Significant westward range expansion of the Steppe mouse *Mus spicilegus* Petényi, 1882 between 1999 and 2019

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The Steppe or Mound-building mouse (*Mus spicilegus*) in Austria is known from the northern Burgenland and the most eastern part of Lower Austria. In the course of looking at its reaction to the intensified agricultural use of the area a westbound extension of this so far known western-most range of the species of approximately 15 km was observed since 2000. This western movement coincides well with the increase of the mean winter temperatures in the area as it was observed in other regions and for other mammal species.

Herzig-Straschil B. & Schmelzer E., 2022: Erweiterung des Verbreitungsgebietes der Ährenmaus, *Mus spicilegus*, an der Westgrenze zwischen den Jahren 1999 und 2019.
Die Ährenmaus (*Mus spicilegus*) ist in Österreich vom Nordburgenland und dem äußersten Osten von Niederösterreich bekannt. Im Zuge einer Untersuchung zur Gefährdung der Art durch moderne landwirtschaftliche Methoden, zeigte sich eine Erweiterung des Verbreitungsgebietes und damit Verschiebung der Westgrenze der Art um etwa 15 km seit 2000. Diese Ausbreitung fällt auffallend mit der Erhöhung der mittleren Wintertemperatur zusammen. Die Entwicklung wurde auch in anderen Gegenden und für andere Säugetiere beobachtet.

Keywords: *Mus spicilegus*, range expansion, temperature change.

Introduction

The Steppe mouse or Mound building mouse (*Mus spicilegus*) is endemic to Europe. The distribution is restricted to plains from the extreme south-west of Russia in the east to eastern Austria in the west with isolated populations in Montenegro, Albania, and northern Greece (Macholán 1999). In Austria, the species is restricted to parts of the Pannonian east, i.e. the northern Burgenland and the extreme southeast of Lower Austria, thus representing the westernmost part of the species range (Fig. 1).

M. spicilegus looks rather unspectacular. In size and appearance, it is very much like its close relative, the Eastern house mouse *Mus musculus*. The fur is gray-brownish, the tail slightly shorter than the head-body length and ears are well visible. It clearly differs from the commensal *M. musculus* by avoiding human buildings and the lack of the typical odour of the house mouse (Brauner 1925, Festetics 1961, Mezhzherin & Kotenkova 1992). Further, the species exhibits a special social organization by being at least mainly monogamous (Garza et al. 1997, Gouat et al. 2003) and showing the unique cooperative behaviour of communal overwintering, whereas *M. musculus* is polygynous and tends to breed cooperatively. Finally, *M. spicilegus* are almost unique among rodents by the habit of constructing conspicuous mounds above ground with a nest for overwintering in the ground underneath (Fig. 2).

M. spicilegus inhabit natural steppe grasslands and agrocoenoses. Generally, open areas with concentrations of plants which produce seeds, buds, grains and leaves they feed on and need to build their mounds. In Austria, these mounds were found on fallow lands, harvested grain fields, disturbed vegetation around building sites, young afforestations,

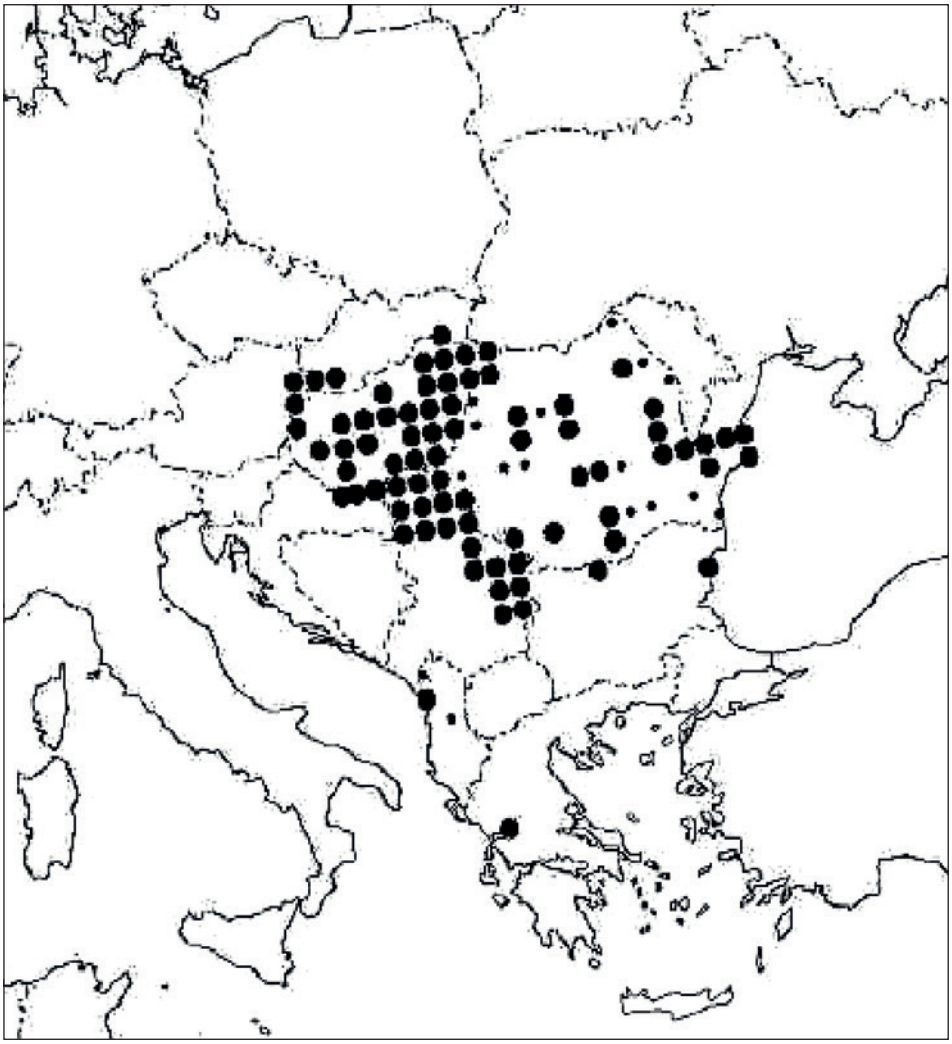

Fig. 1: The distribution of *M. spicilegus* is restricted to south eastern Europe. The distribution in Moldavia, Ukraine and extreme south-western Russia is not covered by this map (according to Macholan 1999, modified). – Abb. 1: Die Verbreitung von *M. spicilegus* ist auf den Südosten Europas beschränkt. Die Verbreitung in Moldavia, Ukraine und dem äußersten Südwesten Russlands ist in der Karte nicht erfasst (nach Macholan 1999, verändert).

orchards and food plots for game. The species was originally known from a greater part of the northern Burgenland and adjacent areas of the extreme south-east of Lower Austria (Fig. 3). As can be seen, the distribution changed significantly after 1999. The primary aim of the study was to see how Steppe mice in their original range in Austria were affected by the intensified agricultural activities since the last detailed investigation (Unterholzner & Willenig 2000, Bauer 2002).

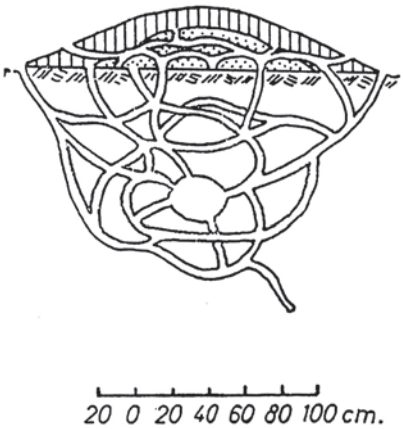

Fig. 2: Architecture of a mound of *M. spicilegus*: Plant material is collected, piled up and finally covered with earth; the winter nest of the animals is underneath in the ground, tunnels lead to the inside of the mound, to the outside around the mound or are dead ends (according to Mikes 1971, modified). – Abb. 2: Architektur eines Ährenmaushügels: das gesammelte Pflanzenmaterial im Zentrum wird mit Erde überdeckt; das Winternest der Tiere befindet sich darunter im Boden; Gänge reichen vom Nest in den Hügel und nach außen oder enden blind (nach Mikes 1991, verändert).

Mounds which indicate the presence of *M. spicilegus* are usually built between August and December and thus to an extent during harvesting time (Fig. 4). Cultivation of most fields commences shortly after the harvest and many freshly started or finished mounds are destroyed. Modern harvest machines leave almost no grains behind and the regular use of biocides reduces the growth of plants which they use as food and for construction of the mounds.

The status of *M.spicilegus* in the IUCN Red List is "Least concern" (Coroiu et al. 2016).

In the Red List of Mammals of Austria (Spitzenberger 2005), the species is listed as "Endangered" and regarded threatened with extinction due to habitat loss of natural steppe areas and intensified agricultural activities.

Therefore an update of our knowledge of the situation of the species in Austria was urgently needed. When we received owl pellets from the "National Park Neusiedler See – Seewinkel" with remains of *M. spicilegus* we noted localities of Steppe mouse mounds when we came across them from early 2000 onwards and intensified the search after 2008. In 2010, a LEADER project ("Schutzprogramm Ährenmaus", Naturschutzbund Burgenland, ISBN 978-3-902632-29-6) started and enabled us to study the distribution of the species in more detail. The project was financed by the government of Burgenland and the EU. Intensive mapping of mounds ended in 2013 with the termination of the project but we continued casually recording *M. spicilegus* mounds.

While studying the species in its known range in the eastern part of Austria we realized its range had grown since the last detailed description of its distribution by Bauer (2002) and discuss the expansion of the species range.

Material and Methods

M. spicilegus live in agrocoenoses and areas with disturbed vegetation in eastern Austria. Their presence is easily detected by the characteristic and conspicuous mounds they build from parts of the surrounding vegetation. Underneath such mounds in the ground are the nests of the overwintering animals (Fig. 2).

Petényi (1881) gives a first description of the mounds. Mikeš (1971) illustrates the architecture of these characteristic mounds (Fig. 2). Unterholzner & Willenig (2000) describe the construction of a mound in detail on the Parndorfer Platte, the main distribution area in Austria. Each member of a group of up to 11 specimens carries seeds, buds and

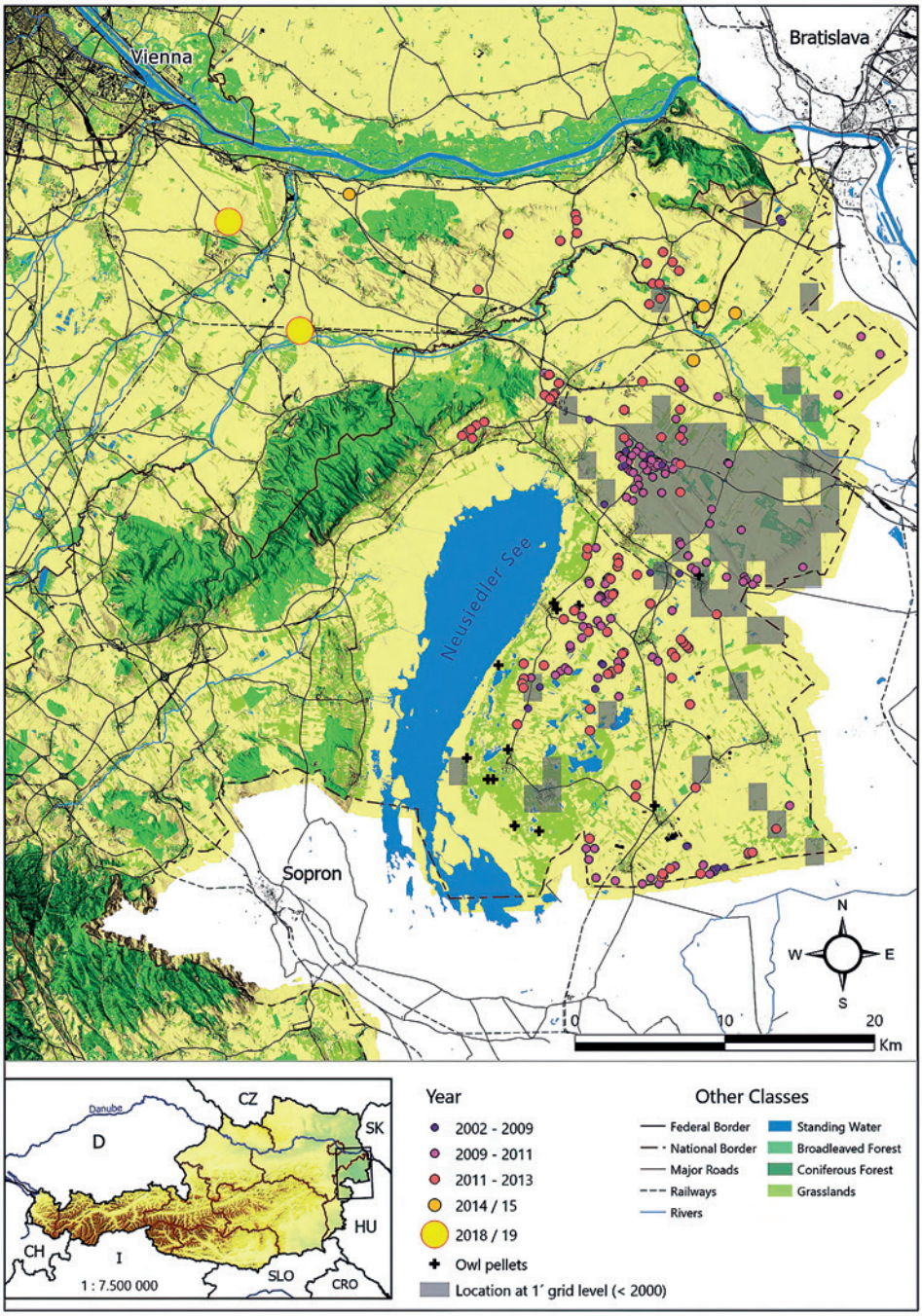

Fig. 3: Distribution of *M. spicilegus* in Austria until 2019. The distribution up to 1999 (Bauer 2002, plus additions) are the grey shaded areas on 1° grid level. – Abb. 3: Verbreitung der Ährenmaus in Österreich bis 2019. Die Verbreitung bis 1999 (Bauer 2002 mit Ergänzungen) ist als grau schattierte 1° Felder dargestellt.

Fig. 4: Mounds of *M. spicilegus* in a stubble field. – Abb. 4: *M. spicilegus* Hügel in einem Stoppelfeld.

Fig. 5: The first step of a mound construction: in this case collected sun flower seeds. – Abb. 5: Der Beginn eines Hügels: in diesem Fall zusammengetragene Sonnenblumenkerne.

Fig. 6: Details of a finished mound of *M. spicilegus*. The ditch around the mound deriving from scraping up the earth to cover the mound and some tunnel openings are well visible. – Abb. 6: Details eines fertigen Ährenmaus Hügels mit einem deutlichen Graben an der Basis, der durch die Verwendung der Erde zur Überdeckung des Hügels entsteht und einige Tunnelöffnungen.

multiple fruits to a chosen locality and deposits them in layers until a mound has developed (Fig. 5). Plant material is collected from 5–10 m in the surrounding. Finally, the mound is covered with a thin layer of plant material like pieces of straw. Then the animals scratch earth from the basis of the heap up to the sides with the hind legs and, if convenient, carry earth in the mouth to the top until the mound finally is completely covered with earth. This way of construction leads to a well visible ditch around the base of the heap where they take the earth from. Several tunnel entrances are around the basis of a mound (Fig. 6). Some of these lead to the winter nest in the ground underneath, others are just dead ends. The builders of a mound overwinter in the nest in the ground underneath without reproducing. The inhabitants are usually a pair of adult specimens and a few subadults (Garza et al. 1997, Gouat et al. 2003,). In spring, when the old pair has usually already disappeared, the other specimens leave the nest and start reproducing somewhere else (Muntyanu 1990). The reproduction period at the Parndorfer Platte lasted from March until October. The average number of young was 2–11 (Unterholzner & Willenig 2000).

We observed mound building from August to December, with one exception, when we found fresh mounds already in June. Mounds were round to elliptic with diameters of up to 150 cm and a length of more than 200 cm (where two neighbouring heaps were growing together). The height was up to 40 cm. These measurements resemble published data

for the area, and the list of plants used is not much different than the ones published already (Csanády et al. 2019, Hölzl et al. 2009, Szenczi et al. 2011, Unterholzner & Willenig 2000).

While mounds were originally regarded as pure food storage for the wintertime, recently a thermoregulatory effect for the nest in the ground by insulating against cold and wet conditions during wintertime is discussed (Bihari 2003, Hölzl et al. 2011a, Szenczi et al. 2011). Food preferences and plant rests in faeces showed other plants than cached in the mounds (Hölzl et al. 2011b, Szenszi et al. 2011) which indicates that the steppe mouse feeds outside even during wintertime. Csanády et al. (2019) studied the morphology of burrows and mounds in Slovakia. They found winter nests not always exactly beneath the mounds but displaced to the side. They, therefore, question a thermoregulatory effect of the mounds.

In any case, sightings of mounds prove the presence of *M. spicilegus*. During the years from 2000 onwards we noted the exact location of mounds of *M. spicilegus* whenever we came across them and intensified our investigation further towards 2010 when the LEADER project "Schutzprogramm Ährenmaus" started. Between 2011 and 2013 we noticed a clear expansion of the distribution to the west north of the Neusiedler See.

For the distribution map, we mainly used results of our mapping from 2000 to 2019 based on the presence of the characteristic mounds. We further used data of collected specimens and documented observations of activities of these mice in the collection of the Natural History Museum Vienna as well as published data (Unterholzner et al. 2000, Bauer 2002). Also included in the distribution map are collecting localities of owl pellets with remains of *M. spicilegus* (until 2016), and the locations of reliable observations of mounds reported to us by colleagues. It must be mentioned that although the mice might use some fields for several years, most locations shift from year to year depending on the change in suitable natural vegetation and cultivated plants. Mounds appear alone or in groups. The number of mounds per hectare varied strongly, and we recorded between 1 to 17 mounds per hectare.

For recording the (central) coordinates of the plots with mounds we used a GPS Garmin 62s or cell phone apps. Some localities of older data and reports we localized on Google Earth Pro. Data up to 1999 are indicated in the map (Fig. 3) in 1° grid level following Bauer (2002) and some additions.

The region of the previously known distribution and adjacent areas of the species in Austria was regularly controlled from 2010 to 2013. When we found mounds slightly out of the range north of the Neusiedler See we subsequently further expanded our search. With the end of the project in 2013 intense controls stopped but sightings of mounds were recorded when coming across them during other fieldwork 2019. During regular trips between the northern Burgenland and Vienna by car or train mound sightings were recorded and a more detailed search of the area followed.

Results and discussion

The most striking result of our investigation is the proof of an expansion of the range of *M. spicilegus* from eastern-most Austria (the northeast part of the federal state Burgenland: Seewinkel, Heideboden, Parndorfer Platte and the extreme east of adjacent Lower Austria) to the west into Lower Austria until slightly east of Vienna. The western border of the worldwide distribution thus moved by about 15 km west between ca. 2000 and 2019.

For the distribution of the Steppe mouse in Austria until 1999 we followed Bauer (2002) with some additions, marked in the map as 1° grid level (Fig. 3). In the years before this publication a network of volunteers in the Pannonian east of Austria existed who reported observations and donated material to the Mammal Collection of the Natural History Museum Vienna. Furthermore, an intensive survey of the mammal fauna of Austria was carried out from 1975 to 1980. Therefore, it can be assumed that the distribution of *M. spicilegus* was well documented and resulted in a reliable map in the Säugetierfauna Österreichs (Spitzenberger 2002).

Between 2011 and 2013, an expansion of the distribution to the west north of the Neusiedler See became obvious. There a further move to the west is inhibited by the Leithagebirge covered with woods. We kept on mapping mounds of Steppe mice and widened our search further to the northwest where possible habitats existed. In the winter of 2014/15 we received a message of a sighting of mounds further northwest near the Danube. It took until February 2019 that we spotted 10 mounds on fallow land between the villages of Götzendorf an der Leitha and Trautmannsdorf an der Leitha (48.023088 N/16.617514 E). Further investigations in the area resulted in locating few isolated mounds until we discovered seven mounds on a stubble field at 48.088720 N / 16.553995 E near the village of Schwadorf bei Wien marking sofar the western-most point of the distribution.

The present distribution (Fig. 3) still shows a concentration of locations of mounds in the originally known area of distribution. Slight shifts in the coverage within this area are most probably due to changes in agricultural regimes. But the map clearly illustrates that the western border of the species range has moved westwards by about 15 km.

So far, all localities in Austria are south of the Danube. In 2019 T. Schernhammer sent us a photograph asking for a confirmation of the possible Steppe mouse mound on the picture. He had come across it north of the Danube towards the border of the Czech Republic. Unfortunately, there were not enough details visible to be absolutely sure of the presence of Stepp mice in Austria north of the Danube. East of Austria, in Slovakia, specimens were verified close to the Austrian border on the right bank of the Danube as part of the Austrian range (Bauer et al. 1998). On the other hand, the distribution in Slovakia north of the Danube stretches to the Austrian border at the river March. It might well be that by now the range of *M. spicilegus* reaches from Slovakia across the river March into adjacent Austrian territory north of the Danube. In line with this, in southern Slovakia a tendency of range expansion was observed as well (Krištofík & Danko 2003).

Tytar et al. (2019) modelled several bioclimatic variables to find their influence on the northwards range extension of *M. spicilegus* in Ukraine and adjacent areas. They mainly regard the conditions under increasing winter temperature since 1980 responsible for this development.

According to records at ZAMG (Zentralanstalt für Meteorologie und Geodynamik) a clear upward trend of the annual mean winter temperature in the northern subregion of Austria becomes obvious since 1970 (Fig. 7). About 2000 presumably the westward range expansion of the species started, possibly triggered by the warmer winters.

The range expansion of about 15 km to the west during ca. 20 years means 0.75 km per year. It is a distance easily covered by small mammals invading new areas. *Clethrionomys*

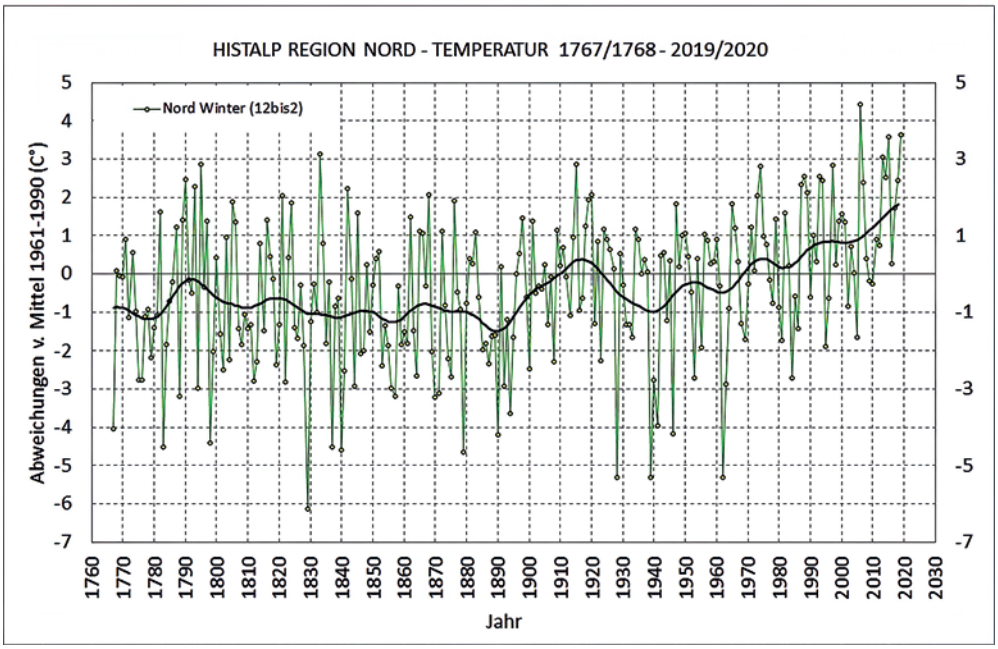

Fig. 7: Development of the mean winter temperature in the northern part of Austria. ZAMG (Zentralanstalt für Meteorologie und Geodynamik)/Histalp. – Abb.: 7: Entwicklung der durchschnittlichen Wintertemperatur in der Nordhälfte Österreichs. ZAMG/Histalp.

glareolus for instance were introduced to Ireland in the 1920s. Smal & Fairley (1984) give a summary of the following spread of the species. They found a highly variable speed of dispersal with an average of 2–4.5 km / year. White et al. (2013) found an expanding rate of the species in Ireland of 2.5 km / year based on genetic results.

That this expansion by *M. spicilegus* was not discovered earlier might be due to a lack of faunistic research on small mammals in eastern Austria. However, another development must be considered: Naumov (1940) already guessed that these mice could well survive the winter without the shelter of the mound. Simeonovska-Nicolova & Mehmed (2009) observed the behaviour of *M. spicilegus* during autumn and winter under laboratory conditions and found some mice not building a nest/mound at all. They regard the mound-building behaviour of the mice as genetically determined but very flexible corresponding to the environment. Muntyanu (1990) suggests that overwintering of individuals in their simple summer burrow might be an emergency reaction when there is food shortage and/or an insufficient number of young are around to construct a mound. If we now accept that these mounds serve not or at least not only as food storage but might also have an insulating effect (Bihari 2003, Hölzl et al. 2011a, Szenszi et al. 2011), dry mild winters could well enable more individuals to survive without mounds. Hence, no mounds do not necessarily mean no mice.

Furthermore, it can be assumed that the overall density of animals in the new surroundings was rather low in the beginning. In that case, it is reasonable to accept that the spreading of the species far beyond its original distribution in Austria went unnoticed for years.

The changing density of mounds per area does not give a reliable indication of density of mice because of movements of specimens according to availability of suitable plants in acceptable numbers, and milder winters which induce lower numbers of mounds.

A decrease in concentrations of mounds is induced by agricultural regimes like early harvesting in the year and ground hygienic measures with fields free of any vegetation.

The cultivation of intermediate catch crop like buckwheat, field bean, white mustard or amaranth fosters the settlement of *M. spicilegus*. The present distribution indicates that so far, they are doing well in eastern Austria.

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