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¿Cómo pueden cambiar las investigaciones científicas las prioridades de conservación? Una revisión de una década de investigación con ratas topo ciegas (Rodentia: Spalacinae) en la Cuenca de los Cárpatos

How can scientific researches change conservation priorities? A review of decade-long research on blind mole-rats (Rodentia: Spalacinae) in the Carpathian Basin

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Introduction: From time to time, it could be useful to revise and re-assess the results of long-term programs in conservation and research. This paper overviews an ongoing research program that started 10 years ago in Central Europe and focuses on blind mole-rats, a scarcely investigated and consequently enigmatic group of rodents.

Results: *Systematics and Taxonomy*. By means of molecular biological methods targeting the sequences of mitochondrial genes we conclude that five species of blind mole-rats, representatives of genera *Spalax* and *Nannospalax*, occur in the Carpathian Basin. Based on our present knowledge they are the only terrestrial vertebrate species endemic to the region.

Mapping of distributions. As recently as one hundred years ago blind mole-rats were widespread and common all over the Carpathian Basin. In the last decade, all the regions in Hungary, the Transylvanian Basin and Vojvodina where previous genuine records were known, were checked systematically. Maps and aerial photography provided information on the exact location of habitat patches that are supposed to be suitable for blind mole-rats even today. In recent years (from 2008 onwards) the survey area was extended to all locations where residents reported on the occurrence of mole-rats.

Threatening factors. The main cause of population decline is agricultural development which brought about significant changes in cultivation and land use. The following specific threatening factors were defined: cultivation, tree plantations, natural reafforestation, invasive plants, overgrazing, site developement, genetic bottlenecks, extreme weather conditions, and inadequate legal protection.

Risk assessment. Red List categories for all species of Carpathian Basin blind mole-rats were assessed according to the 2001 criteria. Accordingly, one species is proposed to be ranked as Vulnerable, two as Endangered, one as Critically Endangered, and one as Data Deficient (probably extinct).

Conclusions: Results from molecular biological and systematic studies, distribution mapping and determination of threatening factors, have had profound effects on practical conservation. These include action plans, wide international co-operations, establishment of a new protected area, updated protected species' list, species-level risk assessment, and the first-ever relocation program of a subterranean mammal.

Key words: *Nannospalax*, protected species, recent distribution, risk assessment, Spalacinae, *Spalax*, threatening factors

Introduction

There are many conservation programs all over the world seeking solutions for a diverse array of problems ranging from global challenges to grassroots issues. The main priority of many long-term scientific research projects is to provide information that could aid decision-makers and experts in their line of work. From time to time, it could be useful to revise and re-assess the results of long-term programs in conservation and research. Such reviews are valuable resources of information for future guidelines in science and planning as well as for the evaluation of current conservation status quos (*e. g*. Ostrowski *et al*. 1998; Amori and Gippoliti 2000; Towns *et al*. 2001). In our case study, we review the results of an ongoing research program that started 10 years ago in Central Europe and focuses on a scarcely investigated and consequentially enigmatic group of rodents. Our results so far had dramatically changed the group's stance in conservation and had completely re-designed the regional priorities in mammal conservation. In addition, they taught us a memorable lesson about the importance of scientific research both for practical nature conservation and in decision-making processes. On the down side, our research has also shed light on a phenomenon that may well be common in all cryptic and little known creatures. The lack of research coupled with obscure taxonomy often escorts a species hand-in-hand towards extinction while the whole process remains unnoticed even for experts and responsible decision-makers.

Eurasian blind mole-rats (subfamily Spalacinae) are adapted to exclusively underground life (Méhely 1909; Topachevskii 1969; Savić and Nevo 1990). These small mammals have cylindrically shaped bodies with no external ears and a vestigial tail, and are completely blind spending their entire life in their tunnel system built underground (Topachevskii 1969; Figure 1). Species of the subfamily can be found in the Balkan Peninsula, in steppe grasslands in Central and Eastern Europe, in the Middle East (Asia Minor and the coastline of the Levant), and in a narrow coastal strip in north-east Africa (Musser and Carleton 2005). Because of their rather uniform external appearance and gross cranial morphology, the systematics of blind mole-rats has been hotly debated over the last century. Compared to other rodent groups, the conditions resulting from their lifestyle created a decreased morphological variability and all species are very similar both externally and osteologically (Nevo 2000). The first comprehensive work, a milestone in blind mole-rat systematics, was published by Méhely (1909) who, based on his study of subtle differences in cranial and dental structures, recognized one genus with three subgenera and eight species with 14 additional subspecies. His opinion was later regarded as overly 'splitting', whereas at the other extreme, Ellerman and Morrison-Scott (1951) accepted only three species in one genus. The next baseline work in Spalacinae systematics was published by the outstanding Ukrainian morphotaxonomist, Topachevskii (1969), who, after studying hundreds of specimens, basically came to the same conclusions as Méhely (1909) as regards the genus-group systematics. However, his concept of a basic taxonomic divide between 'small' and 'large' blind mole-rats, although supported by craniodental differences, was not always followed in the literature published in English (*e. g*. Savić and Nevo 1990; Nevo *et al*. 2001; Musser and Carleton 2005). Nevertheless, as cytogenetic (Lyapunova *et al*. 1971) and molecular genetic (Hadid *et al*. 2012) investigations provided further support of deep taxonomic divergences within the subfamily, and support of the presence of two genera (*Spalax* and *Nannospalax*), this old established classification scheme has finally been accepted in the most recent publications (Németh *et al*. 2009; Arslan *et al*. 2011; Kryštufek *et al*. 2012; Chisamera *et al*. 2013). Putting aside the lineage of large blind mole-rats (genus *Spalax*), taxa belonging to *Nannospalax* present a long-standing source of dispute and disagreement over their systematics (Savić and Nevo 1990; Musser and Carleton 2005). Within the latter genus, one of the recognised species groups (regarded as superspecies) that includes a large number of karyologically different taxa (for the list of these see Savić and Soldatović 1984) is the

Lesser blind mole-rat, *Nannospalax* (superspecies *leucodon;* Musser and Carleton 2005). Although the species status of taxa differentiated solely on chromosomal grounds has not been widely accepted (Sözen *et al*. 2006; Ivanitskaya *et al*. 2008; Kryštufek *et al*. 2012), the results of the until now fairly limited molecular genetic investigations of this superspecies (Hadid *et al*. 2012; Németh *et al*. 2013a) and the results of breeding experiments with several Central European and Balkan chromosomal forms (Savić and Soldatović 1984) raises the necessity of species level separation at least of some of them. Alongside with taxonomic uncertainty the determination of conservation status of different mole-rat taxa is further hampered by their exclusively subterranean lifestyle which makes it difficult to evaluate their population size. While the *leucodon*-superspecies itself was categorised for a long time as Least Concern (Temple and Terry 2007, 2009), and changed recently to "Data Deficient" (Kryštufek and Amori 2008) to express the systematic problems within the group, while populations and habitats of many different European chromosomal taxa are disappearing at an alarming rate, a phenomenon which has just recently been realized (Kryštufek 1999; Kryštufek and Amori 2008; Németh *et al*. 2009).

Figure 1. *Spalax antiquus* (Aiton, Romania) in its natural habitat.

At the onset of the second millenium, all the available taxonomic and other scientific data as well as information related to the conservation of Central European blind mole-rats come from decades earlier (Németh 2011). While the whole region underwent a grand-scale and substantial change in land-use, blind mole-rats slowly sank into obscurity. Basically nothing was known about the actual distribution, population sizes or, due to the lack of modern taxonomic investigations, the sytematic position of the populations (Csorba 1998). Even though several authors throughout the region tried to raise awareness concerning the potentially threathened status of certain populations or even of the Lesser blind mole-rat in general (Báldi *et al*. 1995; Mikes *et al*. 1982; Habijan-Mikes *et al*. 1986; Savić *et al*. 1984), no comprehensive study was carried out. In Hungary for example, where blind mole-rats are strictly protected, data were only available on the monotonous and very likely unescapable demise of the extremely isolated and small population fragments. Due to the lack of practically applicable information, no plan was implemented to stop these processes. In 2003, in order to bridge the above-mentioned gaps in our knowledge, we started a research project on the Hungarian blind mole-rats. However, the scope of our investigation soon overstepped political boundaries and embraced the entire Carpathian Basin as a topographically well-defined unit of the European landscape.

Results

Systematics and taxonomy

Early taxonomy. Nehring (1897, 1898a, b, c) was the first to separate the single recognized species of blind mole-rats into several distinct species. He considered all the populations within the Carpathian Basin belonging to a single species that he described as *Spalax hungaricus* (Nehring 1898b). A few years later, Méhely (1909) recognised three dinstinct blind mole-rat taxa within the Carpathian Basin: *S. hungaricus hungaricus* (Central part of the Carpathian Basin), *S. hungaricus transsylvanicus* (Transylvania), and *S. monticola syrmiensis* (western part of the Carpathian Basin). He also made mention of an extinct taxon, *S. graecus antiquus,* only known from paleontological records. Almost three decades later, based on his review of Transylvanian specimens in the collection of the Hungarian Natural History Museum, Szunyoghy (1937) described an extant subspecies of *S. graecus* as *S. graecus mezösegiensis.* Ellerman and Morrison-Scott (1951) did not find Méhely's arguments convincing and saw the distinction of only three species justified for the entire distribution area of blind mole-rats. According to them, blind mole-rats in the Carpathian Basin belong to two species: *S. leucodon* and *S. microphthalmus.* In the monograph by Topachevskii (1969), all small European blind mole-rats (including *S. hungaricus* and *S. monticola*) were uniformly classified as Nordmann's *S. leucodon* (1840); he also agreed to the existence of a separate species, *S. graecus,* into which he assigned the larger blind mole-rats of Transylvania.

The 60's and the 70's were the golden age for cytogenetics. These investigations contributed significant information to the ongoing dispute on blind mole-rat taxonomy and it became clear that the karyotypes of taxa that had been previously classified on purely morphological grounds now suggested a completely different status in many cases (for a summary see Savić and Nevo 1990; Nevo *et al*. 2001). On a European scale, blind mole-rats of the Balkan Peninsula were under intense scrutiny through cytogenetic research. Karyotyping specimens from the territory of the former Yugoslavia provided evidence that *S. hungaricus* and *S. syrmiensis* had different number and structure of chromosomes (Savić and Soldatović 1984). During these investigations, the authors also discovered a so far unknown species with a unique karyotype which they named *S. montanosyrmiensis* (Savić and Soldatović 1974; Soldatović and Savić 1983). Additional research into their reproductive biology provided convincing evidence for the species-level separation of these taxa (Savić and Soldatović 1984). In Romania, the cytogenetic investigations of Raicu *et al*. (1968; 1969; 1973) determined the karyotype of *S. transsylvanicus* and *S. graecus*.

In their comprehensive work, Musser and Carleton (2005) listed 13 species of blind mole-rats, accepting all the different karyotypes in Israel as distinct species. However, the authors did not take a stand as to the taxonomic status of the different karyotypes occurring in Europe. Therefore, the current status of the Lesser blind mole-rat which is an aggregation of distinct biological species several of which could be threatened could not be ranked in the latest IUCN publication (IUCN 2014).

Recent investigations. As blind mole-rats in Hungary were not sampled during the extensive cytogenetic mapping of the 70's, no karyological information was available on the central populations of the Carpathian Basin. Due to increasing pressure to conserve these populations, our genetic sampling started in 2005. We first studied chromosomes and later carried out mitochondrial DNA analyses. Instead of the direct bone marrow preparation method routinely used with rodents (which requires culling the sampled individuals), we drafted a novel and less drastic approach. For tissue cultures, we used blood and connective tissue samples taken by experienced veterinarians, applying local and systemic anesthesia (Sós *et al*. 2009). Lymphocyte and fibroblast cultures were used for chromosomal investigations. Even though small sample sizes and bacterial or mycotic infections imposed several difficulties on this approach, we managed to assess the karyotype of four out of the six sampled populations. Our results supported the presence of two chromosomal species in Hungary. The karyotype of populations around Debrecen-Józsa, Hajdúbagos and Hajdúhadház (2*n* = 50, *NF* = 84, Németh *et al*. 2006, 2009) was found to be the same as that of the *S. transsylvanicus* populations in the vicinity of Jucu (Raicu *et al*. 1968). The karyotype of the blind mole-rats in the Kelebia region (2*n* = 54, *NF* = 86 (Németh *et al*. 2013a) agrees with the one that previously had only been found in Serbian populations near Stražilovo and Čortanovci, and described as *S. montanosyrmiensis* (Savić and Soldatović 1974; Soldatović and Savić 1983).

By means of molecular biological methods targeting the sequences of five mitochondrial genes (12S rRNA, tRNA-Val, 16S rRNA, tRNA-Leu (UUR), NADH1, tRNAIle, 3742 bp in total) we could conclude that large and small blind mole-rats belong to distinct genera, *Spalax* and *Nannospalax*, respectively (Hadid *et al*. 2012). The results based on the widest taxonomic and geographic coverage so far also support the hypothesis that Transylvanian representatives of the genus *Spalax* do in fact belong to a species endemic to the Carpathian Basin (Figure 2). Méhely's blind mole-rat (*S. antiquus*) was separated from its closest relatives *S. graecus sensu stricto* and *S. istricus* approximately 1.4 mya (Hadid *et al*. 2012; Németh *et al*. 2013b). The robustness of the mentioned conclusion is supported by the combined evidence of morphology, multilocus phylogeny, species distribution, and taxon history

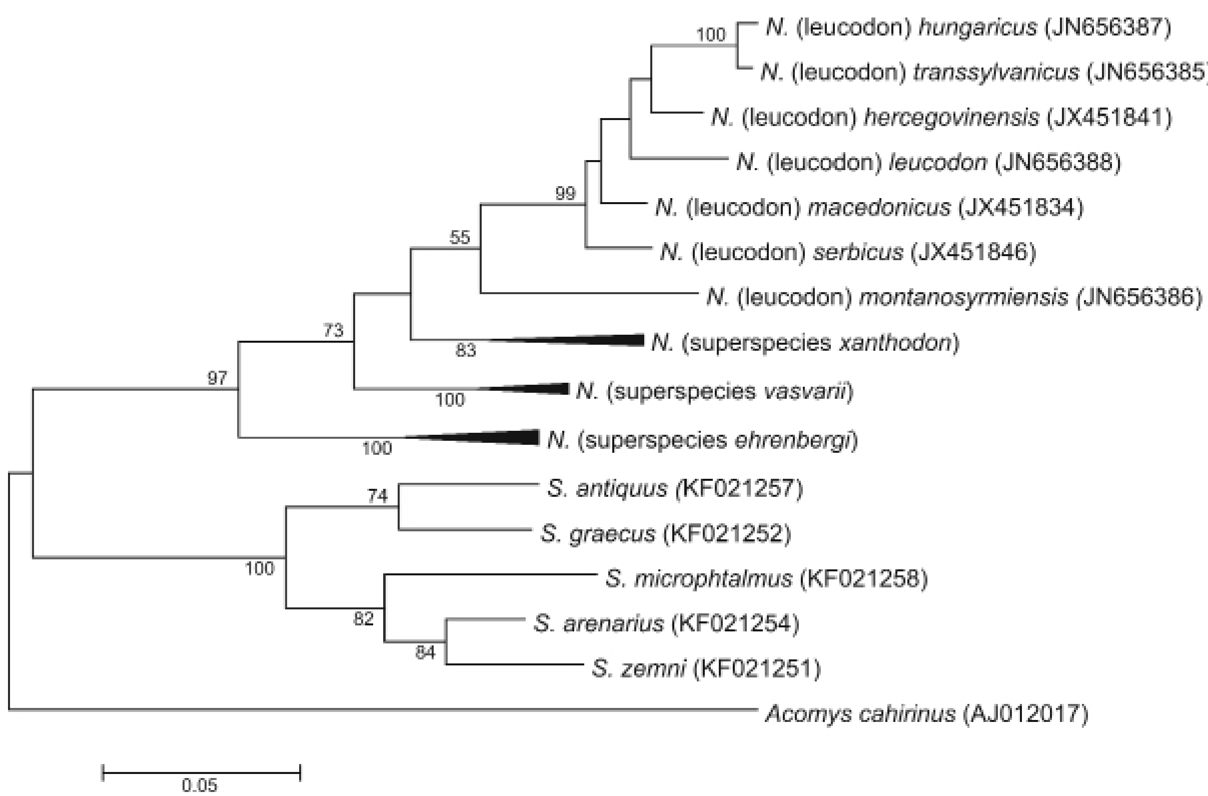

Figure 2. Phylogenetic tree showing evolutionary history of *Spalax* (S.) and *Nannospalax* (N.) species based on 870 bp long partial sequence of cytochome b gene using the Maximum Likelihood method and the Tamura-Nei model. The percentage of trees in which the associated taxa clustered together (after 10 000 replications) is shown next to the branches. Bar represents the number of substitutions per site; GeneBank accession numbers are written in parentheses. Analysis was performed using MEGA6 software (Tamura *et al.* 2013). *Acomys cahirinus* was used as outgroup.

(species congruence with past tectonic and climate events).

Based on an 870-bp-long section of the cytochrom-b gene, the Srem blind mole-rat (*N.* (*leucodon*) *syrmiensis*), the Vojvodina blind mole-rat (*N.* (*leucodon*) *montanosyrmiensis*), the Hungarian blind mole-rat (*N.* (*leucodon*) *hungaricus*) and the Transsylvanian blind mole-rat (*N.* (*leucodon*) *transsylvanicus*) all represent distinct lineages within the genus *Nannospalax* (Németh *et al*. 2013a; Németh unpublished data; Figure 2). These Carpathian Basin taxa were previously distinguished from each other by craniodental attributes as well as by their karyotypes (Savić and Soldatović 1984). Among all studied *Nannospalax* taxa, the Vojvodina blind mole-rat occupies a basal position on the phylogenetic reconstructions, representing an ancient group that parted from other European taxa about 2 million years ago (Hadid *et al*. 2012; Németh *et al*. 2013a). According to our present knowledge, five species of blind mole-rats, representatives of two genera, occurring in the Carpathian Basin are the only terrestrial vertebrate species endemic to the region (Table 1).

Table 1. Extant populations of blind mole-rats, estimated numbers of individuals, extent and protection status of habitats for species inhabiting the Carpathian Basin.

Species	Locations	Number of individuals	Area of occupancy (ha)	Protection status	Reference
Nannospalax (leucodon) hungaricus	Kunmadaras	5	1	not protected	Németh *et al*. 2013c
	Mezőtúr	30	6,6	not protected	Németh *et al.* 2013c
	Tompapuszta	20-30	21	Natura2000-HUKM20009	Horváth and Vadnay 2006
	Battonya	20	37	Natura2000-HUKM 20009	Németh *et al*. 2013c
	Deliblatska peščara	5500-5800	29350	Deliblatska peščara Special Nature Reserve	Németh *et a*l. 2009
Nannospalax (leucodon) montanosyrmiensis	Baja	150-200	120	not protected	Sendula 2014
	Kelebia – Subotićka peščara	150-200	416	partly protected (Kőrös-ér Landscape Protection Area, Natura2000-HUKN20008, Subotićka peščara Protected Area)	Krivek 2014
	Stražilovo - Čortanovci	100	50	not protected	Németh *et al.* 2013a
Nannospalax (leucodon) syrmiensis	not known	0	0	probably extinct	Németh unpublished data
Nannospalax (leucodon) transsylvanicus	Cluj-Napoca - Dăbâca	8800-8900	40000	partly protected (Apahida Spalax Reserve, Fânaţele Clujului Nature Reserves, Natura2000-ROSCI0295, ROSCI0099)	Sugár 2012
	Hajdúhadház	800	1675	Natura2000-HUHN21164	Bihari *et al*. 2009
	Debrecen-Józsa	50	60	Natura2000-HUHN20122	Németh *et al*. 2013c
	Hajdúbagos 1	130-150	265	Natura2000-HUHN20217	Bihari *et al*. 2009
	Hajdúbagos 2	15-20	15	not protected	Németh *et al*. 2013c
Spalax antiquus	Budeşti – Cătina – Mociu	500-600	min. 1800	partly protected (Natura2000-ROSCI0333)	Sugár 2012 and Sugár unpublished data
	Aiton – Cojocna – Iuriu de Câmpie – Ploscoș	2500-2600	19500	partly protected (Natura2000-ROSCI0238, ROSPA0113)	Sugár 2012
	Turda	450-500	1720	partly protected (Natura2000-ROSCI0034, ROSCI0035, ROSPA0087)	Sugár 2009, Sugár and Hegyeli 2010
	Rădeşti – Beța	100-120	min. 350	partly protected (Natura2000-ROSCI0187)	Sugár 2012 and Sugár unpublished data

Mapping of distributions

Early records. As recently as one hundred years ago blind mole-rats were widespread and common all over the Carpathian Basin. They were known to occur in all nonmountainous and unforested regions including steppes of the central Transylvanian Plateau, Romania and were recorded in almost the whole lowland areas of Vojvodina, northern Serbia (Petényi and Glos 1845; Orosz 1902; 1903; 1904; 1905; 1906; Lendl 1899; 1900; Méhely 1909; Horváth 1918a, 1918b; Vásárhelyi 1929; 1931; 1932; 1960; Szalay 1932; Szunyoghy 1937; Sterbetz 1965; 2002; Tóth 1991; Figure 3). Although their occurrence west of the river Danube was last recorded in 1925 (Éhik 1925), blind mole-rats were still common in suitable habitats of the Great Hungarian Plain in the inter-World Wars period (Vásárhelyi 1926; 1932); up to the 1950s Sterbetz (1960) recorded high numbers of blind mole-rats in the southeastern area of the Plain. Blind mole-rats in Vojvodina were abundant even in the 1970s (Savić and Soldatović 1984).

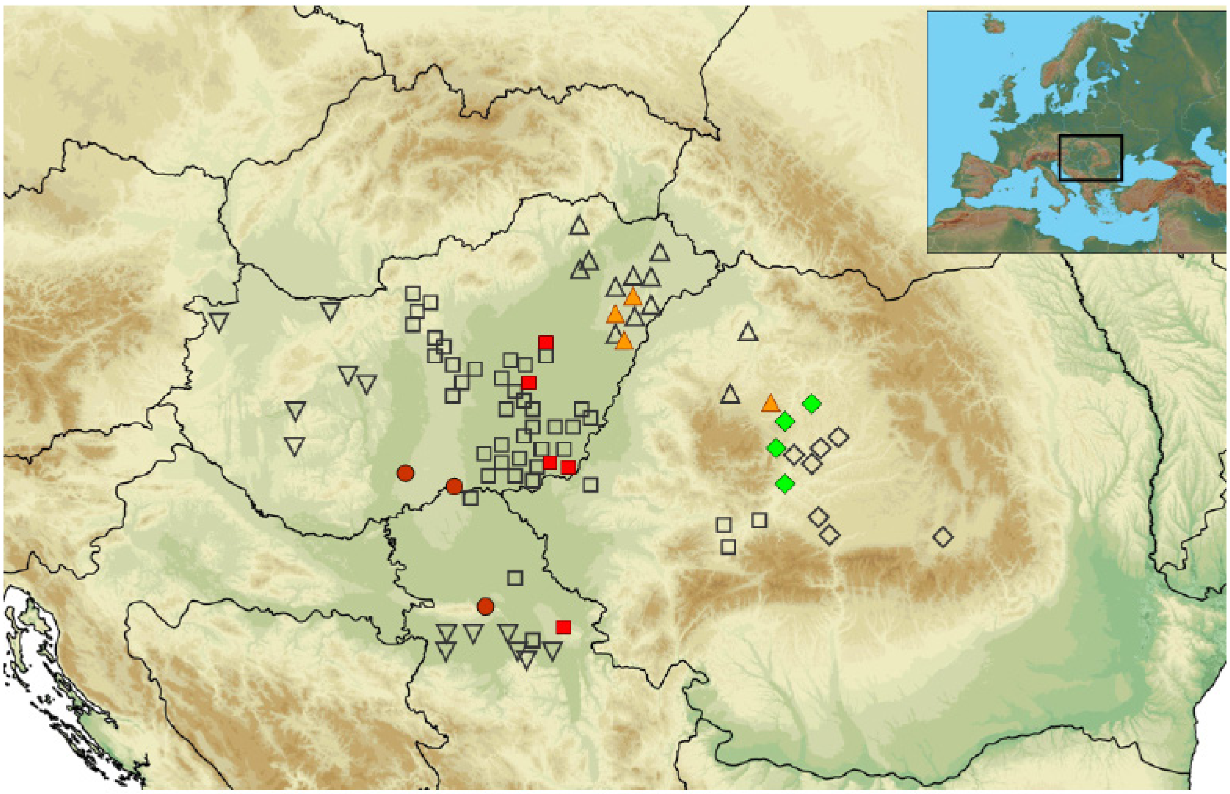

Figure 3. Former and recent distribution of blind mole-rat species in the Carpathian Basin. Full symbols represent existing populations, whereas empty symbols denote historical records.

▽ = *Nannospalax* (*leucodon*) *syrmiensis*
□ = *Nannospalax* (*leucodon*) *hungaricus*
○ = *Nannospalax* (*leucodon*) *montanosyrmiensis*
△ = *Nannospalax* (*leucodon*) *transsylvanicus*
◇ = *Spalax antiquus*

Degradation, transformation of habitats, and shrinking of distribution area can all be blamed for the decrease in the number of mole-rats in the formerly vast grasslands (Csorba 1998; Figure 4). The main cause of population decline is agricultural development which brought about significant changes in cultivation and land use. Extensive livestock farming and pasture-farming were replaced by intensive monocultures. These changes led to the dramatic decline, fragmentation and in many cases to the final disappearance of grasslands (Csorba 1998; Németh *et al* 2013c). Changes in habitat structure had negative impacts on animal species inhabiting steppes of Central Europe. As a result, blind mole-rats, which were formerly defined as a pest, became endangered and therefore gained legal protection in Hungary (Németh *et al*. 2013c).

The very first and most rapid changes in habitat structure took place in Hungary between the second half of the 1950s and the 1970s. A similar progression started in Transylvania at the same time, however on less extensive areas, owing to the scarcity of vast plain areas adequate for large-scale agriculture. Grassland habitats of Vojvodina were affected in the 1990s. As a consequence of habitat deterioration blind mole-rat populations retreated to remnant grassland fragments and became completely isolated from each other. Recent regional development and urbanisation had particularly adverse impacts on the remaining blind mole-rat populations of Hungary and Vojvodina (Németh *et al* 2013c; Krivek 2014; Sendula 2014). In the early 2000s only five populations in Hungary and two in Vojvodina were recorded (Horváth and Vadnai 2006; Delić 2007), and there was no information on either the localities or the size of mole-rat populations in Transylvania.

Figure 4. Vast, dry grasslands are the typical habitats of blind mole-rats (Aiton, Romania)

Recent studies. As a first step in mapping blind mole-rat populations, all the regions in Hungary, the Transylvanian Basin and Vojvodina where previous genuine records were known, supported by scientific publications or voucher specimens, were checked systematically. Maps and aerial photography provided information on the exact location of habitat patches that are supposed to be suitable for blind mole-rats even today, that is, areas not affected by afforestation, housing/industrial developement or large-scale cultivation. In recent years (from 2008 onwards) the survey area was extended to all locations where residents reported on the occurrence of mole-rats.

The investigations were carried out during the peak activity period of blind mole-rats in spring and in autumn months. When large, widely-spaced mounds and tunnels with hard-packed walls (characteristic of blind mole-rats) were found, capture of individuals was attempted. In each of such cases the occurrence of blind mole-rats was succesfully proven by catching live specimens. The animals were caught by opening the tunnel system and capturing the animal trying to mend the damage (Németh *et al*. 2007), a method allowed by research permits issued by the National Inspectorate for Environment, Nature Conservation and Water no. 14/05173-3/2006 and 14/1840-3/2008.

Animals were handled in the field in accordance with guidelines approved by the American Society of Mammalogists (Gannon *et al*. 2007). After genetic sampling and recording body weight and external reproductive features the individuals were released back to their own tunnel system. Locations that were confirmed to have extant populations are listed in Table 1.

Threatening factors

Cultivation. In the 20th century, the expansion of agriculture was the most prominent cause for the loss of the best habitats for wildlife. The most fertile loess soils were the first to undergo changes in land use which has pushed blind mole-rat populations to less favourable areas. The widespread use of deep tillage was the single most important direct effect that so drastically reduced blind mole-rat population sizes and distribution in Hungary as to push the species to the brink of extinction (Csorba 1998). On the one hand, repeated ploughing does not allow the formation of the vegetation type necessary for the survival of blind mole-rats; on the other hand, deep ploughing destroys their underground burrow systems as well as the animals themselves. Nowadays, the most common reason causing tillage is not so much the cultivation itself as the fulfilment of the requirements to apply for funding from the European Community (Németh *et al*. 2010, 2013c). Provided that before its admission to the EU, Romanian agricultural practice sustained adequately large areas to include habitats for blind mole-rats, the present changes in this new member state give rise to grave concerns. Small plot farming with mosaics of fallow land has often given way to intensive crop production in large monocultures. As the same process presumably led to the drastic decrease of the Hungarian populations (Csorba 1998), the same tendencies within the Romanian habitats are more than alarming. Severe reduction in the numbers of Romanian blind mole-rats is imminent (Temple and Terry 2007, 2009; Németh 2011).

Tree plantations. This leads to the complete eradication of the former habitat, and restoration of once afforested areas is a time and resource consuming procedure. Many grasslands have been turned to black locust (*Robinia pseudoacacia*), hybrid poplar (*Populus* x *euramericana*) and pine (*Pinus sylvestris* and *P. nigra*) plantations, which not only exclude blind mole-rats from the transformed areas themselves, but also isolate the population fragments from each other (Németh *et al*. 2010, 2013c).

Natural reafforestation. Arboreal vegetation may spontaneously invade in small meadows surrounded by forest as well as fallow land. This mainly presents a problem when the canopy of trees closes and herbaceous food plants of the blind mole-rats disappear from the undergrowth. Problematic tree species are the black locust (*Robinia pseudoacacia*), grey poplar (*Populus canescens*), box elder (*Acer negundo*), hawthorn (*Crategus* spp) and blackthorn (*Prunus spinosa*) (Németh *et al*. 2010; 2013c). Their appearance is usually the consequence of the lack or reduction of grazing due to the termination of extensive animal husbandry of traditional breeds of cattle and sheep.

Invasive plants. Certain exotics, such as the common milkweed (*Asclepias syriaca*) can grow in such density that other species, including the ones providing forage for the blind mole-rats, disappear from the area. This mainly causes problems on sandy soil; fortunately, the presently known blind mole-rat habitats are not strongly infested yet (Németh *et al*. 2013c; Krivek 2014).

Overgrazing. This is a threat found in some habitats of both *N. (leucodon) transsylvanicus* and *S. antiquus* in Transylvania (Sugár 2009), where overexploitation of the sheep-grazed habitat greatly reduces species diversity, probably causing a significant decrease in the food resources of blind mole-rats.

Urbanization, site development and road constructions. One of the most pressing issues of our times is property development, the construction of new suburbs, industrial parks, solar panel parks, shopping malls, parking lots, and other types of built-up areas. In Hungary, some blind mole-rat populations can be found within settlements (Figure 5). Most of the land in these cases is the property of the municipality and impending industrial investments can mean complete eradication (Krivek 2014; Sendula 2014). A Serbian population inhabits a popular vacation resort, where actual and planned development projects may result in losing the entire population (Németh *et al*. 2013c; Krivek 2014). Road construction can also annihilate populations. This is an omnipresent risk factor in all countries of the region that mainly concerns non-protected areas. In Hungary, one subpopulation disappeared due to the contruction of a new highway exit (Németh *et al*. 2013c).

Figure 5. In many cases, property development poses imminent threat to the remaining population fragments (Mezőtúr, Hungary).

Even though new roads mean the loss of natural habitat, extant roads also pose a threat for wildlife. Heavy traffic kills many animals that set foot on the pavement as it was proven at a location in Hungary where several individuals got hit by vehicles. There is evidence that even lesser roads have a detrimental effect on such isolated and small population fragments (Németh *et al*. 2013c; Krivek 2014). Typically, blind mole-rat habitats are criss-crossed by dirt roads, the effect of which is currently unknown. As a rare type of site development, some localities are the target of specific interventions for military purposes. The Hajdúhadház Military Training Area in Hungary awaits impending development with a large investment and a substantial increase in the frequency of field-days as well as the number of participants. These changes will likely have a dramatic impact on the local Transylvanian blind mole-rat population that was previously counted upon as the only stable population in Hungary, but after the implementation of military plans, their long-term survival is rather doubtful (Németh *et al*. 2013c).

Genetic bottlenecks. Because many populations have become fragmented the resulting limited habitat sizes and low population sizes threaten the long-term viability of populations with inbreeding and other genetic problems (Krivek 2014). Asymmetrical albino spots on each captured individual from the smallest known Transylvanian blind mole-rat population support our assumptions on inbreeding (Németh *et al* 2013c).

Direct and indirect killing. Even though blind mole-rats are protected in all countries within the region, there are still cases of intentional destruction. It is extremely hard to measure this kind of activity, but in small population fragments even the loss of a few individuals may have disastrous effects. Conflicts arise from some individuals living and foraging within human settlements, damaging ornamental plants and vegetables. In the Deliblát region (Serbia), blind mole-rat control incurs an hourly wage rate paid by the human population, even though the species is strictly protected in Serbia (Krivek 2014). It further aggravates the situation that in all countries concerned, rodent traps capable of catching and killing blind mole-rats are routinely available at local vendors. The utility of the traps is sometimes enhanced by using the blind mole-rat in the advertisements. Another anthropogenic threat is the disturbance and destruction caused by pets (dogs as well as cats). Stray dogs and herding dogs are known to have killed several individuals (Németh *et al*. 2010, 2013c).

Natural enemies, predators. The almost exclusively subterranean lifestyle protects blind mole-rats from most predators. As of today, the impact on population dynamics by owls, raptors and mammalian predators is largely unknown.

Extreme weather conditions. Chronically high levels of ground water displaces the mole-rats from lower reliefs, making population fragmentation even more pronounced. Periods of extremely high precipitation or the spring thaw cause inundation at several locations, killing individuals in a number of known populations (Horváth-Vadnay 2006; Németh *et al*. 2010, 2013c).

Global climate change. Hadid *et al*. (2012) analysed the phylogeny of the subfamily Spalacinae calibrated by fossil records. Revealed evolutionary events show a remarkable synchronization with the cycles of solar orbital fluctuations (eccentricity and precession) driving the ice ages. This makes it plausible that global climate changes following the ice ages played an important role in the formation of the unusually high genetic diversity of blind mole-rats.

We can also be sure that the present changes in global climate will significantly impact blind mole-rats, but the direction and the extent of this impact cannot be predicted. In the past, such processes resulted in new taxa of blind mole-rats, but current changes are heavily distorted by human influence. There is a whole host of evidence (Nevo *et al* 1994a, b, 1995; 2000a, b; Reyes *et al*. 2003; Karanth *et al*. 2004) that genetically and geographically distinct taxa adapted to the specific climate of their own range during their speciation. However, blind mole-rat habitats have shrunk to small, isolated fragments that are few and far between, within a matrix impenetrable for blind mole-rats. Isolation is further abetted by their severely limited dispersal capacities. Thus, there is a high likelihood that ongoing climatic changes would rather wipe out blind mole-rat species than give rise to new ones.

Inadequate legal protection. The Natura 2000 system itself is not suitable for blind mole-rat conservation, as it does not target those species that have been completely ignored by Annexes 2 and 4 of the EU Habitats Directory. Another handicap of the Natura 2000 network is that it does not limit infrastructure development, expansion of large-scale agriculture, or renewable energy investments, as long as they do not threaten the survival of species or habitats of community interest in a direct way. As a result, they often ignore conservation needs of taxa outside of EU legislation. The interpretation of Natura 2000 sites as protected areas may therefore be misleading when assessing the conservation status of species that are not of community interest such as blind mole-rats.

Risk Assessment

The Red List categories of the Carpathian Basin blind mole-rats were assessed according to the 2001 criteria (IUCN 2001). Habitats and threats were classified (and terms used) according to the IUCN Habitats Classification Scheme 3.0 and Threats Classification Scheme 2.1, respectively (www.iucnredlist.org).

Nannospalax (*leucodon*) *transsylvanicus* is proposed to be ranked as Vulnerable B1ab (iii); B2ab (iii). Rationale: extent of occurence and area of occupancy are estimated to be no more than 120 square kilometres, known to exist at no more than 10 locations and estimates indicate a continuing decline in area, extent and quality of habitat. Accession of Romania to the EU has already resulted in agricultural intensification (Németh *et al*. 2009).

Nannospalax (*leucodon*) *hungaricus* is proposed to be ranked as Endangered B1ab (iii); B2ab (iii). Rationale: the extent of occurrence and area of occupancy are estimated to be approximately 300 square kilometres; estimates indicate severely fragmented populations in no more than five locations; continuing decline in observed area, extent and quality of habitats. More than 95 % of the population can be found in a single locality.

Nannospalax (*leucodon*) *montanosyrmiensis* is proposed to be ranked as Critically Endangered B1ab (iii); B2ab (iii). This assessment is based on the extent of occurrence which is estimated to be less than 100 square kilometres; area of occupancy is estimated to be less than 10 square kilometres. The populations are severely fragmented, persist in no more than three locations, are continuing to decline in numbers, and are experiencing a loss in the size and quality of habitats.

Nannospalax (*leucodon*) *syrmiensis* is proposed to be ranked as Data Deficient. No definite record is known from the last thirty years. The latest information on the occurrence of this species (determinations were based on karyological data) was published by Soldatović and Savić (1983). No new data pertaining to the distribution and abundance have ever been published (Németh *et al*. 2009). It is very likely that this taxon is extinct (Németh *et al*., in press).

Spalax antiquus is proposed to be ranked as Endangered A3 (c) and B2ab (ii), (iii), (iv)). The categorization is based on the suspected decline in extent of occurrence and quality of habitat within the next 10 years; area of occupancy estimated to be less than 500 km^2, and the species is known to exist at no more than five locations. Accession of Romania to the EU has already resulted in agricultural intensification (Németh *et al*. 2009) that will presumably impact this species negatively.

Conclusions and Future Directions

A decade of investigating the blind mole-rats of the Carpathian Basin fundamentally changed what we had previously assumed about these rodents in this region. The genetic investigations have shown that five, genetically well-differentiated species occur within and exclusively within the Carpathian Basin (Németh 2011; Hadid *et al*. 2012; Németh *et al*. 2013a; 2013b). That is, the blind mole-rats of this region are not locally endangered, peripheral populations of a wide-ranging species, but very localized endemics some of them with extremely low population sizes. One species is probably already extinct, and others are, facing extinction.

Our investigations have also influenced the approach of decision makers towards conservation of blind mole-rats. Already the very first results gave rise to a species action plan laying down the strategy required to protect the blind mole-rat populations of Hungary (Németh *et al*. 2010). The plan has been updated to suit more recent discoveries (Németh *et al*. 2013c). In 2009, a Mole-rat Protection Consulting Committee was established by the relevant ministry in Hungary. It involves experts at national parks, zoological gardens, the nature protection authority, museums, and universities. Its charges are to define priorities, work out conservation actions and offer their opinions on related issues. Members of the Committee were consulted during the protocol of updating Hungary's list of protected species resulting in the acceptance of the latest systematic opinion and in elevating species of the Lesser blind mole-rat complex (*Nannospalax*; superspecies *leucodon*) to the highest conservation rank. Acknowledging the presence of the Vojvodina blind mole-rat near Kelebia was one of the main arguments to establish the Kőrös-ér Landscape Protection Area which provides a safe shelter for approximately 20 % of the remaining individuals of this Critically Endangered species.

A good working relationship has been established between the Mole-rat Protection Consulting Committee and the staff of the Novi Sad Department, Institute for Nature Conservation of Serbia resulting in joint field research and publications. In 2011, the intergovernmental Hungarian–Romanian Joint Committee on the Environment set the investigations of all blind mole-rat species occurring in the two countries as one of its main priorities, so that their habitats and populations can be protected.

The scientific evidence and empirical know-how gathered during the years made it possible to carry out a so far unparalelled conservation intervention on subterranean rodents. As a pilot project, we successfully relocated individuals from the largest Hungarian population of the Transylvanian blind mole-rat to establish new populations and the practical information yielded will make the immediate conservation actions in urgent cases feasible (Németh *et al*. 2013d).

Our research on blind mole-rats of the Carpathian Basin has not only emphasized the importance of scientific investigations for conservation purposes, but also highlighted a phenomenon in which less known and cryptic species can be pushed to the brink of extinction as a result of the lack of information, unclear taxonomic status and unrecognised tasks in conservation. Counterproductively though, conservation initiatives will continue to be biased towards the most studied mammal groups and species (Amori and Gippoliti 2000), while a whole host of less "attractive species" disappears, drastically reducing global biodiversity. Surviving blind mole-rats can serve as umbrella species to protect the wildlife of Central European steppes. We believe it is extremely important that the experts of the IUCN Species Survival Commission re-evaluate the status of the endemic blind mole-rat species of the Carpathian Basin, and possibly also bring their conservation status to the attention of decision makers at the EU level. Moreover, blind mole-rats are unassuming animals; their needs can be satisfied by being appropriately managed and by providing adequately sized grasslands that would allow for population growth (Krivek 2014). With our present knowledge, this is only a question of good intentions and funding. If the latest scientific results serve to raise the awareness of decision-makers to these questions, not only can these endemic mammals evade extinction, but also many other species connected to our remaining Central European steppes can survive as well.

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Resumen

Introducción: De vez en cuando, podría ser útil para revisar y volver ha evaluar los resultados de los programas de conservación y la investigación a largo plazo. Este artículo revisa un programa de investigación en curso que se inició hace 10 años en Europa central sobre las ratas topo ciegas, un grupo de roedores, que no se ha investigado y en consecuencia es enigmático.

Resultados: *Sistemática y Taxonomía*. Por medio de métodos moleculares de secuenciación de genes mitocondriales concluimos que existen cinco especies de ratas topo ciegas, representantes de géneros *Spalax* y *Nannospalax*, en la Cuenca de los Cárpatos. Sobre la base de nuestros conocimientos actuales son las únicas especies de vertebrados terrestres endémicas de la región.

Mapeo de las distribuciones. Las ratas topo ciegas estaban apliamente extendida y eran comunes en toda la Cuenca de los Cárpatos hace cien años. En la última década, todas las regiones de Hungría, la Cuenca de Transilvania y Voivodina, de donde se conocen registros se revisaron sistemáticamente. Mapas y fotografías aéreas proporcionan información sobre la ubicación exacta de los parches de hábitat que se supone deben ser adecuados para las ratas topo ciegas incluso hoy en día. En los últimos años (a partir de 2008) el área de estudio se extendió a todos los lugares donde los residentes informaron sobre la aparición de ratas topo.

Factores que amenazan. La principal causa de la disminución de la población es el desarrollo agrícola que provocó cambios significativos en el cultivo y uso de la tierra. Se definieron los siguientes factores amenazantes específicos: cultivo, plantaciones de árboles, reforestación natural, plantas invasoras, pastoreo excesivo, desarrollo de los sitios, los cuellos de botella genéticos, condiciones tiempo externo, y protección legal inadecuada.

La evaluación de riesgos. Todas las especies de la Cuenca de los Cárpatos ratas topo ciegas fueron evaluados de acuerdo a los criterios de 2001 de las categorías de la Lista Roja. En consecuencia, se propone que una especie a ser clasificado como Vulnerable, dos como en peligro de extinción, una como En Peligro Crítico, y una como Datos Insuficientes (probablemente extinta).

Conclusiones: Los resultados de los estudios biológicos y de sistemática molecular, mapeo de la distribución y la determinación de los factores amenazantes, han tenido efectos profundos en la conservación práctica. Estos incluyen planes de acción, amplias cooperaciones internacionales, el establecimiento de una nueva área protegida, la lista de especies protegidas actualizados, la evaluación de riesgos a nivel de especie, y el primer programa de reubicación de un mamífero subterráneo.

Palabras Clave: distribución reciente, especies protegidas, evaluación de riesgos, factores amenazantes, *Nannospalax*, Spalacinae, *Spalax*

Literature cited

Amori, G., and S. Gippoliti. 2000. What do mammalogists want to save? Ten years of mammalian conservation biology. Biodiversity and Conservation 9:785-793.

Arslan, A., Akan, S., and J. Zima. 2011. Variation in C-heterochromatin and NOR distribution among chromosomal races of mole rats (Spalacidae) from Central Anatolia, Turkey. Mammalian Biology 76:28-35.

Báldi, A., Csorba, G., and Korsós, Z. 1995. Magyarország szárazföldi gerinceseinek természetvédelmi szempontú értékelési rendszere (Setting priorities for the conservation of wildlife species in Hungary). Magyar Természettudományi Múzeum, Budapest, Hungary (in Hungarian with English abstract).

Bihari, Z., Balogh, P., and N. Pethő. 2009. A nyugati földikutya (*Spalax leucodon* Nordmann, 1840) hazai állománynagysága és a faj térhasználata a legeltetés függvényében a Hajdúbagosi élőhely példáján bemutatva (Population size and spatial distribution of Lesser blind mole-rats (*Spalax leucodon* Nordmann, 1840) and the influence of grazing in the Hajdúbagos locality). Természetvédelmi Közlemények 15: 46-56 (in Hungarian with English abstract).

Chişamera, G., E. V. Bužan, T. Sahlean, D. Murariu, S. Zupan, and B. Krystufek. 2014. Bukovina blind mole rat *Spalax graecus* revisited: phylogenetics, morphology, taxonomy, habitat associations and conservation. Mammal Review 44:19–29. doi: 10.1111/mam.12001

Csorba, G. 1998. A földikutya múltja és jelene Magyarországon (The past and present of the blind mole-rat *Nannospalax leucodon* in Hungary). Pp. 288–292. in II. Kelet-magyarországi erdô-, vad- és halgazdálkodási, természetvédelmi konferencia. Elôadások és poszterek öszefoglalója (Palotás, G., ed.). Agrártudományi Egyetem, Debrecen (in Hungarian with English abstract).

Delić, J. 2007. Monitoring of Lesser blind mole rat in the Subotićka peščara" Protected Area. Ludaški zapisi 6:37-40.

Éhik, G. 1925. *Spalax monticola syrmiensis* lelőhely Fehér megyéből (A locality for *Spalax monticola syrmiensis* from Fehér County). Állattani Közlemények 22:52 (in Hungarian).

Ellerman, J. R., and T. C. S. Morrison-Scott. 1951. Cheklist of Palearctic and Indian mammals 1758 to 1946. British Museum (Natural History), London.

Gannon, W. L., R. S. Sikes, and the Animal Care and Use Committee of the American Society of Mammalogists. 2007. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 88:809-823.

Habijan-Mikes, V., M. Mikes, I. Savić, and B. Mikes. 1986. Znacaj kopacke aktivnosti slepog kuceta *Nannospalax hungaricus* (Nehring, 1898). Priroda Vojvodine 9:59-63. (in Serbian).

Hadid, Y., A.Németh, S. Snir, T. Pavlíček, G. Csorba, M. Kázmér, Á. Major, S. Mezhzherin, M. Rusin, Y. Coşkun, and E. Nevo. 2012. Is evolution of blind mole rats determined by climate oscillations? PLoS One 7:e30043. doi:10.1371/journal.pone.0030043.

Horváth, G. 1918a. Kitaibel Pál állattani megfigyelései (Zoological observations of Pál Kitaibel). Annales Musei Nationali Hungarici 16:1-26 (in Hungarian).

Horváth, G. 1918b. Budapest környékének emlősfaunája száz év előtt (Mammals of the surroundings of Budapest a century ago). Állattani Közlemények 17:150-151 (in Hungarian)

Horváth, R., and R. Vadnai. 2006. A földikutya (The Lesser blind mole-rat). Szabolcs-Szatmár-Beregi Természet- és Környezetvédelmi Kulturális Értékőrző Alapítvány, Fehérgyarmat, Hungary (in Hungarian).

Ivanitskaya, E., M. Sözen, L. Rashkovetsky, F. Matur, and E. Nevo. 2008. Discriminiation of 2n = 60 *Spalax leucodon* cytotypes (Spalacidae, Rodentia) in Turkey by means of classical and molecular cytogenetic techniques. Cytogenetic and Genome Research 122:139-149.

IUCN. 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN, Gland, Switzerland and Cambridge.

IUCN. 2014. IUCN Red List of Threatened Species. Version 2014.2. Available at: http://www.iucnredlist.org Downloaded on 18 September 2014.

Karanth, K. P., Avivi, A., Beharav, A. and Nevo, E. 2004. Microsatellite diversity in populations of blind subterranean mole rats (*Spalax ehrenbergi* superspecies) in Israel: speciation and adaptation. Biological Journal of the Linnean Society 83:229–241.

Krivek, G. 2014. A délvidéki földikutya (*Nannospalax* (*leucodon*) *montanosyrmiensis*) gyakorlati védelme. (Practical conservation of the Vojvodina blind mole rat (*Nannospalax* (leucodon) *montanosyrmiensis*). BSc Thesis. University of Szeged, 55 pp. (in Hungarian with English abstract).

Kryštufek, B. 1999. *Nannospalax leucodon*. Pp. 262-263 in Atlas of European Mammals (Mitchell-Jones, A. J., G. Amori, W. Bogdanowicz, B. Kryštufek, P. J. H. Reijnders, F. Spitzenberger, M. Stubbe, J. B. M. Tissen, V. Vohralik, and J. Zima, eds.). The Academic Press. London, United Kingdom.

Kryštufek, B., and G. Amori. 2008. *Spalax leucodon*. In: IUCN Red List of Threatened Species. Version 2014.2. <www.iucnredlist.org> Accessed 17 September 2014.

Kryštufek, B., E. Ivanitskaya, A. Arslan, E. Arslan, and E. V. Buzan. 2012. Evolutionary history of mole rats (genus *Nannospalax*) inferred from mitochondrial cytochrome b sequence. Biological Journal of the Linnean Society 105:446–455.

Lendl, A. 1899. Hazánk néhány speczialitásáról (On some specialities of our country). Természettudományi füzetek 23:39–55 (in Hungarian).

Lendl, A. 1900. Egy új emlősfaj hazánk faunájában (A new mammals species in the fauna of Hungary). A magyar orvosok és természetvizsgálók XXX. Vándorgyűlésének munkálatai 1900:624–627. (in Hungarian).

Lyapunova, E. A., N. N. Vorontsov, and L. Y. Martinova. 1974. Cytological differentiation of burrowing mammals. Pp. 203–215 in the Palaearctic in Symposium Theriologicum II. (Kratochvíl, J., and R. Obrtel, eds.). Academia, Prague, Checen Republic.

Méhely, L. 1909. Species generis *Spalax*. A földi kutyák fajai származás- és rendszertani tekintetben. Magyar Tudományos Akadémia, Budapest, Hungary (in Hungarian).

Mikes, M., V. Habijan, and I. Savić. 1982. Distribution and dispersion of the species *Spalax leucodon* Nordmann, 1840. Säugetierkundliche Mitteilungen 30:161-167.

Musser, G., and M. Carleton. 2005. Superfamily Muroidea. Pp. 894-1531 in Mammal species of the world: A taxonomic and geographic reference, 3rd edition (Wilson, D. E., and D. M. Reeder, eds.). The Johns Hopkins University Press, Baltimore, USA.

Nehring, A. 1897. Mehrere neue *Spalax-Arten*. Sitzungberichte der Berlinischen Gesellschaft Naturforschender Freunde 10:163-183.

Nehring, A. 1898a. Eine neue Nesokia-Species aus Palästina. Sitzungberichte der Berlinischen Gesellschaft Naturforschender Freunde 11:1-8.

Nehring, A. 1898b. *Spalax hungaricus* n. sp. Zoologische Anzeiger 21:479-481.

Nehring, A. 1898c. *Spalax graecus*. Zoologische Anzeiger 21:228–230.

Németh, A. 2011. Taxonomy, distribution and conservation status of Eurasian blind mole rats (Rodentia: Spalacinae) in the Carpathian Basin. PhD. Thesis, Eötvös Loránd University of Budapest, Hungary (in Hungarian with English summary).

Németh, A., G. Csorba, and J. Farkas. 2006. A hazai földikutyák (*Spalax leucodon*) kromoszóma-vizsgálatának módszertana és első eredményei. (First results and methodology of the karyology of the strictly protected Hungarian Lesser Blind Mole Rat (*Spalax leucodon*)). Állattani Közlemények 91:153–157 (in Hungarian with English abstract).

Németh, A., D. Czabán, G. Csorba, and J. Farkas. 2007. Egy fokozottan védett emlős, a nyugati földikutya (*Spalax leucodon*) csapdázásának lehetőségei. (Evaluating the methods for live-trapping of the Hungarian lesser blind mole rat (*Spalax leucodon*)). Természetvédelmi Közlemények 13:439–444 (in Hungarian with English anstract).

Németh, A., T. Révay, Z. Hegyeli, J. Farkas, D. Czabán, A. Rózsás, and G. Csorba. 2009. Chromosomal forms and risk assessment of *Nannospalax* (superspecies leucodon) (Mammalia: Rodentia) in the Carpathian Basin. Folia Zoologica 58:349–361.

Németh, A., J. Farkas, G. Krnács, and G. Csorba. 2010. KvVM Fajmegőrzési tervek: Nyugati földikutya (*Nannospalax leucodon*) (Species Protection plans: Lesser blind mole-rat (*Nannospalax leucodon*). KvVM Természetvédelmi Szakállamtitkárság, Budapest, Hungary (in Hungarian).

Németh, A., Gy. Krnács, V. Krizsik, T. Révay, D. Czabán, N. Stojnic, J. Farkas, and G. Csorba. 2013a. European rodent on the edge: status and distribution of the Vojvodina blind mole rat. SpringerPlus doi:10.1186/2193-1801-2-2.

Németh, A., Z. G. Homonnay, V. Krizsik, M. Csorba, T. Pavlicek, Zs. Hegyeli, Y. Hadid, Sz. Sugár, J. Farkas, and G. Csorba. 2013b. Old views and new insigths – taxonomic revision of the Bukovina blind mole rat, *Spalax graecus* (Rodentia: Spalacidae). Zoological Journal of the Linnean Society 169:903–914. doi: 10.1111/zoj.12081.

Németh, A., G. Csorba, J. Farkas, G. Krnács, A. Molnár, G. Boldog, and B. Szelényi. 2013c. VM Fajmegőrzési tervek: Kárpát-medencei Nyugati földikutya kisfajok (*Nannospalax* (superspecies *leucodon*)) (Species protection plans: the Lesser blind mole-rat species complex (*Nannospalax* (superspecies *leucodon*)). VM Környezetügyért Felelős Államtitkárság, Budapest, Hungary (in Hungarian).

Németh, A., A. Molnár, L. Szél, T. Horváth, L. Demeter, and G. Csorba. 2013d. Hogyan telepítsünk át földikutyát? Módszertani megfontolások szélsőségesen talajlakó rágcsálók megmentéséhez (Relocating mole-rats recommendations on the methodology to save exclusively subterranean rodents). Természetvédelmi Közlemények 19:15–33 (in Hungarian with English abstract).

Nevo, E. 2000. Mosaic evolution of subterranean mammals: Regression, progression, and global convergence. Oxford University Press, Oxford, United Kingdom.

Nevo, E., M. G. Filippucci, and A. Beiles. 1994 a. Genetic polymorphisms in subterranean mammals (*Spalax ehrenbergi* superspecies) in the Near East revisited: patterns and theory. Heredity 72:465–487.

Nevo, E., M. G. Filippucci, C. Redi, A. Korol, and A. Beiles. 1994b. Chromosomal speciation and adaptive radiation of mole rats in Asia Minor correlated with increased ecological stress. Proceedings of the National Academy of Sciences EE.UU. 91:8160–8164.

Nevo, E., M. G. Filipucci, C. Redi, S. Simson, G. Heth, and A. Beiles. 1995. Karyotype and genetic evolution in speciation of subterranean mole rats of the genus *Spalax* in Turkey. Biological Journal of the Linnean Society 54:203–229.

Nevo, E., E. Ivanitskaya, G. M. Filippucci, and A. Beiles. 2000a. Ecological speciation of *Spalax ehrenbergi* superspecies in Jordan: four new putative species. Israel Journal of Zoology 46:169.

Nevo, E., Ivanitskaya, E., Filippucci, M. G. and Beiles, A. 2000b. Speciation and adaptive radiation of subterranean mole rats, *Spalax ehrenbergi* superspecies, in Jordan. Biological Journal of the Linnean Society 69: 263–281.

Nevo, E., E. Ivanitskaya, and A. Beiles. 2001. Adaptive radiation of blind subterranean mole rats: naming and revisiting the four sibling species of the Spalax ehrenbergi superspecies in Israel: *Spalax galili* (2n = 52), *S. golani* (2n = 54), *S. carmeli* (2n = 58), and *S. judae*i (2n = 60). Bachkhuys Publishers, Leiden, the Netherlands.

Orosz, E. 1903. Adatok a földi kutya (*Spalax typhlus* Pall.) életének és előfordulásának ismeretéhez (Data to the knowledge of the blind mole-rat's (Spalax *typhlus* Pall.) life and distribution). Természet 6:3-6 (in Hungarian).

Orosz, E. 1904. Adatok a földi kutya (*Spalax typhlus* Pall.) életének és előfordulásának ismeretéhez (Data to the knowledge of the blind mole-rat's (*Spalax typhlus* Pall.) life and distribution). Természet 7:26–30; 163–165; 177–179 (in Hungarian).

Orosz, E. 1905. Adatok a földi kutya (*Spalax typhlus* Pall.) életének és előfordulásának ismeretéhez (Data to the knowledge of the blind mole-rat's (*Spalax typhlus* Pall.) life and distribution). Természet 8:116–118 (in Hungarian).

Orosz, E. 1906. Adatok a földi kutya (*Spalax typhlus* Pall.) életének és előfordulásának ismeretéhez (Data to the knowledge of the blind mole-rat's (*Spalax typhlus* Pall.) life and distribution). Természet 9:285–286 (in Hungarian).

Ostrowski, S., E. Bedin, D. M. Lenain, and A. H. Abuzinada. 1998. Ten years of Arabian oryx conservation breeding in Saudi Arabia achievements and regional perspectives. Oryx 32:209–222.

Petényi, S. J., and S. Glos. 1845. A fogas vakony (természetrajzi tekintetben Petényi Salamontól, élettani tekintetben Glos Sámueltől) (The mole rat natural history by Salamon Petényi, physiology by Sámuel Glos). A Királyi Magyar Természettudományi Társulat Évkönyvei 1:15 (in Hungarian).

Raicu, P., and D. Duma. 1969. Cytogenetical study in Sp. *leucodon* in Moldavia (Romania). Genetics Research 13:99–104.

Raicu, P., and Ş. T. Torcea. 1973. Chromosomal polymorphism in the lesser mole rat *S. leucodon*. Chromosomes Today 4:383–386.

Raicu, P., S. Bratosin, and M. Hamar. 1968. Study on the karyotypes of *Spalax leucodon* and *S. microphthalmus*. Caryologia 21:127–135.

Reyes, A., E. Nevo, and C. Saccone. 2003. DNA sequence variation in the mitochondrial control region of subterranean mole rats, *Spalax ehrenbergi* superspecies, in Israel. Molecular Biology and Evolution 20:622–632.

Savić, I., M. Habijan-Mikes, V. Mikes, and M. Mikes. 1984. Dinamika prostornog rasporeda i gustine populacije vrste *Nannospalax leucodon* (Nordm, 1840) na Deliblatskom pesku. Pp. 199-203 in III Jugoslavian Ecological Congress, Beograd, Yugoslavia (in Serbian).

Savić, I., and E. Nevo. 1990. The Spalacidae: Evolutionary history, speciation, and population biology. Pp. 129–153 in Evolution of subterranean mammals at the organismal and molecular levels (Nevo E., and A. O. Reig, eds.). Alan R. Liss, New York, EE.UU.

Savić, I., and B. Soldatović. 1974. Die Verbreitung der Karyotypen der Blindmaus *Spalax* (*Mesospalax*) in Jugoslavien. Arhiv Bioloskih Nauka 26:115–122.

Savić, I., and B. Soldatović. 1984. Karyotype evolution and taxonomy of the genus *Nannospalax* Palmer 1903, Mammalia, in Europe. Separate edition of the Serbian Academy of Science and Arts, Beograd 560.

Sendula, T. 2014. A fokozottan védett nyugati földikutya (*Nannospalax leucodon*) újonnan felfedezett állományának természetvédelmi vonatkozásai (The conservation biology aspect of the discovery of a new population of the strictly protected Lesser blind mole-rat). MSc Thesis. Eötvös Loránd University of Budapest, Budapest, Hungary (in Hungarian with English abstract).

Soldatović, B. and I. Savić. 1983. New data on distribution of the representatives of the genus *Nannospalax* Palmer, 1903, in SR Serbia. Pp. 171–174 in Proceedings of the Second Symposium on Fauna of SR Serbia. Beograd, Yugoslavia.

Sós, E., V. Molnár, T. Révay, A. Németh, J. Farkas, A. Hidas, and G. Csorba. 2009. Veterinarian participation at the critically endangered lesser blind mole rat (*Nannospalax* (superspecies *leucodon*)) research in Hungary. Pp. 118–121 in Proceedings of the International Conference on Diseases of Zoo and Wild Animals (Wibbelt, G., P. Kretzschmar, H. Hofer, and S. Seet, eds.). Beekse Bergen, the Netherlands.

Sözen, M., F. Matur, E. Çolak, Ş. Özkurt, and A. Karataş. 2006. Some karyological records and a new chromosomal form for *Spalax* (Mammalia: Rodentia) in Turkey. Folia Zoologica 55:247–256.

Sterbetz, I. 1965. A földikutya új magyarországi lelőhelye Nyírbélteken (Nyírbéltek, a new Hungarian locality for the blind mole-rat). A Nyíregyházi Jósa András Múzeum Évkönyve 8:203–205 (in Hungarian).

Sterbetz, I. 1960. S zabadföldi és laboratóriumi vizsgálatok a földikutyán (In situ and laboratory studies on the blind mole-rat). Állattani Közlemények 47:151–158 (in Hungarian).

Sterbetz, I. 2002. Földikutya (*Microspalax leucodon*, Nordmann 1840) előfordulások a Délkelet-Alföldről (Records of blind mole-rats (*Microspalax leucodon*, Nordmann 1840) from the Southeastern Hungarian Plains). A Békés Megyei Múzeumok Közleményei 23:17–22 (in Hungarian).

Sugár, Sz. 2009. Két erdélyi földikutyafaj (Rodentia: Spalacidae) járatméret szerinti elkülönítésének lehetőségei és populációbecslésük túrások alapján (Possibilities of distinguishing two Transylvanian mole rat (Rodentia: Spalacide) species based on tunnel diameter and their population estimation by mound counts). BSc Thesis, Babes-Bolyai University, Cluj-Napoca, Romania (in Hungarian).

Sugár, Sz., and Z. S. Hegyeli. 2010. Possibilities of distinguishing two Transylvanian mole rat (Rodentia: Spalacide) species based on tunnel diameter and their population estimation by mound counts. Pp. 20 in Abstracts of the 11th Biology Days Babeş-Bolyai University, Cluj-Napoca, Romania.

Sugár, Sz. 2012. A földikutyák (*Spalax* spp.) nagyléptékű élőhelypreferenciája a Szamosmenti dombságon és az Erdélyi Mezőségen (Large-scale habitat preference of blind mole-rats *(Spalax* spp.) in the Someș Hillside and the Transylvanian Plain). MSc Thesis, Babes-Bolyai University, Cluj-Napoca, Romania (in Hungarian).

Szalay, A. 1932. Egy régi magyar okmány a földi kutyákra vonatkozólag (An old Hungarian document regarding blind mole-rats). Állattani Közlemények 64:969–970 (in Hungarian).

Szunyoghy, J. 1937. Egy új Spalax Erdélyből (A new species of *Spalax* from Transylvania). Állattani Közlemények 34:185–191 (in Hungarian).

Temple, H. J., and A. Terry. 2007. The status and distribution of European mammals. Office for Official Publications of the European Communities, Luxembourg.

Temple, H. J., and A. Terry. 2009. European mammals: Red List status, trends, and conservation priorities. Folia Zoologica 58:248–269.

Topachevskii, V. A. 1969. Fauna of the USSR: Mammals. Mole rats, Spalacidae. Smithsonian Institution and the National Science Foundation. Washington, EE.UU.

Tóth, J. 1991. Hazánk rejtett életű, ritka állata a földikutya (Blind mole-rat, an elusive and rare animal of our country). A Természet 42:92–95 (in Hungarian).

Towns, D. R., C. H. Daugherty, and A. Cree. 2001. Raising the prospects for a forgotten fauna: a review of 10 years of conservation effort for New Zealand reptiles. Biological Conservation 99:3–16.

Vásárhelyi, I. 1929. Pusztapó apróemlős-faunája (The small mammal fauna of Pusztapó). Állattani Közlemények 26:150–186 (in Hungarian).

Vásárhelyi, I. 1931. Felsőméra emlős-faunája (Mammals of Felsőméra). Állattani Közlemények 28:49–54 (in Hungarian).

Vásárhelyi, I. 1932. A földikutya (*Spalax hungaricus h.* Nhrg.) Abaújtorna megyei előfordulása (A record of the blind mole-rat (*Spalax hungaricus h.* Nhrg.) from Abaújtorna County). Állattani Közlemények 29:75–77 (in Hungarian).

Vásárhelyi, I. 1960. A földikutya (The blind mole-rat). Természettudományi Közlemények 91:566–567 (in Hungarian).

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