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Hungarian birch mouse, Sicista trizona (Frivaldszky, 1865): past achievements, present status and future visions (Rodentia: Sminthidae)

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Abstract – The aim of this review is to provide a brief summary, based on a decade and a half of intensive research, of the past and future of the rodent species currently known as the Hungarian birch mouse, *Sicista trizona* (Frivaldszky, 1865). The species is endemic to the Carpathian Basin and listed as Endangered by International Union for Conservation of Nature. Past evidence is reinterpreted to provide an updated perspective on the species' probable historical distribution and to discuss expectations for the future. In addition, a brief summary of previously unpublished results is provided: vegetation surveys of the known habitats, annual census and monitoring, genetic studies, and the launch of a captive breeding programme. Ten years ago, experts working on the conservation of this species were very pessimistic about its future, but today the results of the latest surveys, having knowledge of the appropriate management techniques and new directions in the species conservation, are encouraging. If we are able to maintain the *Sicista* research and conservation programme based on the results, and environmental factors do not change drastically, there is a good chance that we can manage to ensure long-term protection and maintenance for the population of Hungarian birch mouse. With five figures.

Key words – endangered species, monitoring, species conservation, population genetics, grassland

INTRODUCTION

The last review about this rodent, formerly classified as Southern birch mouse – *Sicista subtilis* Pallas, 1773), was published in Hungarian seventeen years ago (Cserkész *et al.* 2004). Since then, the species has been the focus of several research and nature conservation projects and re-classified from *S. subtilis* to Hungarian birch mouse (*Sicista trizona* Frivaldszky, 1865) (Cserkész *et al.* 2016). The Hungarian birch mouse is endemic to the Carpathian Basin, listed now as Endangered by the IUCN and on Annex IV of the Habitats Directive, and strictly protected in Hungary.

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The aim of this short review is to provide a summary of the past and what future we envision for the species. Hence I reinterpret past evidence to provide an updated perspective on the species' probable historical distribution and discuss expectations for the future. In addition, I provide a brief summary of unpublished results: vegetation surveys of the known habitats, the results of annual censuses, monitoring and genetic studies. I also report on launching of a captive breeding programme in the Budapest Zoo & Botanical Garden.

The subject of this review is clearly related to the present *Annales* volume dedicated to the 150th anniversary of Imre Frivaldszky's death. The scientific binomen *Mus trizonus* was introduced by him as a junior synonym of *Sminthus vagus* Blasius, 1857 (Frivaldszky 1865). However, in this short summary the focus is not on the history of the nomenclature, as it has been already presented by Bálint & Gubányi (2006). Instead, my aim is to inform the reader about the past and possible future status of the Hungarian Birch Mouse (hereinafter referred to as HBM).

THE PAST

Although the species-group name *trizona* was introduced by Imre Frivaldszky (1799–1870), Lajos Méhelÿ (1862–1953) was the first to carry out scientific research on birch mice, and separated the birch mouse population inhabiting grasslands of the Great Hungarian Plain as a subspecies *trizona* based on the morphology of penile spines (Méhelÿ 1913). By examining the morphology of the male sexual organ, Méhelÿ was far ahead of his time. The significance of his discovery is shown by the fact that 100 years later, the re-evaluation of this anatomical characteristic combined with genetic studies led to a proposal to elevate the subspecies *trizona* to species- level and the description of one novel subspecies *Sicista trizona transylvanica* Cserkész et al. 2016 (Cserkész *et al.* 2016). As it was observed in many other species now assessed as endangered, HBM distribution was much larger in the early 20th century. Prior to the 1950s, when ploughing of grasslands was limited and grasslands were more intact, HBM was found in all suitable grassland habitats (Fig. 1).

The locations of the known occurrences indicate more where researchers actively gathered data than the distribution area: Frigyes Cerva, Salamon, János Petényi and Mihály Svoj found HBM in several places in the vicinity of Budapest, while István Vásárhelyi in the central part of the Great Hungarian Plain, around Kisújszállás (Chyzer 1882; Cerva 1929; Vásárhelyi 1929; Vásárhelyi 1941). Egon Schmidt received owl pellets and found the remains of HBMs from several regions of Hungary. The most important records are from Baja and the Hernád valley, and it is especially interesting that HBM was also found in an owl pellet collected in Telki at the western foot of the Buda Hills (Schmidt 1962; Schmidt 1971; Schmidt & Sipos 1971). Due to the long distance (approximately

50 km), it can be ruled out that the owl flew over Budapest to the northern edge of the Kiskunság and captured the mouse there; in fact the record clearly indicates that the HBM also lived in Transdanubia, even near Budapest!

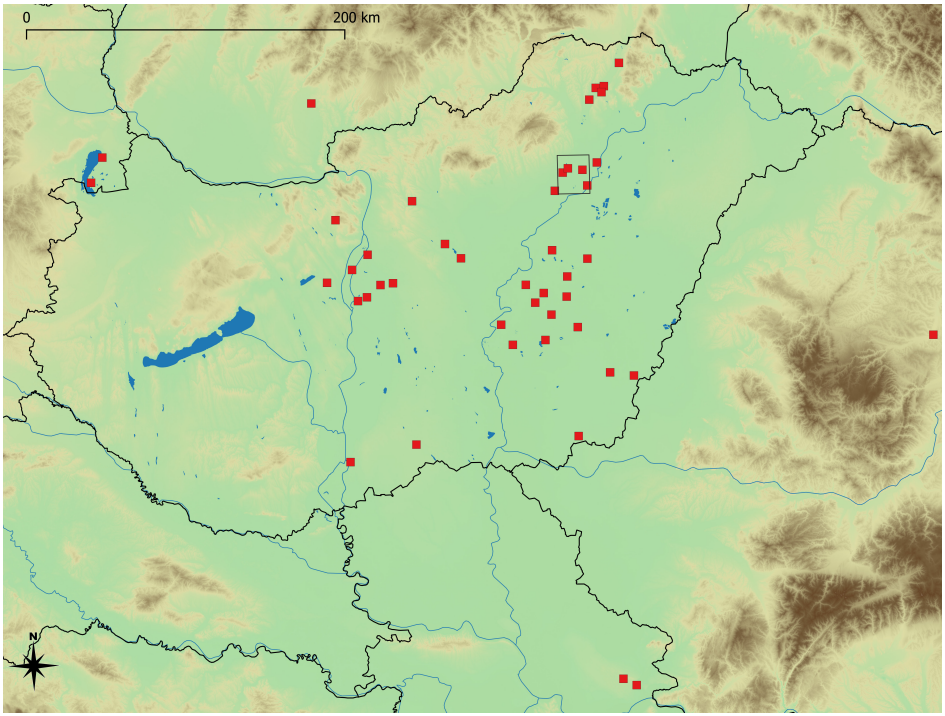

Figure 1. Map of the all known occurrences of the Hungarian birch mouse *Sicista trizona* (Frivaldszky, 1865); the recent occurrences in Hungary are in frame as indicated.

After Schmidt's research, Péter Szentgyörgyi also found HBM in owl pellets originating from the Hernád valley, most recently in a sample from 2008 (Szentgyörgyi *et al.* 1996; Szentgyörgyi 2014; Kondor *et al.* 2015). Kondor *et al.* (2015) argue that the HBM may have still inhabited the Hernád valley at the turn of the millennium, but the population size could be very small. The extent of HBM's range may have halved during the last 50 years in the Hernád valley. However, relatively large habitat fragments can still be found here, so the size of habitat patches has not reduced to such an extent as to justify the disappearance of the species. However, the cumulative effects of improper land use (e.g. burning of grasslands, decrease in number of grazing livestock) have radically changed the quality of the habitats (Kondor *et al.* 2015). The HBM has probably been extirpated in the Hernád valley during the past decade; it could have been saved if the surveys had started 10–15 years earlier. It is an unfortunate fact that between 1936 and the early 2000s, the HBM fell into oblivion in Hungary.

There is a large information gap on the occurrence of HBM in the Great Hungarian Plain and historical data on species occurrences are not available from the Little Hungarian Plain. These gaps are certainly due to a lack of surveying for the HBM there in the last century, and today it is unlikely that the HBM would be present due to intensive ploughing, which means that the area no longer meets the requirements of HBM. However, the HBM was previously found on the other side of the border, in Austria and Slovakia, so it is not unreasonable to conclude that the HBM inhabited the northern side of Transdanubia in Hungary, too (Bauer 1954, Demeter & Obuch 2004). This indicates that the HBM almost became extinct in Hungary and Central Europe during the 20th century, and only a single population survived in north-eastern Hungary.

HBM-research during the last 15 years in the region of Borsodi-Mezőség

HBM research in Hungary began on 20th June 2006, when the first individual was captured in pitfall traps targeting HBM. During the last 15 years regular and consistent monitoring using pitfalls has taken place, supplemented with trail camera surveys in the last four years (Fig. 2). We also prioritised gathering data on the total extent and spatial patterns of distribution. We found the population size fluctuated significantly due to variation in habitat management and weather conditions: the lowest population density was estimated in 2015, while the highest in 2020 when the wild boar (*Sus crofa* Linnaeus, 1758) population collapsed in Hungary due to rapid spreading of the African swine fever virus. The wild boar may be one of the key predators of the HBM.

Thanks to ongoing molecular studies, the population genetic structure of the population is becoming better known. The heterozygosis is similar to what was detected in *S. subtilis vaga* (Pallas, 1779) sampled in the "infinite steppes" of Kazakhstan indicates the HBM population has high genetic diversity and the (effective) population size may be higher than was previously assumed (Sramkó *et al.* 2017). The population went through a bottleneck between 2007 and 2011, which can also be seen in monitoring data (see Fig. 3). Mechanical mowing of HBM habitats may be the cause of this bottleneck, so this type of management is not recommended for birch mouse habitats. Tissue samples collected in the Borsodi-Mezőség were used for the taxonomic revision of *S. subtilis* species group based on CytB and IRBP sequences. It led to elevation of *trizona* to species-level (Cserkész *et al.* 2016). The population genetic structure dataset also supported this taxonomic rearrangement (Sramkó *et al.* 2017). The changes in the taxonomy of the *S. subtilis* species group has now been accepted (see Holden *et al.* 2017; Burgin *et al.* 2020) and the *S. trizona*, already treated as a separate species, was assessed as Endangered by the IUCN (Cserkész 2019).

A

B

Figure 2. A living specimen of Hungarian Birch Mouse *Sicista trizona* (Frivaldszky, 1865) photographed by a trail camera, in the red circle (A), and normal camera (B).

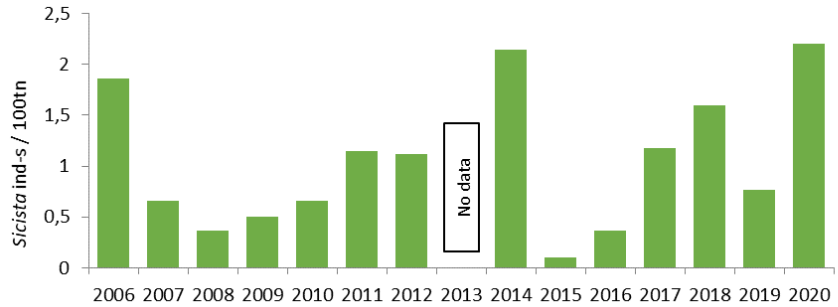

Figure 3. Fluctuating population density of Hungarian birch mouse estimated by pitfalls. x: years, y: captured individuals/ 100 trapnights

Vegetation patterns were mapped and surveyed in 2006 (Sramkó 2006), then a new survey was completed in 2020 to document the change and the newly found habitat patches (Barina 2020). HBM occurrence and range is not related to a narrow range of habitats. The consistent conclusions of the two surveys indicate that HBM presence is not limited to natural habitat patches, but that it also persists in environments significantly disturbed. Both survey findings suggested that HBM was present in degraded habitats, apparently preferring habitat patches which were recently disturbed. However, due to regular disturbance, these degraded habitat patches are unlikely to be suitable for the medium and long-term survival of an animal species.

It is recommended that the species' habitat preferences are examined in a larger perspective, taking into account that due to the changing land use and habitat management, HBM occurrences at a fine scale may have changed even in a short time (Barina 2020). It is also assumed that the presence of the species is not tied to a particular plant species and possibly neither to a specific habitat. It is more likely that a sufficiently diverse and structurally complex habitat will promote the long-term survival of the species, across a mosaic of different landscapes that preserve biodiversity on a wider scale (Barina 2020).

THE PRESENT

In Austria and Slovakia, the HBM is considered extinct, hence the chances of a population still existing in Transdanubia (W. Hungary) is negligible. The distribution area in Hungary is limited to a single landscape protected area, the region Borsodi-Mezőség, where it currently occurs in eleven separate habitat patches, covering twelve 1x1 km ETRS grids. The size of the known habitat patches is 243 hectares; the area of potential habitats is about ten times that.

The central habitat "Nagyecsér", covering almost 45 hectares, was not leased by the Bükk National Park Directorate, but kept under its own management. The

area functions as an unofficial "Sicista Reserve", where the habitat management meets the needs of the HBM: the mowing is neglected; excessive scrubbing is prevented by moderate cattle and horse grazing in the autumn. Part of the central habitat patch is protected by mobile electric-fence from wild boars, foxes and other mammalian predators. In other known HBM habitat patches, the management is suitable for the requirements of the species. The HBM population has been maintained and strengthened, which is an indication that we are managing the habitat in a suitable way.

After a long preparation, the HBM captive management programme was launched in the Budapest Zoo and Botanical Garden. In late May and early June of 2021, two adult pairs were captured in the Borsodi-Mezőség and relocated to the Zoo to observe the little-known behaviour and reproduction of these special animals. However, the long-term aims are not limited to keeping but to maintain the gene pool, with minimal losses of diversity, and establishing a breeding population that could even be vital to conserving the species. The time may come when captive breeding may represent the only hope of maintaining genetic stocks of this species or populations. However, a detailed study of reproduction in the HBM has, to the best of the author's knowledge, never been undertaken and only a few anecdotal descriptions have been published (VÁSÁRHELYI 1929).

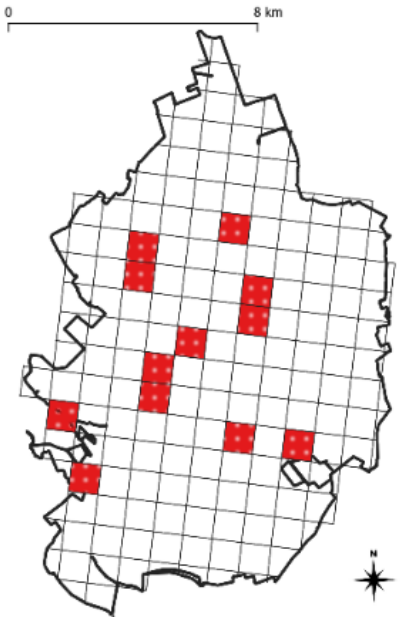

Figure 4. Sematic map of the region Borsodi-Mezőség where the occurrence of the Hungarian birch mouse is confirmed in twelve 1x1 km ETRS grids (red squares)

Some might ask why the HBM or the other *Sicista* species are so special when they are just a mouse, and mice have long been kept and bred for lab research. However, in spite of their vernacular name, the HBM is not a "true mouse" but a member of an ancient rodent superfamily, the Dipodidea, which is only distantly related to the true mice of the family Muridae. It has a special lifestyle and behaviour: on one hand it behaves like a predatory species feeding on a wide range of insects, but on the other hand it is surprisingly gentle and tame to handle, and, unlike true mice, not very prolific, as it breeds only once in a year. They may have many other special characteristics yet to be uncovered, which may have contributed to the failure of previous captive breeding trials. These birch mice have never reproduced in captivity, and so researchers and zoo professionals face a major challenge in establishing a breeding population.

According to the latest surveys, the HBM is not rare in the region Borsod-Mezőség, which allows us to capture a few animals in every year (with permission from the competent authority) and try to study them in captivity under controlled conditions. Our goal is to study the species' reproduction biology and take the first steps towards implementing the breeding programme before populations decline further and we are forced to experiment with captive breeding.

Figure 5. A typical Hungarian birch mouse *Sicista trizona* (Frivaldszky, 1865) habitat patch in the region Borsodi-Mezőség (NE Hungary).

VISION OF THE FUTURE FOR THE HBM

The long-term objective of the captive breeding program is to establish a population via controlled breeding that is large enough to be demographically stable and genetically healthy. This objective will ensure that populations exhibit a healthy age structure, resistance to disease, consistent reproduction, and preservation of the gene pool to minimize and/or avoid problems associated with inbreeding. If the keeping proves successful, more mice will be moved to the Zoo over the years, and some of the offspring will gradually be released into the wild. Our final goal is to re-establish a self-sustaining population in the wild. In our vision of the HBM's future, we imagine a steady increase in populations both

in the wild and captivity, which can be used to reintroduce HBM into its former habitats in the Kiskunság, Hortobágy or the valley of river Hernád.

However, reintroduction is only feasible if survival can be assured; the home range and survival of captive-born and released individuals will need to be continuously monitored using radiotelemetry. It was mentioned earlier that the HBM is a tame rodent, it does not bite or escape when taken in hand. Using the opportunities presented by this behaviour, we could hold demonstrations with captive-born mice at the Zoo and the Hungarian Natural History Museum, where visitors could be supervised in handling the animals. This would provide an unforgettable opportunity for the public to connect with nature and one of the country's most hidden natural treasures. Budapest Zoo has limited space, so to maintain healthy population and using the breeding protocol that the Zoo would develop, a breeding centre could be established in Mezőnagymihály (County Borsod-Abaúj-Zemplén), in an easy accessible place, close to Miskolc, Eger, Budapest and the M3 motorway. It is generally recognized that captive breeding is most effective when integrated into a comprehensive conservation program that addresses problems faced by the species in the wild. Successful captive breeding does not diminish the importance of addressing habitat-based threats to the species. Maintaining and increasing wild populations and suitable habitat continues to be essential for HBM conservation and will remain a priority.

We have to use the leading innovations in conservation, genetic research, and the protection of endangered species to provide solutions to future conservation challenges. High-quality and complete reference genome assemblies are fundamental for the application of genomics to biodiversity conservation. Complete and error-free genome assemblies of HBM will be available and cell cultures maintained in a cryobank that can be used later for cloning to increase the genetic diversity of the captive population, if necessary.

CONCLUSIONS

Ten years ago, the experts working on the conservation of the HBM were very pessimistic about the future of the species. Today, the results of the latest surveys, having knowledge of the appropriate management techniques and the new directions in the species conservation are encouraging. If we can maintain the *Sicista* research and conservation programme, and the environmental pressures do not change drastically, there is a good chance that we can manage to ensure long-term protection and maintenance for the HBM population.

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Acknowledgements – The *Sicista* research and conservation programme is carried out in collaboration with a number of institutions and organizations: Bükk National Park Directorate, Bükk Mammalogical Society, Budapest Zoo & Botanical Garden, MTA-DE "Lendület" Evolutionary Phylogenomics Research Group. I am grateful to cooperation of these partners. Preparing of this review and the surveys of the last two years were supported by the GRASSLAND-HU LIFE (LIFE17 IPE/HU/000018). I am really thankful to Katherine Sainsbury for her help in improving the English of the manuscript. I thank Péter Balázsi and Botond Bakó for their discussion and corrections.

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A magyar szöcskeegér, Sicista trizona (Frivaldszky, 1865) múltja, jelene és jövője (Rodentia: Sminthidae)

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Összefoglalás – A tanulmány rövid összefoglalást kíván adni arról, hogy bő másfél évtized szöcskeegér-kutatás tapasztalatával felvértezve, miképpen látjuk az immáron magyar szöcskeegérnek, *Sicista trizona* (Frivaldszky, 1865), nevezett Kárpát-medencére nézve endemikus, a Természetvédelmi Világszövetség (International Union of Conservation for Nature) szerint veszélyeztetett állatfaj múltját, melyek a kutatás aktualitásai, és milyen jövőképet vázolhatunk fel a faj számára. A hangsúlyt az újraértelmezésre, az aktualitásokra, a nem publikált, vagy csak pályázati jelentésekben leírt eredmények rövid összegzésére, valamint a jövőkép bemutatására helyezzük. A cikk áttekinti az élőhely-felmérések, a monitorozás, a genetikai vizsgálatok eredményeit, valamint a zárthelyi tartás kezdetét és tervezetét. Tíz évvel ezelőtt még pesszimisták voltak a faj védelmével foglalkozó szakemberek, ma a legújabb felmérések eredményei, az élőhelyek megfelelőnek tartott kezelése és a fajmegőrzés új irányvonalai bizakodásra adnak okot. Amennyiben sikerül fenntartani a magyar szöcskeegér kutatásával és védelmével foglalkozó programot és a környezeti hatások nem változnak drasztikusan, jó eséllyel hosszútávon is biztosító a faj magyarországi populációjának fennmaradása. Öt ábrával.

Kulcsszavak – veszélyeztetett faj, monitoring, fajmegőrzés, populáció genetika, gyepek

ÁBRAMAGYARÁZATOK

1. ábra: A magyar szöcskeegér, *Sicista trizona* (Frivaldszky, 1865) ismert lelőhelyei a Kárpát-medencében; a recens magyarországi előfordulási pontok keretben.

2. ábra: Magyar szöcskeegér, *Sicista trizona* (Frivaldszky, 1865) élő példánya kameracsapdával (A) és kézi kamerával (B) készült felvételen.

3. ábra: A magyar szöcskeegér, *Sicista trizona* (Frivaldszky, 1865) becsült egyedsűrűség talajcsapdákkal mért ingadozása a nagyecséri monitoring területen. x-tengely: felmérés éve, y-tengely: szöcskeegér egyed/100 csapdaéjszaka.

4. ábra: A magyar szöcskeegér, *Sicista trizona* (Frivaldszky, 1865) jelenléte 2021-ben tizenkettő 1x1 km-es ETRS négyszögben ismert.

5 ábra. A magyar szöcskeegér, *Sicista trizona* (Frivaldszky, 1865) jellegzetes élőhelye a Borsodi-Mezőség Tájvédelmi Körzetben.