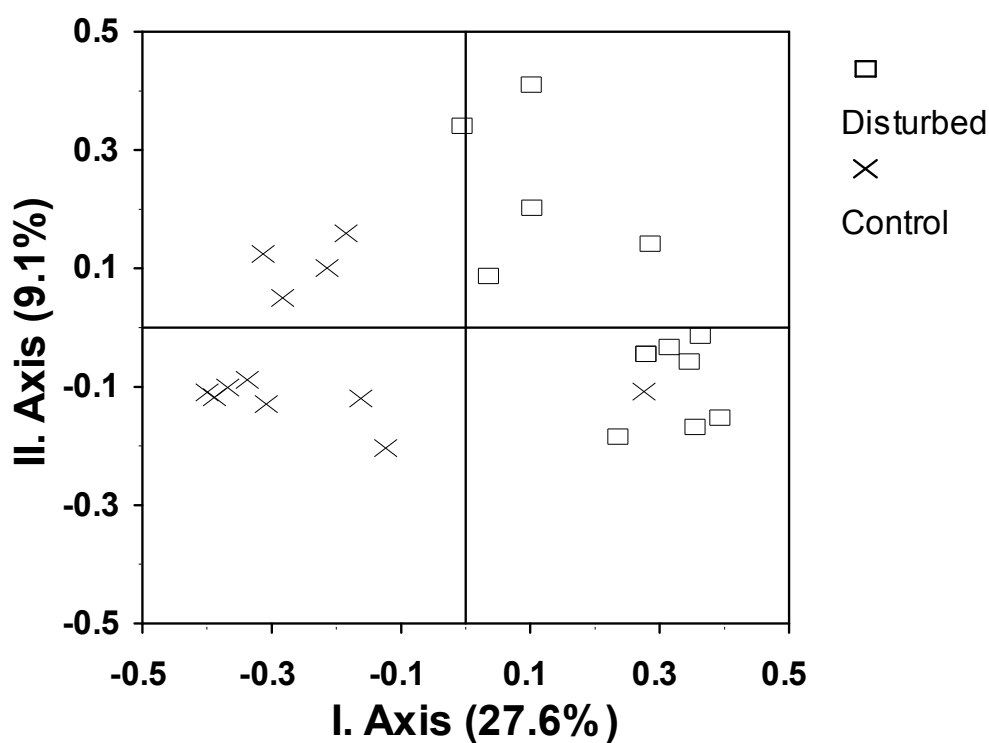


Figure 4. Compositional differentiation between disturbed and control plots analysed by PCO ordination

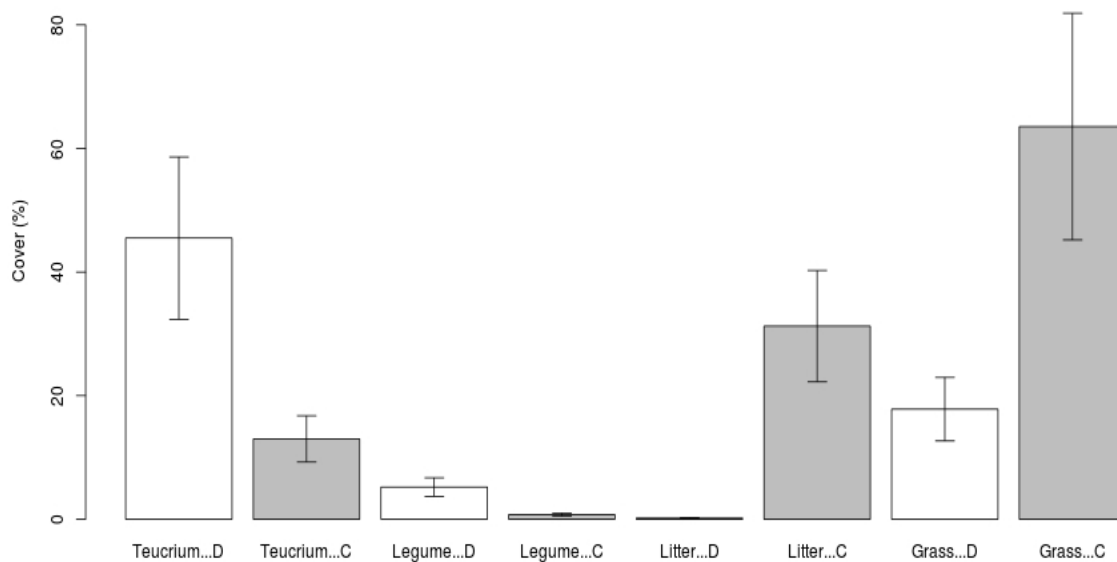


Figure 5. The cover of particular species (*Teucrium chamaedrys*) and functional groups (legume species, grasses and litter) on the disturbed (D) and control (C) sites (mean $\pm$ SE)

Discussion

Our first hypothesis was confirmed by the results as remarkable differences were detected in the species composition between the disturbed and the control plots. The distinction is caused probably by the traits of dominant matrix species. Open surfaces are formed due to the activity of the mole rats and colonized by legumes as Hagenah and Bennett (2013) also confirmed. These open spaces also suitable for species with high seed production, and high vegetative and generative dispersal capacity (Bartha, 2007). We found that the cover of grasses was significantly lower on the mounds as it was also detected by Sigler et al., (2011). The disturbance of fossorial rodents can increase the amount of dicots (Spencer et al., 1985). It was found that the amount of litter also decreased on open surfaces, while litter accumulated in grass dominated swards. These patterns were also confirmed by a former study (Rebollo et al., 2002) analysing *Microtus* species' mounds. They found that the amount of total cover, litter and perennial species was also lower on the mounds than in the surroundings.

Although we found clear differences at the population and functional group levels, the community-level characteristics (total cover, species number, diversity) did not show significant differences. Thus, our second hypothesis was not supported. Other research related to pocket gophers (*Geomys bursarius*), having similar lifestyle to mole rat, showed higher species number on mounds (Deets et al., 2010). Sherrod et al. (2005) and Case et al. (2013) found higher species diversity on mounds while in contrast Rezsutek and Cameron (2000) and Rogers et al. (2001) did not find significant differences between the diversity of the disturbed and control plots.

The presence of the mole rats and their disturbance is characteristic to the area. This type of disturbance is a natural process which can highly contribute in maintaining diversity in dry grasslands (Sousa, 1984; Pickett and White, 1985). Disturbance was obtained by the foraging and trampling of the grazing animals for a long time. On the basis of our results the activity of the mole rats can supplement the lack of the grazing animals after the abandonment of grazing.

The abundance of rodents usually fluctuates in time. In case of a drastic increase in their population size they can have a negative effect on the vegetation composition and cover. Hagenah and Bennet (2013) detected such decrease of species diversity due to the increasing disturbance by the mole rats. The mole rat is a valuable species from the nature conservation point of view, thus it is important to state based on our results that their mounds do not affect negatively the diversity of the protected steppe grassland. Moreover, they enrich the disturbance regime and converge it to the complex disturbance regime of the natural grasslands.

In the studied grassland the only grassland management activity is mowing once a year. According to former studies, mowing once a year should be appropriate to preserve diversity in dry Pannonian grasslands (e.g. Illyés and Bölöni, 2007). We found that mowing once a year was not effective to prevent litter accumulation, which was considerable even in dry years. Thus, especially in abandoned or not properly managed grasslands diversity generated and maintained by the disturbance of mole rat can be very important.

Acknowledgements. We would like to thank the Körös-Maros National Park Directorate for supporting our research and Attila Németh for the revision of the manuscript and the remarks about taxonomical details. Part of this research was supported by the Hungarian National Science Foundation grants OTKA

K 105608, TAMOP project (TÁMOP-4.2.2.A-11/1/KONV-2012-0007) and Research Centre of Excellence- 8526-5/2014/TUDPOL project. Péter Török gave valuable comments on the manuscript.

REFERENCES

- [1] Agnew, W., Uresk, D. W., Hansen, R. M. (1986): Flora and fauna associated with prairie dog colonies and adjacent ungrazed mixed-grass prairie in western South Dakota.-*Journal of Range Management* 39(2): 135-139.
- [2] Anon. (1785): I. Military Mapping Survey of Austria-Hungary (1763-1785) 1:28.800 Digitized Map of The Hungarian Kingdom. Arcanum Kft, Budapest.
- [3] Anon. (1869): II. Military Mapping Survey of Austria-Hungary (1806-1869) 1:28.000 Digitized Map of The Hungarian Kingdom and Temes Banat. Arcanum Kft, Budapest.
- [4] Anon. (1887): II. Military Mapping Survey of Austria-Hungary (1869-1887). 1: 25.000 Digitized Map of the Habsburg Empire. Arcanum Kft, Budapest.
- [5] Barczy, A., Schellenberger, J., Jurák, P., Hegyi, T., Penksza, K. (2011): Talajterképezés a Tompapusztai löszgyepen [Soil mapping in Tompapuszta Pannonian loess steppic grassland]. - *Crisicum* 7: 111-129.
- [6] Bartha, S. (2001): Spatial relationships between plant litter, gopher disturbance and vegetation at different stages of old-field succession. - *Applied Vegetation Science*, 4: 53–62.
- [7] Bartha, S. (2007): Kompozíció, differenciálódás és dinamika az erdőssztyep biom gyepeiben. [Composition, differentiation and dynamics in the grasslands of forest steppe biom.] – In: Illyés, E., Bölöni, J. (ed.): *Lejtőssztyepek, löszgyepek és erdőssztyeprétek Magyarországon*. [Slope steppes, loess steppes and forest steppe meadows in Hungary] Budapest, pp. 72–103. (in Hungarian)
- [8] Bartha, S., Csathó, A., I., Virágh, K., Szentes, Sz., Csathó, A., J., Sutyinszki, Zs., Horváth, A., Ruprecht, E. (2011a): A Tompapusztai löszgyep mikrocönológiai értékelése. I. Florális diverzitás és koordináltság [Assessing naturalness in the Tompapuszta loess steppe meadow I. Diversity of species combinations and stationarity of fine scale patterns]. *Crisicum* 7:45-57.
- [9] Bartha, S., Csathó, A. I., Csathó, A. J., Házi, J., Juhász, M., Selmecsi, M., Sutyinszki, Zs., Szentes, Sz., Virágh, K., Balázs, T. (2011b): A Battonya-tompapusztai Kis-gulya löszpusztarét bővítési területének hosszú távú cönológiai vizsgálata I. Kutatási jelentés [Long-term coenological research in the extend of the Kis-gulya loess steppe in Battonya-Tompapuszta I. Research report], Körös-Maros Nemzeti Park Igazgatóság. (in Hungarian)
- [10] Bartha, S., Csathó, A. I., Szentes, Sz., Virágh, K., Juhász, M., Komoly, C., Szabó, G., Zimmermann, Z., Házi, J., Csathó, A. J., Balázs, T. (2012): A Battonya-tompapusztai Kis-gulya löszpusztarét bővítési területének hosszú távú cönológiai vizsgálata II. Kutatási jelentés [Long-term coenological research in the extend of the Kis-gulya loess steppe in Battonya-Tompapuszta II. Research report], Körös-Maros Nemzeti Park Igazgatóság. (in Hungarian)
- [11] Belsky, A. J. (1992): Effects of grazing, competition, disturbance and fire on species composition and diversity in grassland communities. - *Journal of Vegetation Science*, 3(2): 187-200.
- [12] Borhidi, A. (2003): Magyarország növénytársulásai. [Plant communities of Hungary] - Akadémia Kiadó, Budapest. (in Hungarian)
- [13] Braun-Blanquet, J. (1964): *Pflanzensoziologie: grundzüge der vegetationskunde*. - Springer, Wien - New York.

- [14] Case, M. F., Halpern, C. B., Levin, S. A. (2013): Contributions of gopher mound and casting disturbances to plant community structure in a Cascade Range meadow complex. - *Botany* 2013, 91(8): 555-561.
- [15] Collins, S. L. (1987): Interaction of disturbances in tallgrass prairie: a field experiment. - *Ecology* 68(5): 1243-1250.
- [16] Collins, S. L., Barber, S. C. (1986): Effects of disturbance on diversity in mixed-grass prairie. - *Vegetatio* 64(2-3): 87-94.
- [17] Cox, G. W., Gakahu, C. G. (1985): Mima mound microtopography and vegetation pattern in Kenyan savannas. - *Journal of Tropical Ecology* 1(1): 23-36.
- [18] Csathó, A. I., Jakab, G. (2012): Löszyepek növényvilága. [Flora of loess steppes] – In: Jakab, G. (ed.): A Körös-Maros Nemzeti Park növényvilága. A Körös-Maros Nemzeti Park természeti értékei I. [Flora of the Körös-Maros National Park. Natural values of the Körös-Maros National Park] Körös-Maros Nemzeti Park Igazgatóság, Szarvas, pp. 286–299. (in Hungarian)
- [19] Csathó, A. J. (1985): Sziget a szárazföldön. [Island in the mainland] – *BÚVÁR* 40 (7): 334. (in Hungarian)
- [20] Csathó, A. J. (1986): A battonya–kistompapusztai löszrét növényvilága. [Flora of the loess steppe in Battonya-Kistompapuszta] - *Környezet- és Természetvédelmi Évkönyv* 7: 103–115. (in Hungarian)
- [21] Csathó, A. J. (2005): A Battonya-tompapusztai löszpusztarét élővilága. [Flora and fauna of the loess steppe in Battonya-Tompapuszta] - *Magánkiadás, Battonya*. (in Hungarian)
- [22] Csathó, A. J., Csathó, A. I. (2007): A battonyai Tompapusztai-löszpusztarét. [The loess steppe of Battonya-Tompapuszta]– In: Deák, J. Á., Csathó, A. I., Grezerné, R., Horváth, D., Pándi, I., Szabó-Szöllősi, T., Tóth, T. (ed.): VIII. MÉTA-túra. – 2007. április 25-29. Kézirat [VIII. MÉTA Tour – 25-29. April 2007. Manuscript], Vácrátót, pp. 277–282. (in Hungarian)
- [23] Csathó, A. J., Csathó, A. I. (2009): A battonya-tompapusztai Külső-gulya flóralistája. [Flora list of the Külső-gulya in Battonya-Tompapuszta] - *Crisicum* 5: 51–70. (in Hungarian)
- [24] Deets, L., Grun, H., Sievert, A. (2010): The impact of *Geomys bursarius* on prairie vegetation diversity in Minnesota. - *Itasca Biological Station Student Papers*, <http://conservancy.umn.edu/handle/97335>
- [25] Ellison, L., Aldous, C. M. (1952): Influence of pocket gophers on vegetation of subalpine grassland in central Utah. - *Ecology* 33(2): 177-186.
- [26] Enyedi, Z. M., Ruprecht, E., Deák, M. (2008): Long-term effects of the abandonment of grazing on steppe like grasslands. - *Applied Vegetation Science* 11(1): 55-62.
- [27] Foster, M. A., Stubbendieck, J. (1980): Effects of the plains pocket gopher (*Geomys bursarius*) on rangeland. - *Journal of Range Management* 33:74-78.
- [28] Gibson, D. J. (2009): *Grasses and Grassland Ecology*. Oxford University Press, Oxford, UK.
- [29] Habel, J. C., Dengler, J., Janišová, M., Török, P., Wellstein, C., Wiezik, M. (2013): European grassland ecosystems: threatened hotspots of biodiversity. - *Biodiversity and Conservation* 22(10):1-8.
- [30] Hadid, Y., Németh, A., Snir, S., Pavlíček, T., Csorba, G., Kázmér, M., Major, Á., Mezhzherin, S., Coşkun, Y., Rusin, M., Nevo, E. (2012): Is evolution of blind mole rats determined by climate oscillations?. *PloS one* 7(1): e30043.
- [31] Hagenah, N., Bennett, N. C. (2013): Mole rats act as ecosystem engineers within a biodiversity hotspot, the Cape Fynbos. - *Journal of Zoology* 289(1): 19-26.
- [32] Herczeg, E., Baráth, N., Wichmann, B. (2011): Morfotaxonómiai és cönológiai adatok a Tompapusztai löszgyep *Festuca* taxonjaihoz. [Morphotaxonomic and coenological data for the *Festuca* species in Battonya-Tompapuszta] - *Crisicum* 7: 77–90. (in Hungarian)

- [33] Heth, G. (1989): Burrow patterns of the mole rat *Spalax ehrenbergi* in two soil types (terra rossa and rendzina) in Mount Carmel, Israel. - *Journal of Zoology* 217(1): 39-56.
- [34] Hickman, K. R., Hartnett, D. C., Cochran, R. C., Owensby, C. E. (2004): Grazing management effects on plant species diversity in tallgrass prairie. - *Rangeland Ecology & Management* 57(1): 58-65.
- [35] Hongo, A., Matsumoto, S., Takahashi, H., Zou, H., Cheng, J. (1993): Effect of mounds of cansu mole-rat (*Myospalax cansus* Lyon.) on shrub-steppe vegetation in the loess plateau, north-west China. - *Journal of Japanese Society of Grassland Science* 39(3): 306-316.
- [36] Huntly, N., Inouye, R. (1988): Pocket gophers in ecosystems: patterns and mechanisms. - *BioScience* 38(11): 786-793.
- [37] Huntly, N., Reichman, O. J. (1994): Effects of subterranean mammalian herbivores on vegetation. - *Journal of Mammalogy* 75:852-859.
- [38] Illyés, E., Bölöni, J. (eds.) (2007): Lejtősztyepek, löszgyepek és erdőssztyeprétek Magyarországon [Slope steppes, loess steppes and forest steppe meadows in Hungary], MTA ÖBKI, Budapest. (in Hungarian)
- [39] Inouye, R. S., Huntly, N. J., Tilman, D., Tester, J. R. (1987): Pocket gophers (*Geomys bursarius*), vegetation, and soil nitrogen along a successional sere in east central Minnesota. - *Oecologia* 72(2):178-184.
- [40] Inouye, R. S., Huntly, N., Wasley, G. A. (1997): Effects of pocket gophers (*Geomys bursarius*) on microtopographic variation. - *Journal of Mammalogy*, 78(4), 1144-1148.
- [41] Janišová, M., Barthá, S., Kiehl, K., Dengler, J. (2011): Advances in the conservation of dry grasslands: Introduction to contributions from the seventh European Dry Grassland Meeting. - *Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology* 145(3): 507-513.
- [42] Jones, C. G., Lawton, J. H., Shachak, M. (1994): Organisms as ecosystem engineers. - *Oikos*, 69:373-386.
- [43] Kerley, G. I., Whitford, W. G., Kay, F. R. (2004): Effects of pocket gophers on desert soils and vegetation. - *Journal of Arid Environments* 58(2): 155-166.
- [44] Kertész, É. (1996): Reliktum löszgyepek a Dél-Tiszántúlon (Adatok és megfigyelések 1984–1992). Kézirat [Relictual loess steppes in South-Tiszántúl (Data and observations 1984-1992). Manuscript]. Békéscsaba. (in Hungarian)
- [45] Király, G. (ed.) (2009): Új magyar fűvészkönyv. Magyarország hajtásos növényei. Határozókulcsok. [New Hungarian Herbal. The Vascular Plants of Hungary. Identification key.]. Aggteleki Nemzeti Park Igazgatóság, Jósvalő. (in Hungarian)
- [46] Kiss, T., Lévai, P., Szentes, S., Hufnagel, L., Nagy, A. (2011): Change of composition and diversity of species and grassland management between different grazing intensity in pannonian dry and wet grasslands. - *Appl. Ecol. Env. Res.* 9: 197-230.
- [47] Knapp, A. K., Briggs, J. M., Hartnett, D. C., Collins, S. L. (1998): *Grassland dynamics: long-term ecological research in tallgrass prairie*. Oxford University Press, New York.
- [48] Központi Statisztikai Hivatal hosszú távú adatsora (2012) [Long-term database of the Hungarian Central Statistical Office (2012)], http://www.ksh.hu/docs/hun/xstadat/xstadat_hosszu/h_omf001c.html
- [49] Kun, A. (1998): Száraz gyepek Magyarországon. [Dry grasslands in Hungary] - In: Kiszél, V. (ed.): Természetvédelem területhasználók számára [Nature conservation for farmers], Göncöl Alapítvány, Vác, pp. 65-90. (in Hungarian)
- [50] Martinsen, G. D., Cushman, J. H., Whitham, T. G. (1990): Impact of pocket gopher disturbance on plant species diversity in a shortgrass prairie community. - *Oecologia* 83(1): 132-138.
- [51] McNaughton, S. J. (1985): Ecology of a grazing ecosystem: the Serengeti. - *Ecological monographs* 55(3): 259-294.
- [52] Mielke, H. W. (1977): Mound building by pocket gophers (*Geomyidae*): their impact on soils and vegetation in North America. - *Journal of Biogeography* 4: 171-180.

- [53] Molnár, Zs. (1997): Az alföldi, elsősorban a dél-tiszántúli löszpusztagyepek botanikai jellemzése. 2.0 változat, kézirat [Botanical characterization of the loess steppes in Great Hungarian Plain, primarily in South-Tiszántúl. Version 2.0, manuscript]. MTA ÖBKI, Vácrátót. (in Hungarian)
- [54] Molnár, Zs., Csathó, A. I., Illyés E. (2007): Tiszántúl [Tiszántúl]. – In: Illyés, E., Bölöni, J. (ed.): Lejtősztyepek, löszgyepek és erdőssztyeprétek Magyarországon. [Slope steppes, loess steppes and forest steppe meadows in Hungary] Budapest. pp. 125–128. (in Hungarian)
- [55] Moran, S. (1998): Control of the subterranean mole-rat, *Spalax ehrenbergi*, with brodifacoum pellets. - *International Journal of Pest Management*, 44(3), 149-151.
- [56] Németh 2011: A kárpát-medencei földikutyák (Rodentia: Spalacinae) rendszertana, elterjedése és természetvédelmi helyzete, PhD Thesis. Eötvös Loránd University, Budapest, pp. 136. (in Hungarian with English summary)
- [57] Németh, A., Révay, T., Farkas, J., Czabán, D., Rózsás, A., Csorba, G. (2009): Chromosomal forms and risk assessment of *Nannospalax* (superspecies *leucodon*) (Mammalia: Rodentia) in the Carpathian Basin. - *Folia Zool*, 58(3), 349-361.
- [58] Nevo, E. (1961): Observations on Israeli populations of the mole rat, *Spalax ehrenbergi* Nehring 1898. - *Mammalia* 25: 127–144.
- [59] Nevo, E., Ivanitskaya, E., Beiles, A. (2001): Adaptive radiation of blind subterranean mole rats: naming and revisiting the four sibling species of the *Spalax ehrenbergi* in Israel: *Spalax galili* (2n=52), *S. golani* (2n=54), *S. carmeli* (2n=58), and *S. judaei* (2n=60). Leiden, The Netherlands: Backhuys.
- [60] Nosal, A., Featherstone, B., Vang, N. (2010): Quantitative and Qualitative Approaches to Study the Effects of Plains Pocket Gopher (*Geomys bursarius*) Mound Building on Vegetation - Itasca Biological Station Student Papers, <http://conservancy.umn.edu/handle/99961>
- [61] Noy-Meir, I. (1995): Interactive effects of fire and grazing on structure and diversity of Mediterranean grasslands. - *Journal of Vegetation Science*, 6(5), 701-710.
- [62] Olff, H., Ritchie, M. E. (1998): Effects of herbivores on grassland plant diversity. - *Trends in Ecology & Evolution*, 13(7), 261-265.
- [63] Pickett, S. T., White, P. S. (1985): Patch dynamics: a synthesis. In: Pickett, S.T., White, P. S. (eds.): *The Ecology of Natural Disturbance and Patch Dynamics*, Academic Press, Orlando, FL, pp. 371–384.
- [64] Podani, J. (1993): SYN-TAXpc. Version 5.0. User's guide. - Scientia Publishing, Budapest.
- [65] R Development Core Team (2008): R: A language and environment for statistical computing. - R Foundation for Statistical Computing, Vienna, Austria.
- [66] Rebollo, S., Perez-Camacho, L., Valencia, J., Gómez-Sal, A. (2002): Vole mound effects and disturbance rate in a Mediterranean plant community under different grazing and irrigation regimes. - *Plant Ecology*, 169(2), 227-243.
- [67] Reichman, O. J., Jarvis, J. U. M. (1989): The influence of three sympatric species of fossorial mole-rats (Bathyergidae) on vegetation. - *Journal of Mammalogy*, 70(4), 763-771.
- [68] Reichman, O. J., Seabloom, E. W. (2002): The role of pocket gophers as subterranean ecosystem engineers. - *Trends in Ecology & Evolution*, 17(1), 44-49.
- [69] Reichman, O. J., Smith, S. C. (1985): Impact of pocket gopher burrows on overlying vegetation. - *Journal of Mammalogy*, 66(4), 720-725.
- [70] Rezsutek, M., Cameron, G. N. (2000): Vegetative edge effects and pocket gopher tunnels. - *Journal of Mammalogy*, 81(4), 1062-1070.
- [71] Rogers, W. E., Hartnett, D. C., Elder, B. (2001): Effects of plains pocket gopher (*Geomys bursarius*) disturbances on tallgrass-prairie plant community structure. - *The American Midland Naturalist*, 145(2), 344-357.

- [72] Savadogo, P., Tiveau, D., Sawadogo, L., Tigabu, M. (2008): Herbaceous species responses to long-term effects of prescribed fire, grazing and selective tree cutting in the savanna-woodlands of West Africa. - *Perspectives in Plant Ecology, Evolution and Systematics*, 10(3), 179-195.
- [73] Savić, I. R., Nevo, E. (1990): The Spalacidae: evolutionary history, speciation and population biology. - *Progress in clinical and biological research*, 335: 129-153.
- [74] Savić, I., Soldatović, B. (1984): Karyotype evolution and taxonomy of the genus *Nannospalax* Palmer, 1903, *Mammalia*, in Europe. *Serbian Acad. of Science and Arts*, Beograd.
- [75] Sherrod, S. K., Seastedt, T. R., Walker, M. D. (2005): Northern pocket gopher (*Thomomys talpoides*) control of alpine plant community structure. - *Arctic, Antarctic and Alpine Research*, 37(4), 585-590.
- [76] Sigler, H., Grunzke, D., Rehmann, A. (2011): The Effects of Plains Pocket Gopher (*Geomys bursarius*) Mounds on Localized Vegetation Diversity. - *Itasca Biological Station Student Papers*, <http://conservancy.umn.edu/handle/99967>.
- [77] Somodi, I., Virágh, K., Aszalós, R. (2004): The effect of the abandonment of grazing on the mosaic of vegetation patches in a temperate grassland area in Hungary. - *Ecological Complexity*, 1(2), 177-189.
- [78] Sousa, W. P. (1984): The role of disturbance in natural communities. - *Annual review of ecology and systematics*, 15, 353-391.
- [79] Spencer, S. R., Cameron, G. N., Eshelman, B. D., Cooper, L. C., Williams, L. R. (1985): Influence of pocket gopher mounds on a Texas coastal prairie. - *Oecologia* 66(1): 111-115.
- [80] Strauss, S. Y., Agrawal, A. A. (1999): The ecology and evolution of plant tolerance to herbivory. - *Trends in Ecology & Evolution* 14(5): 179-185.
- [81] Valkó, O., Tóthmérész, B., Kelemen, A., Simon, E., Miglécz, T., Lukács, B. A., Török, P. (2013a): Environmental factors driving vegetation and seed bank diversity in alkali grasslands. - *Agriculture, Ecosystems and Environment*, DOI:10.1016/j.agee.2013.06.012
- [82] Valkó, O., Török, P., Deák, B., Tóthmérész, B. (2013b): Prospects and limitations of prescribed burning as a management tool in European grasslands. - *Basic and Applied Ecology*, DOI:10.1016/j.baae.2013.11.002.
- [83] Virágh, K., Bartha, S. (1996): The effect of current dynamical state of a loess steppe community on its responses to disturbances. - *Tiscia* 30: 3-13.
- [84] Watson, G. E. (1961): Behavioral and ecological notes on *Spalax leucodon*. - *Journal of Mammalogy* 42: 359-365.
- [85] Whicker, A. D., Detling, J. K. (1988): Ecological consequences of prairie dog disturbances. - *BioScience* 38(11): 778-785.
- [86] Williams, L. R., Cameron, G. N., Spencer, S. R., Eshelman, B. D., Gregory, M. J. (1986): Experimental analysis of the effects of pocket gopher mounds on Texas coastal prairie. - *Journal of Mammalogy* 67(4):672-679.
- [87] Wilson, J.B., Peet, R.K., Dengler, J., Pärtel, M. (2012): Plant species richness: the world records. - *Journal of Vegetation Science* 23, 796-802.
- [88] Zhang, Y., Zhang, Z., Liu, J. (2003): Burrowing rodents as ecosystem engineers: the ecology and management of plateau zokors *Myospalax fontanierii* in alpine meadow ecosystems on the Tibetan Plateau. - *Mammal Review* 33(3-4): 284-294.

Appendix

Nomenclature: Király (2009) for taxa, Borhidi (2003) for syntaxa