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VARIATIONS IN THE MOUND SIZE OF MOUND-BUILDING MOUSE, *MUS SPICILEGUS* BETWEEN BULGARIA AND MOLDOVA

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Abstract

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The mound-building mouse, *Mus spicilegus* is endemic to Europe, adapted to agroecosystems. In autumn, mound-building mice build complex mounds and supply them with seeds. In these mounds, they spend the winter. The mounds have several functions, such as food storage and thermoregulation. Previous studies demonstrated that the mounds vary in size among geographical populations. In this connection we examined whether climatic differences between Bulgaria and Moldova influence the size of the mounds. To describe variations in mound size, mounds were measured and excavated in several locations in Bulgaria and Moldova in autumn and spring between 2000 and 2013. In all studied fields, crops were harvested prior investigations and the habitats were in succession on the place of agroecosystems of sunflower, wheat and corn crops as well as on the boundary strips of the agroecosystems. The comparison between mounds in Bulgaria and Moldova was made on the basis of their length, width, height, depth, number of inhabitants and collected plant material. Data on mound size between sampling localities in Bulgaria and Moldova were compared by Mann-Whitney U test. Spearman rank-order correlation (r_s) was used to examine the relation between mound size and number of inhabitants. In general the length, width and height of the mounds in the two countries had similar values. However, in Moldova mounds were significantly deeper than those in Bulgaria and number of mice per mound was significantly larger than this in Bulgarian population. Mound size was dependent on the number of inhabitants. The reasons for size differences of mounds are discussed in the context of their adaptive significance.

Key words: agroecosystems, animal architecture, mounds, *Mus spicilegus*, population differences

Introduction

The mound-building mouse, *Mus spicilegus* is endemic to Europe, adapted to agroecosystems. In the beginning of autumn, mound-building mice build complex mounds, in which they spend the winter. In spring, mound-building mice leave the mound and begin to reproduce in agricultural fields (Sokolov et al., 1990; Poteaux et al., 2008). Although in some regions this species is considered an agricultural pest, in others loss of steppe grassland and agricultural intensification may cause population declines (Coroiu et al., 2008). So, knowledge of its ecology could be relevant to the preservation of the species.

The mounds built in autumn represent an accumulation of seeds, spikes, and other kinds of plant materials, covered with earth. Several studies demonstrated that mounds could be used for food storage, but also for thermoregulation, water insulation, and protection from predators (Čanády et al., 2009; Hölzl et al., 2009; Hölzl et al., 2011; Szenczi et al., 2011). Individuals in a mound are mostly juveniles born in

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late summer and early autumn (Poteaux et al. 2008). Some authors like Szenczi et al. (2011) demonstrated that mound size is correlated positively with the number of mice, while others like Hölzl et al. (2009) showed that mound size is independent of the number of inhabitants within the mounds.

Previous studies found that mounds vary in size among geographical locations (Bihari, 2004; Hölzl et al., 2009). According to Hölzl et al. (2009) variation in mound size and composition may reflect genetic variation among mice, environmental differences or both. In this connection we examined whether climatic differences between Bulgaria and Moldova influence the size of the mounds. In this study we examined variation in mound size (1) between populations (2) in relation to the number of mound inhabitants. We expected to find significant variations in mound parameters, having in mind that in Bulgaria the climate is comparatively milder than that in Moldova. We also suggest that larger mounds are constructed by more individuals.

Materials and Methods

Mounds were measured and excavated in several locations in Northern Bulgaria (Dolni Dabnik – N43 24.46 E24 23.88; Krushovitsa – N43 22.37 E24 27.11; Telish – N43 20.29 E24 14.47, N43 18.83 E24 15.04, N43 20.69 E24 15.64; Rakita – N43 17.11 E24 15.91, N43 17.36 E24 16.08) and Moldova (mainly in the central part of the country: Bacioi – N46 54.41 E28 52.11; Horesti – N46 51.03 E28 53.44; Sociteni – N46 56.18 E28 44.04; Străisteni – N46 53.40 E28 51.40), periodically during autumn and spring between 2000 and 2013. The climate in Northern Bulgaria and Moldova is moderate continental, with cold winter and warm summer (WeatherOnline <www.weatheronline.co.uk/reports/climate/>). In both countries autumn is characterized by calm and relatively warm weather. The average daily temperatures are around 16°C in September and 10°C in October. However, the winters in Moldova are moderately cold and dry, with daytime January temperatures between –4°C and –7°C, and minimal often far below –10°C. The winters in Moldova, as a rule, are with little snow. Average snow depth is 5–10 cm. Average annual precipitation ranges from 380–550 mm. In Bulgaria the climate is comparatively milder than that in Moldova. This is most obvious from higher winter temperatures. In Northern Bulgaria daytime January temperatures are between –2°C and +2°C, and average snow depth is 12–15 cm. Average annual precipitation in Northern Bulgaria is 600 mm.

We took measurements of 103 mounds – 62 in Bulgaria and 41 in Moldova. Because mouse mounds could vary among different types of habitats, we compared mounds from the same or similar habitat type - abandoned agricultural lands and boundary strips of harvested wheat, corn and sunflower crops. In all studied fields, crops were harvested prior investigations. Considering that soil type can affect the size of the mounds, all studied locations were in areas with chernozem. The comparison between mounds in Bulgaria and Moldova was made on the basis of their length, width, height – in m, volume and depth, as well as number of inhabitants and collected plant material. Mound volume was calculated as pyramid (length (m) x width (m) x height (m))/3, and results were given in litres. The mound composition of stored seeds and ears of different plants was estimated as well and dominant species were elected. The number of mice inhabiting the mounds was determined by excavation of the burrow systems and by using live traps, distributed around each mound from autumn (October) to spring (March-April). Captured animals were weighed, age and sexually determined and then released next to the mound entrances.

To define if there are variations in mound size between Bulgaria and Moldova, data on mound size between sampling localities in Bulgaria and Moldova were compared by Mann-Whitney-U test. Spearman rank-order correlation (r_s) was used to examine the relation between mound size and number of inhabitants. Data are given as median and extreme values (minimum and maximum) of studied mound parameters. In all tests a significant statistical difference was assumed when $P < 0.05$. Data were analyzed using STATISTICA version 7.0 statistical software.

Results

The results showed both similarities and differences in the mound parameters in Bulgaria and Moldova. In general the length, width and height of the mounds in the two countries had similar values (Table 1). Although a statistically significant seasonal difference in the volume of mounds was not established, the mounds in spring were smaller than those in autumn. However, in all habitat types during autumn and spring period mounds were significantly deeper in Moldova than that in Bulgaria (Table 1). Even statistically insignificant, in spring the volume of the mounds in Bulgaria was bigger than this of the mounds in Moldova, while in autumn it was vice versa – in Moldova they were bigger than those in Bulgaria (Table 1).

In the studied fields in Bulgaria and Moldova, apart from collecting crop plants *Zea mays* L., *T. aestivum* L., *Helianthus annuus* L. mice collected parts from at least 20 different plant species. Among them, the most abundant plant species were *Setaria viridis* (L.) *P.Beauv.*, *Sorghum halepense* (L.) *Pers.*, *Chenopodium album* L., *Avena fatua* L., *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Agrimonia eupatoria* L.,

Table 1

Median and extreme values (minimum and maximum) of studied mound parameters in Bulgaria (B) and Moldova (M) during spring and autumn, and significant differences revealed by Mann-Withney U test. Significant results are in bold. Minimal and maximal scores are given in the brackets

Mound parameters	Field types			
	Spring		Autumn	
	Abandoned agricultural lands and boundary strips of harvested wheat, corn and sunflower crops		Abandoned agricultural lands and boundary strips of harvested wheat, corn and sunflower crops	
	B	M	B	M
Length, m	1.5 (1.0–2.1) n = 20	1.3 (0.6–2.0) n = 27	1.5 (0.4–2.3) n = 42	1.45 (1.0–2.4) n = 14
U	Ns, U = 188		Ns, U = 290	
Width, m	1.1 (0.8–1.8) n = 20	1.2 (0.6–1.5) n = 27	1.1 (0.5–2.0) n = 42	1.2 (0.8–1.5) n = 14
U	Ns, U = 247.5		Ns, U = 267	
Height, m	0.3 (0.1–0.45) n = 20	0.25(0.1–0.5) n = 27	0.27 (0.1–0.5) n = 42	0.3 (0.2–0.45) n = 14
U	Ns, U = 264.5		Ns, U = 192	
Volume, dm^3	157.5 (26–567) n = 20	140 (21–350) n = 27	168.6 (21.3–570) n = 42	174 (66.6–540) n = 14
U	Ns, U = 246		Ns, U = 263	
Nest depth, m	0.3 (0.2–0.6) n = 20	0.5 (0.25–0.8) n = 27	0.4 (0.2–0.7) n = 21	0.5 (0.3–0.8) n = 14
U	Significant, U = 126.5, p = 0.002		Significant, U = 86, p = 0.04	
Mice per mound	5 (3–8) n = 20	6 (3–12) n = 27	6 (4–8) n = 21	6.5 (5–12) n = 14
U	Significant, U = 170, p = 0.02		Significant, U = 84, p = 0.03	

Legend: *n* – sample size, *Ns* – not significant

Panicum crus-galli L. *Cirsium arvense* L. Scop., *Ambrosia* sp.*, Artemisia vulgaris* L.*,* depending on availability. Usually, the soil under mounds was dry.

Number of mice per mound in Moldavian population was significantly larger than this in Bulgarian population in autumn, as well as in spring (Table 1). In both countries in autumn all caught individuals in mounds were juveniles, with the exception of some single adult animals. In spring all captured individuals were adults. In Bulgaria and Moldova mound size was dependent on the number of inhabitants. We found correlation between mound size and mice captured per mound in the autumn period ($r = 0.81$, $p<0.001$, $n = 14$ for Moldavian population; $r = 0.75$, $p < 0.001$, $n = 21$ for Bulgarian population), and in the spring period ($r = 0.55$, $p < 0.001$, $n = 27$ for Moldavian population, $r = 0.62$, $p < 0.001$, $n = 20$ for Bulgarian population).

Discussion

The results confirm seasonal and geographical differences in the size of the mounds. Both, in Bulgaria and Moldova volume of mouds was smaller in the spring in comparison with this in autumn. Possibly this tendency may be due to the subsidence of mounds. According to Sokolov et al. (1990) they become wider and lower on account of eaten vegetable stock and inside soil thrown away. Nevertheless, the mounds in Moldova were significantly deeper in comparison with those of Bulgaria and the number of mound inhabitants significantly greater than that in Bulgaria. Considering the significantly lower daytime January temperatures in Moldova (between –4°C and –7°C, and minimal often far below –10°C) in comparison to those in Bulgaria, these findings are not surprising. Besides, the winters in Moldova are with little snow and strong winds that blows the snow away. This explains the relatively smaller volume of mounds in Moldova in spring compared to the volume of the mounds in Bulgaria during this period. Although *M. spicilegus* is unique with its ability to construct complex earthen mounds, previous data also showed that under higher temperatures and a larger availability of food in winter mice can optimize this behavior by building simpler constructions (Mitsainas et al., 2008). Hence, the smaller volume of mounds in autumn in Bulgaria and smaller number of mound inhabitants, compared with that of Moldova is in favor of the aforementioned proposition. Probably, the warmer weather in Bulgaria reflects the earlier dispersion of individuals, which explains the smaller number of mound inhabitants in Bulgaria in spring period.

According to Hölzl et al. (2009) the availability of the amount and type of plant material used for construction could explain much of the variation among mounds. The authors found that the main harvesting area of mound building mice is about three meters surrounding the mound. In the present study we found that mice used several plants as building materials, mainly *Setaria viridis* (L.) P.Beauv., *Sorghum halepense* (L.) Pers., *Chenopodium album* L., *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Agrimonia eupatoria* L., depending on availability. Similar results for the availability of some of these plants in the mounds were obtained by other authors (Hölzl et al., 2009; Szenczi et al., 2011). Probably, anatomical and morphological properties of many of the parts of these plants – seeds, ears etc. allow them to isolate the cold and moisture, which was evident from the dry soil under mounds. Recent studies presume that the stored vegetable matter does not, or not exclusively, serve as food and indicate that the mounds might have insulating role (Hölzl et al., 2011; Szenczi et al., 2011). The authors showed that the plant fill plays a major role in their thermal insulation and waterproof properties. As Szenczi et al. (2011) noted, the thick grass nest, the plant fill of the mound, and the soil itself might have contributed to the reduced temperature fluctuations.

The numbers of mice in a mound and age composition were similar to that described by other authors (Sokolov et al., 1990; Poteaux et al., 2008; Canady et al., 2009; Szenczi et al., 2011). Moreover, like Szenczi et al. (2011) we also found correlation between mound size and mice captured per mound. So, it could be suggested that larger mounds are constructed by more individuals, which seems to contribute for their successful overwintering.

Conclusion

The results confirm the existence of variations in the mound size of *M. spicilegus* between Bulgaria and Moldova. Mound size appears to depend on climatic characteristics of the two countries. The lower winter temperatures in Moldova, accompanied by frequent strong winds probably cause the greater depth of the mounds, the bigger number of mice per mound and better expressed seasonal variation in the volume of mounds. In both countries the mound size was dependent on the number of inhabitants, so it could be suggested that larger mounds are constructed by more individuals. It seems to be a good strategy of *M. spicilegus* for successful overwintering.

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