ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 64 (2), 2012: 135-143

Neighbuor Relationships and Spacing Behaviour of Mound-building Mouse, *Mus spicilegus* (Mammalia: Rodentia) in Summer

Daniela M. Simeonovska-Nikolova

Department of Ecology and Protection of Nature, Faculty of Biology, Sofia University, 8 Dragan Tzankov blvd., 1164 Sofia, Bulgaria; E-mail: mammals@abv.bg

Abstract: The neighbour relationships of territorial male and female *M. spicilegus* were examined in summer in the field in order to clarify their role in spatial behaviouur of individuals in this period. The field research was held in an agricultural field in Northern Bulgaria. The Capture-Mark-Recapture method was used. Neighbour relationships between territorial mound-building mice in the habitat were studied in intraspecific male-male and female-female dyadic encounters. Each mouse was tested with at least two others, but captured at a different distance. Several indices of spacing behaviouur such as recapture rate, distance of recaptures, spatial associations and home ranges were analysed as well. Results indicated that females had higher recapture rate and higher frequency of recaptures than males, but males had longer distance of recaptures. Males responded significantly less aggressively to their immediate neighbours than to more distant ones. In contrast with males, females tended to be more aggressive to their immediate neighbours than to more distant ones, and their home ranges were separated. The reasons for the displayed behaviouur of male and female *M. spicilegus* are discussed.

Key words: *Mus spicilegus*, dear enemy effect, dyadic encounters, agonistic interactions, mating systems, home ranges

Introduction

The mound-building mouse, *Mus spicilegus* Petenyi is an outdoor species from southern-eastern Europe, adapted to agroecosystems (Orsini *et al.* 1983, Bonhomme 1992, Sage *et al.* 1993, Sokolov *et al.* 1998, Mitsainas *et al.* 2009). In the beginning of autumn, mound-building mice build complex mounds, in which they spend the winter. According to Čanády *et al.* (2009), Hölzl *et al.* (2009), Hölzl *et al.* (2011a, b), Szenczi *et al.* (2011), mounds could be used for food storage, thermoregulation, water insulation, and protection from predators. Evidence suggests that mound building appears to be kin based (Garza *et al.* 1997, Poteaux *et al.* 2008). In spring, mound-building mice leave the mound and begin to reproduce in agricultural fields (Orsini *et al.* 1983, Milishnikov *et al.* 1998, Sokolov *et al.* 1998, Simeonovska-Nikolova 2007, Gouat *et al.* 2003a, Poteaux *et al.* 2008). According to Poteaux *et al.* (2008) *M. spicilegus* females are philopatric, while males disappear in spring, which allows inbreeding avoidance. Little is known about the behavioral mechanisms determining the social structure and organization of mice in breeding period.

Many studies on rodents reveal that interactions between neighbors play a major role in determining the spatial distribution and reproductive success of mice (Mackintosh 1981, Hurst 1987, Gray, Hurst 1997). In previous field research, Simeonovska-

Nikolova (2007) found that during the breeding period, home ranges of female mound-building mice are separate, suggesting behavioral mechanisms of home range separation such as aggressive behavior towards other females, and active avoidance of contact. Research conducted under laboratory and semi natural conditions showed that male as well as female *M. spicilegus* are aggressive towards unfamiliar individuals, but that mice are more tolerant to familiar individuals (Patris, Baudoin 1998, Patris *et al*. 2002). However, studies on social relationships of feral male and female *M. spicilegus* in natural habitats have not yet been made. Therefore, in the present study the neighbor relationships of male and female *M. spicilegus* were examined with dyadic encounter tests in the field in summer in order to clarify their role in determining the spatial structure and organization of mice in this period. It was hypothesized that in summer period, when *M. spicilegus* is territorial, both males and females should respond less aggressively to their close neighbors than to the rest, as suggested of other territorial species (Wolff *et al.* 1983, Ydenberg *et al*. 1988, Rosell *et al*. 2008). At the same time, territorial behavior also predicts an important role for other cues like resource potential, habitat structure and resource distribution, density, sex ratio, mating strategy (Krebs 1982, Gray, Hurst 1997, Jensen *et al*. 2005). In this connection, density, demographic structure and spatial associations in the population of *M.spicilegus* were followed from early spring, when animals start to disperse until late summer before they begin construction of mounds. Although the monogamous system in this species has been determined by experiments conducted in the laboratory and in outdoor enclosures (Patris, Baudoin 1998, 2000, Patris *et al*. 2002, Dobson, Baudoin 2002, Baudoin *et al*. 2005), the spacing pattern of animals established in the field by using of CMR method rather tends toward facultative polygyny (Gouat *et al*. 2003b, Simeonovska-Nikolova 2007, Poteaux *et al*. 2008). Based on this, it was supposed that males should put more effort into territorial defence than females.

According to IUCN Red List of Threatened Species the population trend of *M. spicilegus* is decreasing (Coroiu *et al*. 2008). Knowledge of behavioral mechanisms underlying the spatial behavior of *M. spicilegus* could be relevant to the preservation of the species and the management of its populations.

Material and methods

Study area and study animals

The present study was conducted in Danube Plain in Northern Bulgaria (43°17'N, 24°12'E). The climate is continental, with cold winter and warm summer. The average temperatures vary from -2 °C to 2 °C during winter (December-February) and from 20 °C to 23 °C during summer (June, July and August). Precipitation is 150 mm during summer and 70 mm during winter. However, during the summer period of 2008 in the study region the average temperatures were 1 °C higher and precipitation was about 32 mm lower than the common sum of rainfalls for that period.

The study was conducted in 1 ha secondary ecosystem, which was in succession on the place of an agroecosystem of *Helianthus annus* L. As a result of the succession, dominant and most widespread species was *Matricaria inodora*, whereas the rest species in the weed community such as *Sorghum halepensis*, *Cirsium arvensis*, *Erigeron canadensis*, *Rumex* sp, *Lathyrus* sp., *Viola arvensis*, *Euphorbia cyparisies* were occasional. The rodent community consisted of 4 species: *Microtus arvalis*, *M. spicilegus*, *Apodemus sylvaticus* and *Apodemus agrarius*. The ecosystem was situated at least 6 km away from the closest village around.

Trapping procedure

Five-seven day trapping sessions was held in spring (first half of April 2008), and summer (first half of July and second half of August of 2008). Animals were trapped with Sherman live traps located in a 10 × 10 m grid in the habitat patch. Traps were baited with oat flakes, set in the evening and checked at 6:00-8:00 a.m. The Capture-Mark-Recapture method was used (Jones *et al.* 1996, McWilliam 2002, Russel J. 2003). At first captured individuals were marked by toe-clipping. At each capture the following were recorded: trap location, individual number, sex, body mass to ±1 g and reproductive status (females: pregnant, lactating, or perforated vagina; scrotal testes for males). The age of each animal was determined on the basis of its body mass and reproductive status (Simeonovska-Nikolova 2007). Males with testes in the scrotal position and females which were pregnant, lactating, or had a perforated vagina were considered as reproductive. Having in mind that the visual detection of pregnancy becomes secure only during the last week of gestation (Gouat *et al*. 2003a), a female was considered to be pregnant, when pregnancy was clearly observed or when its vagina was closed and its body weight exceeded 19 g.

Several indices of spacing behavior such as recapture rate, distance of recapture, frequency of recapture, spatial associations and home ranges were analyzed. Many of these indices were adapted from similar studies on *M. spicilegus* (Gouat *et al*. 2003b, Baudoin *et al*. 2005, Simeonovska-Nikolova 2007) and other rodent species (Gromov *et al*. 2000, Wu, Yu 2004). The frequency of recapture and distance of recapture were represented by the median. *M. spicilegus* home ranges were established by using the exclusive boundary method (Nikitina 1965). The significance of sexual differences between these indices was checked by Mann-Whitney U test at $p < 0.05$.

Experimental procedure and behavioural observations

Presuming that numerous individuals disappear in spring, the encounters were performed only in summer period. Encounters were performed within an arena made of transparent Plexiglas (50 cm wide × 50 cm high × 50 cm long) situated in the same habitat patch. The duration of every encounter was 5 min. The encounters were conducted between 8:00 a.m. and 10:00 a.m. A total of 29 encounters were run: 12 male-male and 17 female-female (12 between non pregnant and 5 between pregnant mice) involving 10 male and 15 female individuals. All tested mice were adults. Five females were visibly pregnant. The encounters were performed between territorial animals of the same sex, captured and marked on previous days or trapping session. Each mouse was tested with at least two others, but captured at a different distance. Repeated tests were on different days. Only 2 individuals were tested twice in the same day, but in an 1 hour interval.

Both animals were put simultaneously in the arena, one on each side. A transparent wall separated the arena in two parts of equal size. After a period of 3 min for acclimatization, the transparent wall which separated the arena in two parts was carefully removed so that interaction between the two mice could occur, and the 5-min observation period started. Between each trial, the arena was thoroughly cleaned and wiped with alcohol. Immediately after the encounters were finished, individuals tested were put again into their respective traps and carried back to their trapped position.

Behavior of mice was registered by shorthand into the protocols. Then, behavioral events were listed and categorized as follows: Agonistic behavior – Offensive behavior (threat, attack, fight, chase, offensive-upright and sideways postures), and Defensive behavior (defensive-upright posture, retreat, running away, jumping apart), Amicable behavior (approaching, following, nose-nose, nose-anal, nose-body, passing above, grooming, clambering on, and standing side by side). Patterns of behavior and terms used in each pattern were cited from other studies on rodents (Mackintosh 1981, Livoreil *et al*. 1993, Čihákova, Frynta 1996). The number of behavioral events demonstrated were calculated for each encounter and averaged for male-male and female-female encounters. The results are represented by the median and the dispersion – by the extremes. To compare specific levels of agonistic and amicable behavior between males and females, data were quantitatively analyzed. The significance of sexual differences between behavioral patterns, demonstrated by mice, was estimated by Mann-Whitney U test at $p < 0.05$.

The investigation conformed to the international requirements for ethical attitude towards the animals (Lehner 1996).

Results

Demography and spacing indices

In April a total of 28 females and 54 males, were captured (Table 1). A male biased sex ratio ($\chi^2 = 8.24$, $p < 0.05$) was found. In spring of 2008 the population of *M. spicilegus* consisted entirely of adults. Recapture rate was 44% for females and 46% for males (Table 1). The maximal distance between the trapping points was 25 m for females and 30 m for males, respectively. Fifty per cent of the recaptured males and 72% of the recaptured females were found at the same station at nearest mounds. During the capturing period, many of the mounds in the agroecosystem had not been destroyed yet. In April the most frequent social groups registered were male-female pairs as well as groups comprised of two or three males (Table 2). More rarely, groups composed of two females, and a male and two females were observed. Nine females and 21 males were found to be solitary.

In July and in August a total of 58 mice were captured – 16 females and 9 males in July and 13 females and 20 males in August (Table 1). In July adults (both males and females) dominated in captures ($p < 0.05$, $\chi^2 = 6.76$), and adult females were significantly more than adult males ($p < 0.05$, $\chi^2 = 4.26$). In August the number of subadult males was significant increased. Subadult males were significant more than adult males, while subadult females were significantly less than adult females ($p < 0.05$, $\chi^2 = 6.2$). With the exception of one female in July, and one female and 6 males in August, all recaptured individuals were reproductively active adults. Although significant sex differences within indices of spacing behaviour were not found, adult females had higher recapture rate than adult males. In July recapture rate was 68.7% for adult females and 44.4% for adult males (Table 1). Four females and one male were from the previous seasons. In August recapture rate was 53.8% for adult females and 30% for adult males, respectively (Table 1). Besides, the median number of recaptures per individual was about twice higher in adult females, but adult males had longer distance of recaptures. Many of the recaptured individuals appeared to be sedentary. Six females and 2 males were recaptured only at the same station and 5 females and 1 male at one of the four nearest stations. Two males and two females were from July. In July the most frequent social groups were male-female pairs (Table 2). One social group comprised of two females and other one consisting of a male and two females also were registered. In August, like April, social groups comprised of a male and a female, but also two or three subadult males were more frequent observed. However, only 4-6 males and 8-10 females were found to be solitary in summer (Table 2).

In July and August home ranges were determined for 17 adult females and 7 adult males captured at least 3 times on the study plot (Fig. 1). The size of home ranges varied from 200 m^2 to 800 m^2 in males (median size 400 m^2) and from 100 m^2 to 500 m^2 in females (median size 250 m^2). Home ranges of females were exclusive, while those of males overlapped with the female ranges as follows: in 2 cases the home range of one male overlapped this of one female 100%, and in another case 25% (Fig. 1). In 3 cases – one in July and two in August, the home ranges of one male overlapped those of two females. The overlapping with the first female was 50-100%, while the overlapping with the second one was 10-15% (Fig. 1). The home range overlapping between males was till 50%.

Interspecific dyadic encounters

The results showed that, agonistic events were the majority of interactions between individuals in male-male and female-female encounters (Table 3). Both males and females displayed significantly more agonistic events, than amicable ones (Mann-Whitney U test, $U = 24$, $p < 0.05$ for males, $U = 0$, $p < 0.05$ for pregnant mice and $U = 25.5$, $p < 0.05$ for non pregnant mice, respectively). Attacks, fights and threats were observed mainly in the male encounters and in interactions between pregnant mice. Males displayed significantly more agonistic events, than females (Table 3).

The number of aggressive events, displayed by the same individual in its encounters with the two partners, showed that males responded significantly less aggressively to their close neighbours than to more distant ones (Mann-Whitney U test, $U = 2.5$, $p < 0.05$), (Fig. 2). There was a significant positive correlation between numbers of aggressive contacts and distance between individuals ($\rho s = 0.856$, Spearman's correlation coefficient), (Fig. 3a). In contrast with males, females tended to be more aggressive to their immediate neighbours than to more distant ones, although a significant negative correlation between numbers of aggressive contacts and distance between animals was not established (Fig. 2, 3b).

Discussion

The seasonal changes in density and demographic structure of *M. spicilegus* seem to undergo the seasonal changes in its life cycle. The results showed that in spring the number of *M. spicilegus* was three times higher than those in summer, and the number of adult males was twice higher than that of adult females. In the opposite, in July adult females were significantly more than adult males. Some authors like Milishnikov *et al.* (1998) also reported a biased in favour of females during the breeding season. On the base of these finding it could be supposed that numerous males begin to disappear in spring, while female offspring tend to be philopatric, as also found for many other mammalian species (Greenwood 1980, Poteaux *et al.* 2008). Thus, the sharp decrease in the number of breeding males in July and August probably reflects male mortality due to dispersal. The increased number of subadult males established in the second half of August in the present study could be a compensatory mechanism

Table 1. Sex ratio, age distribution and indices of spacing behavior in male and female *Mus spicilegus* in April, July and August of 2008. Recapture rate is expressed in % by calculation of the number of recaptured individuals/total number of animal captured. The distance of recaptures is presented in m, and the frequency of recaptures is expressed by the number of recaptures per individual. The data are presented by median, min and max values – in the brackets. Legend: Juv – number of juveniles, Sub – number of subadults, Ad – number of adults, p – number of pregnant mice. Note: Indices of spacing behaviour presented are only for adult animals.

Trapping period	Sex ratio		Age distribution						Recapture rate %		Distance of recaptures median, min-max values		Frequency of recaptures median, min-max values	
			Juv		Sub		Ad							
	F	M	F	M	F	M	F	M	F	M	F	M	F	M
April 2008	28	54	-	-	-	-	28 (5^p)	54	44% (11/28)	46% (25/54)	0 (0-25)	0 (0-30)	2 (2-4)	2 (2-4)
July 2008	16	9	2	4	-	-	14 (7^p)	5	68.7% (11/16)	44.4% (4/9)	15(0-30)	30(10-50)	3 (2-4)	2 (2-5)
August 2008	13	20	1	1	1	13	11 (4^p)	6	53.8% (7/13)	30% (6/20)	10 (0-50)	30(15-90)	4 (2-5)	2 (2-5)

Table 2. Spatial associations observed during the reproductive period for all animals. Legend: p – number of pregnant mice; sub – number of subadults; juv – number of juveniles. The number of recaptured mice is indicated between brackets.

Type spatial associations	April			July			August		
	Nb of observ.	Nb of females	Nb of males	Nb of observ.	Nb of females	Nb of males	Nb of observ.	Nb of females	Nb of males
F	9	9-(6), 2^p	0	10	10-(6), 4^p, 1^{juv}	0	8	8-(3), 2^p, 1^{juv}	0
M	21	0	21-(10)	4	0	4-(2), 2^{juv}	6	0	6-(2), 4^{sub}, 1^{juv}
FM	11	11-(3), 2^p	12-(4)	4	4-(3), 2^p, 1^{juv}	4-(1), 2^{juv}	5	5-(4), 2^p, 1^{sub}	5-(3), 2^{sub}
FF	2	4-(1)	0	1	2-(2), 1^p	0	0	0	0
MM	7	0	14-(10)	0	0	0	3	0	6-(5), 4^{sub}
MMM	2	0	6-(1)	0	0	0	1	0	3-(3), 3^{sub}
FFM	2	4-(1), 1^p	1	1	2-(2),	1	0	0	0
Total	54	28-(11), 5^p	54-(25)	20	16-(11), 7^p, 2^{juv}	9-(3), 4^{juv}	24	13-(7), 4^p, 1^{sub}, 1^{juv}	20-(13), 13^{sub}, 1^{juv}

of population in the result from male mortality due to dispersal. Similar observations about the seasonal dynamics of density and demographic structure of *M. spicilegus* were reported by Sutova (1969) for the region of Dobrudzha (Romania). In contrast, a female biased sex-ratio and high population density were registered for *M. spicilegus* at the beginning of breeding period (April) in an agricultural field in Gyöngyös region of Hungary (Gouat *et al.* 2003b). Apparently, as Poteaux *et al.* (2008) mentioned, the population structure of *M. spicilegus* seems to be quite geographically variable. However, other cues like resource potential probably also have an important role on social structure.

The results demonstrated that in July and August home ranges of adult female mound-building mice were exclusive and female-female encounters were agonistic. Similar data about spatial behaviour of female *M. spicilegus* in summer period were reported by Simeonovska-Nikolova (2007) for other population of this species in the region of Northern Bulgaria. In most mammalian species, females are less aggressive than males, but become very aggressive during pregnancy and after giving

Table 3. Median number and extreme values (minimum and maximum) of amicable and agonistic – offensive and defensive behaviors during male-male and female-female dyadic encounters in *M. spicilegus*. The significance of intra and intersexual differences revealed by Mann-Whitney U test is shown: $p < 0.05$ *. Explanations: n – number of encounters, M – males, F – all females, F_p – pregnant; F_{np} – non pregnant.

Behavioural patterns	M n = 12	F n = 17	F_p n = 5	F_{np} n = 12
Amicable behaviour	2 (1–3)	2 (1–7)	2 (1–3)	2.5 (1–7)
U	ns $_{(M \times F)}$; ns $_{(M \times F p);}$ ns $_{(M \times F np)}$; ns $_{(F p \times F np)}$			
Agonistic behaviour	9.5 (0–14)	5 (2–10)	6 (5–10)	4 (2–7)
U	Significant $_{(M \times F)}$ U = 56.5*; ns $_{(M \times F p)}$; Significant $_{(M \times F np)}$ U = 32.5*; ns $_{(F p \times F np)}$			
- Offensive behaviour	3.5 (0–7)	2 (0–5)	3 (0–5)	1.5 (0–3)
U	ns $_{(M \times F)}$; ns $_{(M \times F p);}$ ns $_{(M \times F np)}$; ns $_{(F p \times F np)}$			
- Defensive behaviour	5 (0–7)	3 (2–5)	4 (3–5)	3 (2–4)
U	Significant $_{(M \times F)}$ U = 40*; ns $_{(M \times F p)}$; Significant $_{(M \times F np)}$ U = 24*; ns $_{(F p \times F np)}$			

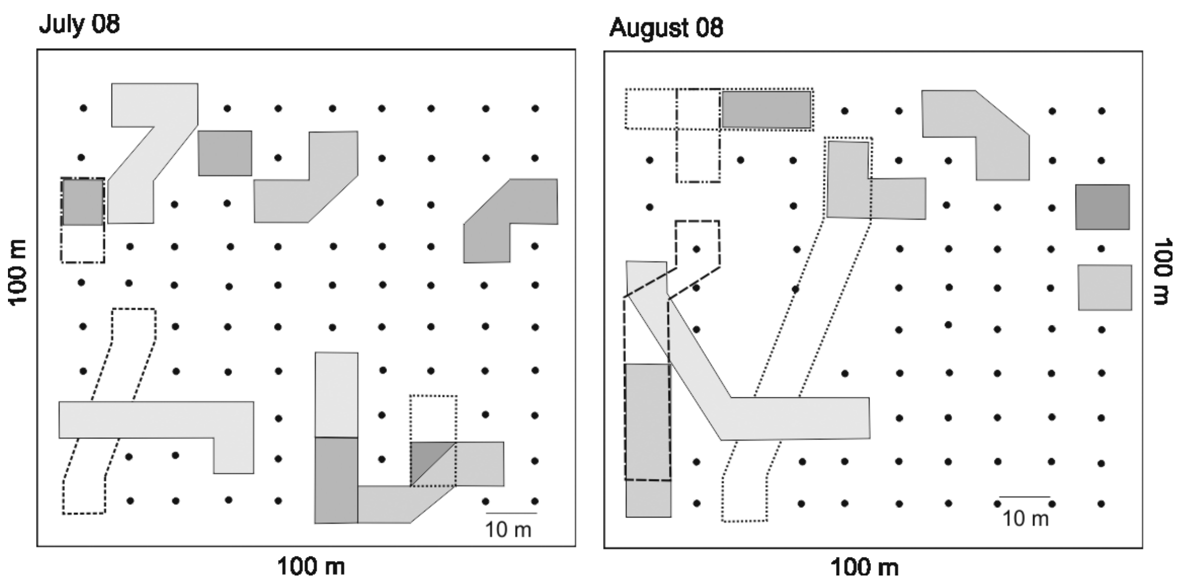

Fig. 1. Location of home ranges of male and female *M. spicilegus* in July and August. Only the home ranges of mice, which were captured at least 3 times in that season, are presented. The dashed lines represent the borders of male home ranges, and the solid lines – the borders of female home ranges, which are in grey. The dots represent 10-m interval trap stations; stations within home ranges are not plotted.

birth (Lonstein and Gammie 2002, Maxson 2009). In this study pregnant mice also showed higher aggressiveness then non pregnant mice. No data exists on how territorial behaviour of mound-bulding mouse changes during the reproductive cycle, but it is reported for other female-territorial species as bank vole that female aggressiveness is lower during early gestation than during late gestation and lactation (Koskela *et al.* 1997, Rosell *et al.* 2008). General opinion is that intraspecific aggression in

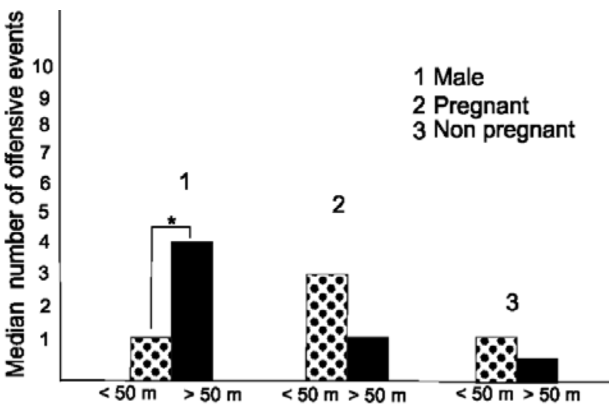

Fig. 2. Median number of offensive events displayed by male and female mound-building mice tested during encounters with their most closed close neighbour (dotted bars <50 m) and most distant once (black bars > 50 m). The significance of differences between numbers of offensive events, Mann-Whitney U test: * p < 0.05

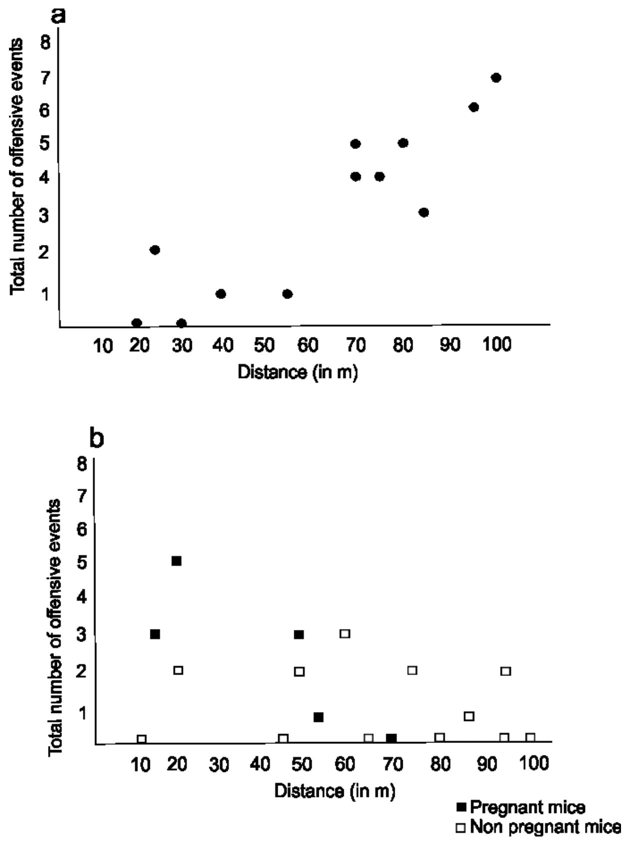

Fig. 3 Scattergram of data on total number of offensive events and distance between individuals during male-male (a) and female-female (b) *M. spicilegus* encounters.

many species of small mammals is used mainly to maintain territories and to defend the offspring. At the same time laboratory and field studies indicate that social relationships, such as territoriality, depend on the spatial distribution of resources such as food, nest sites, and are modified when such resources become limited (Krebs 1982, Ostfeld 1985, Gray, Hurst 1997, Gray *at al.* 2002). In the study area dominant and most widespread species in the weed community was *Matricaria inodora* L., while the species from Poacea and Fabacea families were occasional. This suggests a relatively low nutrient value of the ecosystem. Thus, the species composition of weeds along with higher average temperatures and lower precipitation established at the study period in the region show decreasing of habitat quality. This might explain why the social interaction between females were more agonistic than amicable, and why pregnant mice were significantly more aggressive than non pregnant. Moreover, according to Ostfeld (1985) territoriality in female microtines is likely to be in great degree food dependent since their reproductive success is directly limited by their ability to acquire sufficient nutrients. Thereby, the higher aggressiveness of female *M. spicilegus* to their immediate neighbours, in comparison with more distant ones could be a result from a flexible strategy depending on the habitat in which mice live. On the other hand, an exclusive home range, established by each female in the study habitat could be compatible with a monogamous mating system. A high level of female competition and dispersal is reported for many monogamous species (Greenwood, 1980, Dobson, Jones 1985, Ostfeld 1985, Ribble 1992, Favre *et al.* 1997, Komers, Brotherton 1997, Rychlik 1998; Patris *et al.* 2002).

The results from dyadic encounters demonstrate that male aggressiveness increased according to distance and territorial males respond less aggressively to their immediate neighbours than to distant ones. Such forms of social recognition known as 'dear enemy effect' are described for many other territorial rodent species as well (Wolff *et al.* 1983; Ydenberg *et al.* 1988; Temeles 1994; Rosell *et al.* 2008). It is assumed that it is an adaptive strategy that minimizes the energetic costs of territoriality. With a reduction in the amount of time and energy spent responding to neighbouring individuals, territorial males can devote more time to attract mates, forage and defend the territory from unfamiliar individuals (Krebs 1982, Temeles 1994, Rosell *et al.* 2008, Alcock 2009). At the same time, the higher aggressiveness displayed by males in comparison to females suggest that males put more effort into territorial defence than females. Although the monogamous system in this species has been determined by experiments conducted in the laboratory and in outdoor enclosures (Patris, Baudoin 1998, 2000, Patris *et al.* 2002, Dobson, Baudoin 2002, Baudoin *et al.* 2005), some recent investigations demonstrated that a facultative polygyny could occur mainly due to a shortage of males (Gouat *et al.* 2003b, Gouat, Féron 2005, Simeonovska-Nikolova 2007). The female biased sex-ratio as well as greater median distance between trapping points of males in comparison with those of females found in summer could be related to the attempt of males to mate with more than one female. In the present study in 2 cases the home ranges of one male overlapped those of two females as well. From this point of view, male *M. spicilegus* probably responded more aggressively to distant male individuals because they maybe accept the latter as dispersing individuals, which searched for breeding territories. Similar findings are presented for some voles (Steen 1994, Aars, Ims 2000). Further field studies are necessary to clarify the all factors affecting territoriality of mound-building mouse, and its spacing behaviour in general.

Acknowledgments: I am grateful to Wenfei Tong from the Museum of Comparative Zoology, Harvard University and to Krastio Dimitrov from Institute of Zoology, Bulgarian Academy of Science for their assistance in the field.

References

Aars J., R.A. Ims 2000. Population dynamic and genetic consequences of spatial density-dependent dispersal in patchy populations. – *American Naturalist*, **155**: 252-265.

Alcock J. 2009. Animal Behavior: An Evolutionary Approach, 9th Ed. Sinauer Associates, 281-282.

Baudoin C., N. Busquet, F. Stephen Dobson, G. Gheusi, C. Feron, J. Durand, G. Heth, B. Patris and J. Todrank 2005. Male-female associations and female olfactory neurogenesis with pair bonding in *Mus spicilegus*. – *Biological Journal of the Linnean Society*, **84**: 323-334.

Bonhomme F. 1992. Genetic diversity and evolution in the genus Mus. – In: Goldowitz D., D. Wahlsten and R. Wimer (Eds.): Techniques for the Analysis of Brain and Behaviour: Focus on the mouse, Elsevier, Amsterdam, 41-56.

Čanády A., L. Mošanský and M. Stanko. 2009. First Knowledge of Winter Ecology of the Mound-building Mouse (Mus spicilegus Petényi, 1882) from Slovakia. – *Acta zoologica bulgarica*, **61** (1):79-86.

Čiháková J., D. Frynta 1996. Intraspecific and interspecific behaviour interactions in the wood mouse (*Apodemus sylvaticus*) and the yellow-necked mouse (*Apodemus flavicollis*) in a neutral cage. – *Folia Zoologica*, **45**: 105-113.

Coroiu I., B. Kryštufek and V. Vohralík 2008 *Mus spicilegus*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>

Dobson F. S., W. T. Jones 1985. Multiple causes of dispersal. – *American Naturalist*, **126**: 855-858.

Dobson F.S., C. Baudoin 2002. Experimental tests of spatial association and kinship in monogamous mice (*Mus spicilegus*) and polygynous mice (*Mus musculus domesticus*). – *Canadian Journal of Zoology*, **80**: 980-986.

Favre L., F. Balloux, J. Goudet and N. Perrin 1997. Femalebiased dispersal in the monogamous mammal *Crocidura russula*: evidence from field data and microsatellite patterns. – *Proceedings of the Royal Society of London*, **264**: 127-132.

Garza J.C., J. Dallas, D. Duryadi, S. Gerasimov, H. Croset and P. Boursot 1997. Social structure of the mound-building mouse *Mus spicilegus* revealed by genetic analysis with microsatellites. – *Molecular Ecology*, **6**: 1009-1017.

Gouat P., C. Féron and S. Demouron 2003a. Seasonal reproduction and delayed sexual maturity in mound-building mice *Mus spicilegus*. – *Reproduction Fertility and Development,* **15**: 1-9.

Gouat P., K. Katona and C. Poteaux 2003b. Is the socio-spatial distribution of mound-building mice, *Mus spicilegus*, compatible with a monogamous mating system? – *Mammalia,* **67**: 15-24.

Gouat P., C. Féron 2005. Deficit in reproduction in polygynously mated females of the monogamous mound-building mouse *Mus spicilegus*. – *Reproduction Fertility and Development*, **17**: 617-623.

Gray S., J. Hurst 1997. Behavioural mechanisms underlying the spatial dispersion of commensal *Mus domesticus* and grassland *Mus spretus*. – *Animal Behaviour*, **53**: 511-524.

Gray S., S. Jensen and J. Hurst 2002. Effects of resource distribution on activity and territory defence in house mice, *Mus domesticus*. – *Anim. Behaviour*, **63**: 531-539.

Greenwood P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. *Animal Behaviour*, **28**: 1140-1162.

Gromov V. S., B. R. Krasnov and G. I. Shenbrot 2000. Space use in Wagner's gerbil *Gerbillus dasyurus* in the Negev Highlands, Israel. – *Acta Theriologica*, **45**: 175-182.

Hölzl M., H. Hoi, A. Darolova, J. Krištofik and D. J. Penn 2009. Why do the mounds of Mus spicilegus vary so much in size and composition? – *Mammalian Biology – Zeitschrift fur Saugetierkunde*, **74** (4): 308-314.

Hölzl M, H. Hoi, A. Darolova and J. Krištofek 2011a. Insulation capacity of litter mounds built by Mus spicilegus: physical and thermal characteristics of building material and the role of mound size. – *Ethology, Ecology & Evolution,* **23** (1): 49-59.

Hölzl M., J. Krištofík, A. Darolová and H. Hoi 2011b. Food preferences and mound-building behaviour of the mound-building mice *Mus spicilegus*. – *Naturwissenschaften,* DOI: 10.1007/s00114-011-0837-5

Hurst J. L. 1987. The functions of urine marking in a free living population of house mice, *Mus domesticus* Rutty. – *Animal Behaviour*, **35**: 1433-1442.

Jensen S., S. Gray and J. Hurst 2005. Excluding neighbours from territories: effects of habitat structure and resource distribution. – *Animal Behaviour*, **69**: 785-795.

Jones C., W. J. McShae, M. J. Conroy and T. H. Kunz 1996. Capturing Mammals. – In: Wilson D. E., F. R. Cole, J. D.Nichols, R. Rudran, and M. S. Foster (Eds.): Measuring and monitoring biological diversity: Standard methods for mammals. Smithsonian Institution Press, Washington and London, 115-155.

Komers P. E., P. N. M Brotherton 1997. Female space use is the best predictor of monogamy in mammals. – *Proceedings of the Royal Society of London*, *series B*, **264**: 1261-1270.

Koskela E., T.Mappes and H.Ylonen 1997. Territorial behaviour and reproductive success of bank vole Cletherionomys glarelous females. – *Journal of Animal Ecology,* **66**: 341-349.

Krebs J.R. 1982. Territorial defence in the great tit (*Parus major*): do residents always win? – *Behavioral Ecology and Sociobiology*, **11**: 185-194.

Lehner Ph. 1996. Handbook of ethological methods. Cambridge University press, Cambridge.

Livoreil B., P. Gouat and C. Baudoin 1993. A comparative study of social behaviour of two sympatric ground squirrels (*Spermophilus spilosoma*, *S. mexicanus*). – *Ethology,* **93**: 236-246.

Lonstein, J.S., S.C. Gammie 2002. Sensory, hormonal, and neural control of maternal aggression in laboratory rodents. – *Neuroscience & Biobehavioral Reviews* **26:** 869-888.

Mackintosh J.H. 1981. Behaviour of the House Mouse. – *Symposium of the Zoological Society of London*, **47**: 337-365.

Maxson S. C. 2009. The Genetics of Offensive Aggression in Mice. In: Kim, Yong-Kyu (Ed.): Handbook of Behavior Genetics. Part III, DOI: 10.1007/978-0-387-76727-7_21, Springer, New York, 301-316.

McWilliam A. N. 2002. Small mammals and bats. – In: Grant I. F. and C. C. D. Tingle (Eds.): Ecological Monitoring Methods for the Assessment of Pesticide Impact in the Tropics. Chatham, UK: Natural Resources Institute, 245 p.

Milishnikov A. N., A. N. Rafiev and A. I. Muntianu 1998. Genotypic variability in populations of moundbuilder mice *Mus spicilegus* Pet., 1882, at different life-cycle stages. – *Russian Journal of Genetics*, **34**: 785-790.

Mitsainas G. P., G. A.Tryfonopoulos, E. G. Thanou, R. Bisa, S. E. Fraguedakis-Tsolis, and B. P. Chondropoulos 2009. New data on the distribution of *Mus spicilegus* Petenyi, 1882 (Rodentia, Muridae) and a distinct mtDNA lineage in the southern Balkans. – *Mammalian Biology*, **74**: 351-360.

Nikitina N. A. 1965. The methods of the investigation of the mammals' home ranges by live traps. – *Zoologichesky Zhurnal*, **44**: 598-605. (In Russian).

Orsini P., F. Bonhomme, J. Britton-Davidian, H. Croset, S. Gerasimov and L. Thaler 1983. Le complexe d'espèces du genre Mus en Europe centrale et orientale, II: critères d'identification, répartition et caractéristiques écologiques. – *Zeitschrift fur Saugetierkunde*, **48**: 86-95.

Ostfeld R. S. 1985. Limiting resources and territoriality in microtines rodents. – *American Naturalist*, **126**: 1-15.

Patris B., C. Baudoin 1998. Female sexual preferences in *Mus spicilegus* and *Mus musculus domesticus*: the role of familiarization and sexual experience. – *Animal Behaviour*, **56**: 1465-1470.

Patris B., C. Baudoin 2000. A comparative study of parental care between two rodents species: implications for the mating system of the mound-building mouse *Mus spicilegus*. – *Behavioural Processes*, **51**: 35-43.

Patris B., P. Gouat, C. Jacquot, N. Christophe and C. Baudoin 2002. Agonistic and sociable behaviors in the mound-building mice, *Mus spicilegus*: a comparative study with *Mus musculus domesticus*. – *Aggressive Behaviour*, **28**: 75-84.

Poteaux C., N. Busquet, P. Gouat, K. Katona and C. Baudoin 2008. Socio-genetic structure of mound-building mice, *Mus spicilegus*, in autumn and early spring. – *Biological Journal of the Linnean Society,* **93**: 689-699.

Ribble D.O. 1992. Dispersal in a monogamous rodent, *Peromyscus californicus*. – *Ecology,* **73**: 859-866.

Rosell F., G. Gundersen and J-F Galliard 2008. Territory ownership and familiarity status affect how much male root voles (*Microtus oeconomus*) invest in territory defence. – *Behavioural Ecology and Sociobiology*, doi 10.1007/s00265-008-0585-5

Russel J. 2003. A recent survey of methods for closed populations of small mammals. Unpublished report, The University of Auckland, Auckland, 38 p.

Rychlik L. 1998. Evolution of social systems in shrews. – In: Wójcik J. M. and M. Wolsan (Eds.): Evolution of shrews, Mammal Research Institute, Polish Academy of Sciences, Białowieża, 347-406.

Sage R. D., W. R. Atchley and E. Capanna 1993. House mice as models in systematic biology. – *Systematic Biology,* **42**: 523-561.

Simeonovska-Nikolova D. M. 2007. Spatial organization of the mound-building mouse, *Mus spicilegus* in the region of the northern Bulgaria. – *Acta Zoologica Sinica,* **53**: 22-28.

Sokolov V. E., E. V. Kotenkova and A.G. Michailenko 1998. *Mus spicilegus*. – *Mammalian Species*, **592**: 1-6.

Steen H. 1994. Low survival of long-distance dispersers of the root vole (*Microtus oeconomus*). – *Annales Zoologici Fennici*, **31**: 271-274.

Sutova M. 1969. Importanta factorilor structurali in procesele de dinamica populatiei la *Mus musculus spicilegus* Pet. – *Studii si Cercetari de Biologie Cerie Zoologie,* **5**: 377-384. (In Rumanian).

Szenczi P., O. Bánszegi, A. Dúcs, C. I. Gedeon, G. Markó, I. Németh and V. Altbäcker 2011. Morphology and function of communal mounds of overwintering mound-building mice (Mus spicilegus). – *Journal of Mammalogy*, **92** (4): 852-860.

Temeles E. J. 1994. The role of neighbours in territorial systems: when are they 'dear enemies'? – *Animal Behaviour*, **47**: 339-350.

Wolff J. O., M. H Freeberg and R. D. Dueser 1983. Interspecific territoriality in two sympatric species of *Peromyscus* (Rodentia: Cricetidae). – *Behavioural Ecology and Sociobiology,* **12**: 237-242.

Wu H. Y., H. T. Yu 2004. Spatial Organization of a Forest-Dwelling Murid Rodent, *Niviventer coxingi*, in Subtropical Central Taiwan. – *Zoological Studies*, **43**: 612-621.

Ydenberg R. C., L. A. Giraldeau and J. B. Falls 1988. Neighbors, strangers, and the asymmetric war of attrition. – *Animal Behaviour*, **36**: 343-347.

Received: 27.09.2011
Accepted: 13.02.2012