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POPULATION ANALYSIS AND SPATIAL ACTIVITY OF RODENTS IN FLOODED FOREST CONDITIONS

IVAN BALÁŽ[1], MICHAL AMBROS[2]

[1] Department of Ecology and Environmental Sciences, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Tr. A. Hlinku 1, 949 74 Nitra, Slovak Republic; e-mail: ibalaz@ukf.sk
[2] The Protected Landscape Area Ponitrie, Samova 3, State Nature Protection SR, 949 01 Nitra, Slovak Republic; e-mail: michal.ambros@sopsr.sk

Abstract

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This article solves problems in spatial activity and population size dynamics in *Apodemus flavicollis* and *Clethrionomys glareolus* rodent forest species in the Dvorčiansky forest near Nitra, which was flooded during the vegetation season. Herein the spatial activity values of overruns and home ranges were higher for the males of both species. While the home range size in this season was relatively stable for females of both species, there were fluctuating values for males of both species, with the highest values recorded in spring and the lowest in autumn. This is most likely due to reproduction activity intensity, which is at its peak in spring. The spatial activity of rodent forest species was assessed by the quadrate method of repeated small terrestrial mammals' area of capture. In addition, the *Apodemus sylvaticus* species is also assessed, since it occurs sporadically within the catchments of this monitored quadrate.

Key words: yellow-necked mouse, wood mouse, bank vole, home range

Introduction

The Dvorčiansky forest is a fragment of flooded forest formations located in the former Nitra river mid-stream meanders. The following 8 species of small terrestrial mammals were identified there: *Apodemus flavicollis, A. microps* (*uralensis*), *A. sylvaticus, Clethrionomys glareolus, Crocidura leucodon, C. suaveolens, Microtus subterraneus* and *Sorex araneus* (Dudich et al., 1993). These authors reported the low rate of 5.6% of insectivores and the occurrence of *Crocidura leucodon, Apodemus microps* steppe species. This indicated the gradual degradation of the flooded areas and a slow change to steppe formation. The natural science research of Dvorčiansky forest and its surrounds was carried out by Baláž, Vanková (2005), Petluš, Vanková (2007), and Vanková, Petluš (2009) who analytically evaluated the forest edge of this special area of conservation (SAC). Baláž, Jančová (2008) reported reproduction activity and fertility of *Clethrionomys glareolus* and *Apodemus flavicollis* in the hilly level of this land. These authors evaluated results from 1996 to 2005, including the percentage rate of females in different months and also the number of embryos in uterus. Bridišová, Baláž (2007) also investigated *A. flavicollis* and *Clethrionomys glareolus* species in forest ecosystems in the Nitra highlands and as well as tick and flea ectoparasites samples. The following 6 species of small mammals were in the Dvorčiansky forest: *Sorex araneus*, *Apodemus flavicollis*, *A. sylvaticus*, *Clethrionomys glareolus*, *Microtus subterraneus* and *M. arvalis*.

The aim of this article is to characterize the space activity via the home range size and the dynamics of *Apodemus flavicollis* and *Clethrionomys glareolus* forests rodent species in Dvorčiansky forest throughout the vegetation season. The focus here centred on the size of the species' home range, and on the analysis of the possible inter and intra-specific influences on the population density.

Apodemus flavicollis and *Clethrionomys glareolus* can be found in deciduous forests with a high diversity of species throughout Europe (Mitchell-Jones et al., 1999). They are grain and herb eating rodent species and often accompanied by *Apodemus sylvaticus*, especially in Western Europe (Bergstedt, 1965; Montgomery, 1980).

Although many authors have investigated problems in spatial relationships between dominant species of small mammals by determining the size of their home range (Randolph, 1977; Wolton, Flowerdew, 1985; Kozakiewicz et al., 1993; Bergstedt, 1966; Andrzejewski, Mazurkiewicz, 1976; Karlsson, As, 1987) concentrated on the home range size of the typically dominant forest rodents in European deciduous forests.

Material and methods

Study area

Dvorčiansky forest is situated near Dolné Krškany village in the Nitra district. The area is on the third level of protection, and its size is 142.55 ha at an altitude of 138 m a.s.l. The geo-morphological unit Podunajská pahorkatina highland forms part of the Nitra flat (Mazúr, Lukniš, 2002). The geological bedrock is composed of sediments from the cenozic at a depth of 250 to 300 m in the flood alluvia of the Nitra river. These 5 to 8 m thick deposits are stored in neogene sediments situated on the edges of this area where flood waters could not reach. According to the phyto-geographical classification of Slovakia, this area is situated in the Pannonia region, eupanonic xerotherm flora district (*Eupannonicum*) (Futák, 1972).

The locality can be classified as follows; it has a warm lowland climate with a long to very long, warm and dry summer and a short, mildly warm, dry to very dry winter. The average annual temperature ranges from 9 to10 °C, with July average temperatures of 18 to 20.5 °C and January averages of -1 to -3 °C. The annual average precipitation is 500−600 mm, with snow cover lasting from 30 to 40 days annually (Hreško, Mederly, 2006). This area is in the Nitra river region, where there are several dead river branches and endorheic drainage depressions (Gajdoš, 1990).

The locality is coded SKUEV0176, and it is a Special Area of Conservation according to the Ministry of Environment edict no. 3/2004-5.1, effective from 1st August 2004. The area is protected under the third level of nature protection due to conservation of habitats of riparian mixed forests of *Quercus robur*, *Ulmus laevis* und *U. minor*, *Fraxinus excelsior*, *F. angustifolia*, along the great rivers – *Ulmenion minoris* (habitat code; 91F0) and the Pannonic woods with *Quercus petraea* and *Carpinus betulus* (habitat code; 91G0).

The vegetation of Dvorčiansky forest is endangered by intensively used agricultural land and also by the expansive dispersion of invasive species from the urban areas, such as *Robinia pseudoacacia* and *Ailanthus altissima*. The river-basin of the old Nitra river was regulated, disturbing the water regime and changing the vegetation. The vegetation species are influenced by artificial planting of *Quercus robur*, *Fraxinus excelsior* and *Juglans nigra* species. These problems should be addressed by preservation and restoration of the original species composition of forest vegetation and by the elimination of alien species, in order to halt their spread to adjacent localities.

The studied quadrate (habitat Ls 1.2 oak-elm-ash flooded forests – hard flooded forest with summer oak) is dominated by *Quercus robur* - dom., *Fraxinus angustifolia* - subdom., *Acer campestre* - subdom., *Ulmus minor* - subdom., other woody plants *Sambucus nigra, Swida sanguinea, Euonymus europaea, Malus sylvestris, Prunus spinosa, Negundo aceroides*, dominant herbs among the undergrowth *Urtica dioica* - dom., *Pulmonaria officinalis* - dom., *Mercurialis perennis* - dom., *Lamium maculatum* - dom., *Rubus caesius* - subdom., other dominant or subdominant species in the vegetation cover are *Impatiens parviflora, Circaea lutetiana, Geum urbanum, Glechoma hederifolia, Geranium robertianum, Galium aparine, Brachypodium sylvaticum, Arum alpinum, Rumex conglomeratus, Carex muricata* agg., *Carex sylvatica, Parthenocissus pubescent, Chelidonium majus, Melica uniflora, Ajuga reptans, Stachys sylvatica, Ballota nigra, Alliaria petiolata, Milium effusum, Polygonatum multiflorum, Viola reichenbachiana* and *Heracleum sphondylium* (Košťál, in verb.). Hard flooded forest is a remnant of the original landscape archetype in lowland, resp. hilly (Hreško et al., 2010).

Rodent research methods

Forest rodents *Apodemus flavicollis* and *Clethrionomys glareolus* were caught by quadrate method of repeated entrapment on research localities measuring 70x70 m (0.49 ha) in the Dvorčiansky forest between 2006 and 2008. The quadrate was created by 49 catchment points set up in 7 lines and 7 columns at regular 10 m intervals. Each capture point was created by a live-capture trap. To obtain ecological data, the live-capture traps functioned on the principle of "capture – mark – recapture". Captured individuals were earmarked numerically by a commercial laboratory ear-iron. The traps were checked twice a day at 8 AM and 5 PM. The age, sex and reproductive status were determined. The gender of captured individuals was assessed (males – M, females – F) and divided into the following three categories: (1) juveniles – young individuals, who did not achieve the size of adult individuals and had juvenile fur colour; (2) immature – adult sized rodents who were sexually immature, and (3) sexually mature individuals. The additional category of sub-adult was also considered, where individuals similar to adults in size but sexually immature and inactive were regarded as sub-adult. The sexual maturity of the adult individuals was then examined. Mature females which were pregnant or had open vaginal orifices were distinguished from the sexually immature ones, and mature males with scrotal testes were differentiated from immature ones with abdominal testes.

The acquisition of forest rodents was achieved during 9 field research series: October 2006 – 5 controls, April 2007 – 6 controls, June 2007 – 6 controls, August 2007 – 6 controls, April 2008 – 5 controls, July 2008 – 5 controls, September 2008 – 6 controls, October 2008 – 7 controls, November 2008 – 6 controls. This gave a total of 52 controls.

The home range size was set by counting within the border strip (Stickel, 1954). The maximum distance between traps where the individual was caught formed the basis for the identification of the home range index. Here, the observed length of the range, overrun – ORL was determined, as in Mazurkiewicz, Rajska-Jurgiel (1987, 1998).

The adult and sub-adult gender ratio was evaluated on the basis of the frequency χ^2 test. Dependent on the χ^2 and significance level, this could exhibit a significant or highly significant difference. Where individual numbers were less than 200, the Yates correction was applied (Pelikán, 1984). The following formula was used from the difference between the proven and expected number of individuals.

$$\chi^2 = \frac{[(M - F) - 1]^2}{n},$$

where M = males, F = females, n = number of individuals is count out. To achieve zero difference between the proven and expected values, the standard deviation was calculated by:

$s = \sqrt{p.q.n}$ where p = 0.5 = q and n = number of individuals.

The spatial activity of forest rodents was established by the simple application of Java which loads the text file with instructions concerning the position of capture points and numbers. Traps were set in 7 rows with 7 columns, and csv-files formed the algorithm exit where data was separated by a comma. This data basically created the graphic output in jpg format, containing the home range information for each captured individual.

Results

A total of 345 small terrestrial mammals were caught. These consisted of 152 males and 193 females (Table 1), comprising; 131 *Apodemus flavicollis* (59 males, 72 females), 171 *Clethrionomys glareolus* (77 males, 94 females), 40 ex. *Apodemus sylvaticus* (14 males, 26 females) and 2 *Microtus arvalis* (1 male and 1 female). One male *Sorex araneus* was also found in the studied quadrate. A total of 716 captures were achieved. These consisted of, 209 *Apodemus flavicollis*, 421 *Clethrionomys glareolus* and 86 *Apodemus sylvaticus*. We also analyzed 177 individuals which were recaptured at least once (44 *A. flavicollis*, 106 *Clethrionomys glareolus* and 27 *Apodemus sylvaticus*), in order to assess the size of their home range. The most recaptured individuals were as follows: *A. flavicollis* – 9 females between 3.9.2008 and 20.3.2009, and 5 males from 3.9.2008 to 18.3.2009, *Clethrionomys glareolus* – 3 females from 14.10.2008 to 18.3.2009 and also10 males from 3.9.2008 to 13.11.2008.

The abundance of individual species varied considerably in this study period (Table 1, Fig. 1). The maximum value for population density of *Apodemus flavicollis* was recorded in

T a b l e 1. Synopsis of analyzed forest rodents in Dvorčiansky forest in the period 2006–2008.

Season	Species	No. of males		No. of females		ex./ha	χ^2 (s)
		juv + sad	ad	juv + sad	ad		
Autumn 2006 9 individuals	*A. flavicollis*	0	2	0	3	10	0.2 (1.12)
	C. glareolus	0	3	0	1	8	0.25 (1)
	Total	0	5	0	4	18	0 (1.5)
Spring 2007 58 individuals	*A. flavicollis*	3	16	7	21	99	0.43 (3.04)
	C. glareolus	1	1	0	3	10	0.25 (1)
	A. sylvaticus	0	1	0	5	12	1.5 (1.22)
	Total	4	18	7	29	121	2.13 (3.43)
Summer 2007 134 individuals	*A. flavicollis*	5	8	3	7	47	0 (1.94)
	C. glareolus	21	12	34	13	163	0 (2.5)
	A. sylvaticus	2	10	10	9	63	0 (2.18)
	Total	28	30	47	29	273	0 (3.84)
Spring 2008 24 individuals	*A. flavicollis*	1	4	2	2	18	0.16 (0.25)
	C. glareolus	5	0	7	3	31	1.33 (0.87)
	Total	6	4	9	5	49	0 (1.5)
Summer 2008 53 individuals	*A. flavicollis*	2	9	7	4	45	1.23 (1.8)
	C. glareolus	13	0	9	7	59	5.14 (1.32)
	A. sylvaticus	0	0	0	2	4	0.5 (0.71)
	Total	15	9	16	13	108	0.41 (2.35)
Autumn 2008 64 individuals	*A. flavicollis*	1	8	7	9	51	0 (2.06)
	C. glareolus	18	3	12	5	78	0.13 (1.41)
	A. sylvaticus	1	0	0	0	2	-
	Total	20	11	19	14	131	0.08 (2.5)

Notes: juv – juveniles, sad – sub-adults, ad – adults, testing by χ^2 with Yates correction, s – standard deviation.

spring 2007 at 99 ex./ha, with a second peak in autumn 2008 of 51 ex./ha. The minimum density values were recorded in spring 2008 at 18 ex./ha and in autumn 2006 with10 ex./ha. *Clethrionomys glareolus* population abundance peaked in summer 2007 (163 ex./ha) and in autumn 2008 (78 ex./ha), while minimum density values were recorded in spring 2007 (10 ex./ha) and in autumn 2006 (8 ex./ha).

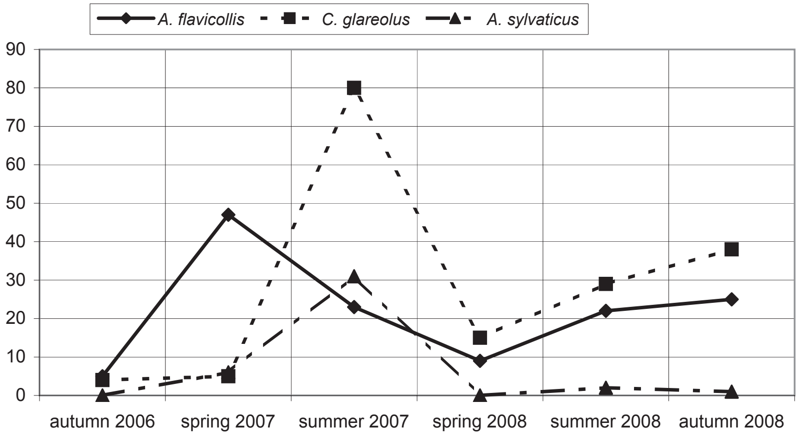

Fig. 1. Changes in abundance values for forest rodents in the Dvorčiansky forest.

The population of *Apodemus sylvaticus* had its peak in summer 2007 at 63 ex./ha, but its abundance was generally very low and its occurrence was not constant. Forests are not typical habitats for this species, as it tries to avoid complete forest cover.

The overall density of small mammals peaked in summer 2007 at 273 ex./ha, and the next highest density was recorded in autumn 2008 at 131 ex./ha. In addition, the abundance was lowest during spring (Table 1, Fig. 2).

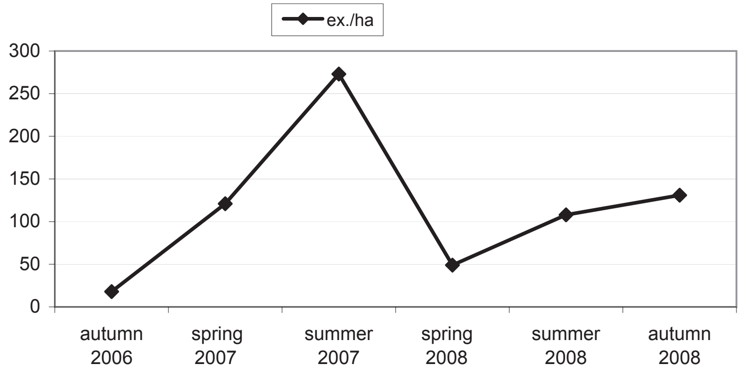

Fig. 2. The dynamics of individuals numbers of small mammals in 1 ha of heavily flooded forest.

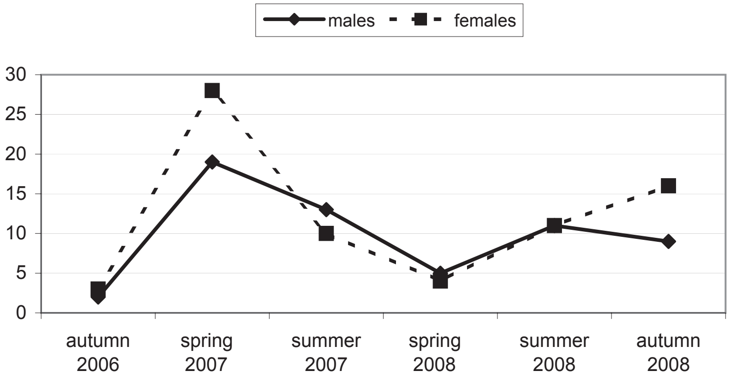

Fig. 3. The dynamics of adult males and females numbers of *Apodemus flavicollis*.

The gender ratio of male to female favoured females as follows; 45.9 : 54.9% for *Apodemus flavicollis*, 45.1 : 54.9% for *Clethrionomys glareolus* and 35 : 65% for *Apodemus sylvaticus* (Table 1). Thus female prevalence was recorded in all three studied forest rodents with just the following exceptions; (1) a small prevalence of *A. flavicollis* males in summer 2007 and in spring 2008, and (2) *Clethrionomys glareolus* and *Apodemus sylvaticus* males prevailed slightly in autumn 2008. We can generally record a balanced ratio of the sexes in all analyzed species, even though the chi-quadrate test of *A. sylvaticus* has the relatively high value of 3.025, s = 3.16. The sex ratios followed a similar course during 2006 and 2008. A striking phenomenon was observed in 2007, where *A. flavicollis* significantly prevailed during the spring, while *Clethrionomys glareolus* dominated during that summer (Figs 3, 4, 5).

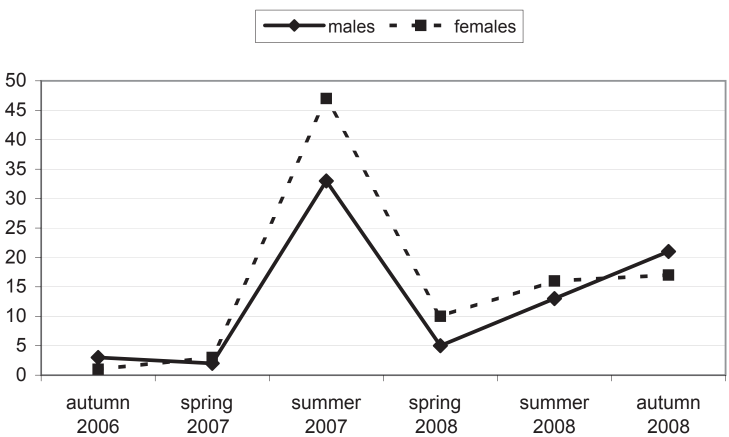

Fig. 4. The dynamics of adult males and females numbers of *Clethrionomys glareolus*.

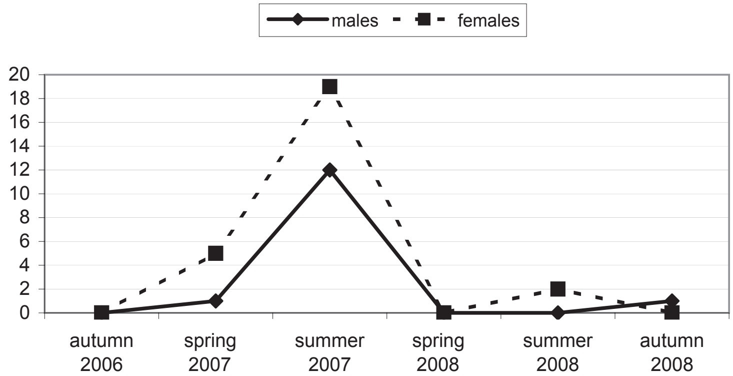

Fig. 5. The dynamics of adult males and females numbers of *Apodemus sylvaticus*.

Although the ratio of *Apodemus flavicollis, Clethrionomys glareolus* and *Apodemus sylvaticus* slightly favoured females, the gender ratio was always balanced.

The size of the *A. flavicollis* male *home range* registered 100 to 1300 m^2, with an average of 294.6 m^2 and an over-run from 0 to 43 m, averaging 10.9 m. The average home range value for males in spring was 514.3 m^2 (200–1300 m^2), in summer 169.2 m^2 (100–300 m^2) and in autumn 281.3 m^2 (100–600 m^2). Meanwhile, the *A. flavicollis* female home range measured from 100 to 400 m^2 (average 230 m^2, Fig. 6), with an over-run from 0 to 14 (average 8.9 m). The average value of home range for females was 225 m^2 in spring (100–400 m^2), 225 m^2 in summer (100–300 m^2) and 235.7 m^2 in autumn (100–350 m^2).

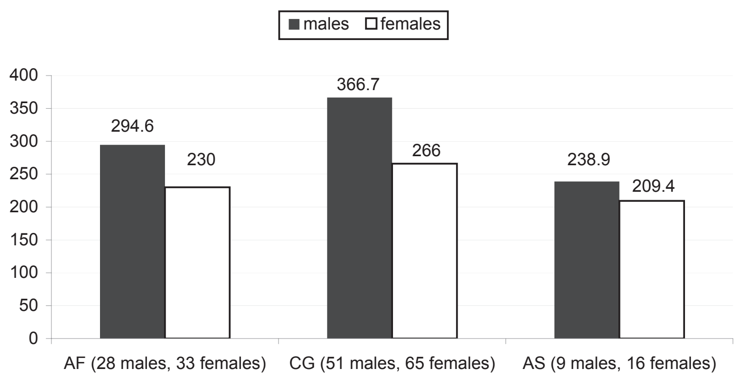

Fig. 6. The mean values of home range size (in m^2) in males and females of forest rodents (AF – *Apodemus flavicollis*, CG – *Clethrionomys glareolus*, AS – *Apodemus sylvaticus*.

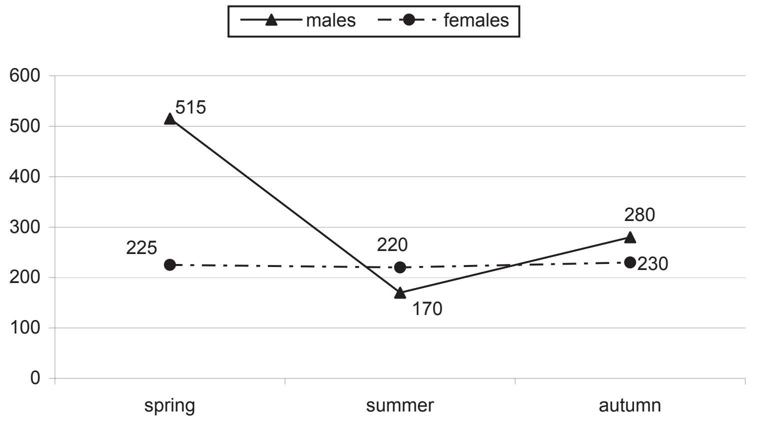

Fig. 7. The dynamics of seasonal home range sizes (in m^2) of both *Apodemus flavicollis* sexes.

The *Clethrionomys glareolus* male home range size was from 100 to 1300 m^2 with an average of 366.7 m^2, while the over-run was from 0 to 55.4 m, at an average of 8.7 m. The average male home range size in spring was 466.7 m^2 (200 – 900 m^2), in summer 432.7 m^2 (100–1300 m^2) and in autumn 265.9 m^2 (100–1050 m^2). Meanwhile, the *C. glareolus* female home range size was from 100 to 750 m^2 (average 266 m^2, Fig. 6) with an over-run from 0 to 46 (average 9.3 m). The female home range size in spring was 312.5 m^2 (100–750 m^2), in summer 255.8 m^2 (100–750 m^2) and in autumn 270 m^2 (100–650 m^2).

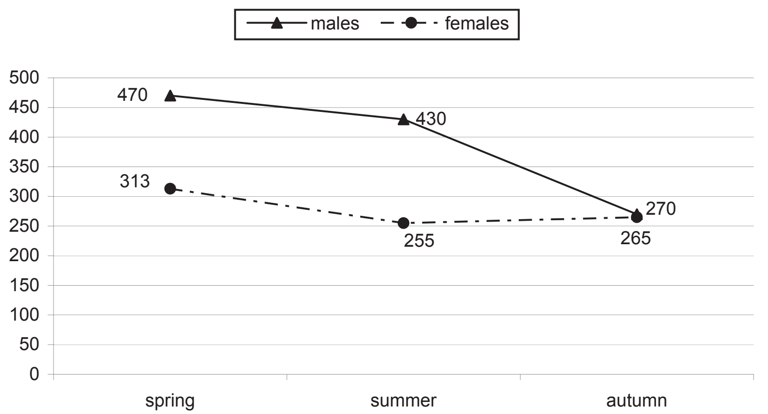

Fig. 8. The dynamics of seasonal home range size (in m^2) of both *Clethrionomys glareolus* sexes.

The *Apodemus sylvaticus* male home range size was from 100 to 400 m^2 (average 238.9 m^2) with an over-run from 0 to 20 m (average 7.9 m), while the *A. sylvaticus* female home range was from 100 to 350 m^2 (average 209.4 m^2, Fig. 6) with an over-run from 0 to 20 (average 7.2 m). The data for this species is only from the summer season. *A. sylvaticus* is not a representative forest species, and the abundance of individuals in the study plot was very low. The correct species determination throughout this study was validated by genetic analysis.

Male home range sizes for both *A. flavicollis* and *Clethrionomys glareolus* species, exhibited seasonal changes, the highest home range values were registered in spring, but these gradually decreased until autumn. In contrast, the seasonal female home ranges did not change markedly. Higher variations were recorded for *C. glareolus* females (Figs 7, 8).

The overall overlap of home range of all these captured small mammals was 76.07%. The overlap of individual species home range was as follows: *Apodemus flavicollis* 15.04% (0–67.6%), *Clethrionomys glareolus* 47.7% and *Apodemus sylvaticus* registered 11.2%. The maximum overlap of 67.6% was recorded for *A. flavicollis* in spring, with low values observed during summer. In contrast, the maximum for *Clethrionomys glareolus* was 100% in summer, with low values noted in spring.

Apodemus flavicollis individuals utilized the Dvorčiansky space vertically as well as horizontally. In the one quadrate, we observed the presence of field mice in nest boxes during the entire research period. Although these nest boxes had been installed to observe the nesting of tree cavity dwellers, these individuals utilized them in each season, including winter. This would perfectly explain the lower values registered for over-runs and home ranges. Overall, increased numbers of *A. flavicollis* were recorded from autumn to spring, while no *Clethrionomys glareolus* individuals were observed in nest boxes throughout the entire study period.

While small terrestrial mammal density values were relatively low in autumn 2006 and spring 2007, highest values were recorded in summer 2007 and values then stabilized in 2008. While *Apodemus flavicollis* individuals prevailed in the above-mentioned low density periods, *Clethrionomys glareolus* individuals dominated all other capture periods. Although the highest average over-run was registered for *Apodemus flavicollis*, the longest distances were recorded for *Clethrionomys glareolus*. *C. glareolus* had the highest average home range values, but *Apodemus flavicollis* individuals also populated the space vertically in the trees and tree cavities. This increased activity and vertical mobility is most likely the reason why the *A. flavicollis* home range is smaller than that of *Clethrionomys glareolus*.

Discussion

The spatial distribution of small mammals has been analyzed by several authors (Szacki, Liro, 1991; Montgomery, Dowie, 1993; Marsh et al., 2001). However, it is still uncertain how individuals settle in an area, and how they interact with each other. The most critical resource for the social organization of mice is space availability.

Spatial activity conditions the settlement of new areas, whereby the influence of low population density lacks intra-species competition, at least at the beginning and until the population density stabilizes. The mobility of the individuals also facilitates exchange of genetic information between different populations, or parts thereof, hence, this possibility is critically important for population genetics and species formation (Pelikán, 1975, 1984).

Home range was defined by Burt (1943) as "... the area used by individuals of species in their normal activities as feeding, mating and taking care of the offspring". Anderson (1982) and Blundell et al. (2001) define home range as "probability of animal localization in a given space utilizing used distribution based on relative position frequency". This "used distribution" is represented by the used space, which is usually described as the size of the home range and structure of the environment. The home range can vary depending on basic requirements for food, reproduction and shelter (Adams, Davis, 1967; Fernandez et al., 1996).

Current observations show that small mammals are able to move far greater distances than previously assumed (Szacki et al., 1993; Kozakiewicz, Szacki, 1995). For example, "long distance" movement of more than 1000 m was recognized in the *Apodemus sylvaticus, Clethrionomys glareolus* and *Mus musculus* species. Kozakiewicz, Szacki (1995) established that small mammals migrate relatively long distances dependent on their colonization of homogeneous or heterogeneous environments. *Clethrionomys glareolus* and *Apodemus flavicollis* species that colonized heterogeneous suburban environments moved greater distances than those who colonized homogeneous environments. Kozakiewicz et al. (1993) observed that *Clethrionomys glareolus*, as a forest species, covered an average of 135 m in a homogeneous forest, but averaged 243 m in a fragmented agricultural landscape environment. This increase may have just indicated a natural reaction to the environmental fragmentation. The average over-run in our Dvorčiansky forest study plot was 8.7 m for males and 9.3 m for females. Increased small mammal mobility depends not only on the average distance they run, but also on their ability to utilize different types of environment (Wagner, Merriam, 1990).

The *Apodemus flavicollis* species is characterized by greater mobility and is strictly depended on the forest environment (Montgomery, 1985). Vukićević-Radić et al. (2006) reported that ORL values for *Apodemus flavicollis* in the *Orno-Quercetum petraeae* forest community ranged from 10 to 134 m in different seasons. The average male over-run in Dvorčiansky forest on 100 to 2300 m^2. Home range was 10.9 and 8.9 m for females. The mean home range size here was 625 m^2 for males and 551 m^2 for females. Vukićević-Radić et al. (2006) reported higher over-run (ORL) and home range (HR) figures for *A. flavicollis*, and indeed, their home range size was double our research findings.

The change in forest rodent density with changing home range size was studied by Wolff (1993), Bujalska, Grüm (1989), and also by Mazurkiewicz, Rajska-Jurgiel (1998). Vukićević-Radić et al. (2006) reported that low population densities of *A. flavicollis* used larger home ranges, and high densities utilized smaller ones. However, ORL and HR sizes in periods of low density were evidently smaller when there was a concurrent high density of other species and these differences were more noticeable in the ORL than in the HR. Mazurkiewicz, Rajska-Jurgiel (1998) considered that the spatial activity of *A. flavicollis* is very flexible and it can change in different environmental conditions. Horváth, Wagner (2003) studied coexistence of *A. flavicollis* and *Clethrionomys glareolus* in forest habitats in southern Hungary, and they concluded that *C. glareolus* has a limiting effect on the density and spatial distribution of *Apodemus flavicollis*.

These mammals' utilization of space varies with gender. This reflects demographic and reproduction differences between the sexes, and also different responses to resource availability. In Stradioto et al. (2009) observations of the spatial activity of *A. flavicollis* in beech forest in the eastern part of the Italian Alps, they reported that males' home ranges were significantly larger than those of females, and these overlapped with areas inhabited by several individuals of both sexes. The females occupied area centres, and never common holes with other females, although their home range overlapped with that of several males (intra-sexual territory). The use of space changed in different seasons and years, and also in relation to quantity and distribution of resources. Females inhabited significantly reduced space and larger home ranges during low food availability, while males changed their spatial distribution according to their home ranges size availability. A rapid and intense dispersion was observed in both species in deteriorating space quality. This indicates that females changed their spatial and social relationships according to existing environmental conditions, and the males changed their use of space in conjunction with the females.

Pusenius, Ylönen (1994) studied *Clethrionomys glareolus*'s spatial activity during gradation in central Finland, comparing open populations and those closed – by captivity. They found that more females mature in open populations, and those home ranges sizes did not vary between populations. The reproducing females in open populations were more territorial than those in enclosed populations, and male home ranges were larger for both populations. The overlapping of home ranges between fertile males of both populations was greater that for fertile females.

C. glareolus exhibited multiphase diurnal activity, with the main maximum occurring in the mornings in spring, while several activity peaks were recorded in summer. *Apodemus flavicollis* had one peak of typical nocturnal activity during the entire year, with maximum between 10 PM and 2 AM (Wójcik, Wołk, 1985). In this present period of forest rodent capture in the Dvorčianky forest, *A. flavicollis* individuals absolutely predominated over *Clethrionomys glareolus* in morning checks, but this situation was reversed during evening checks. Meanwhile, *C. glareolus* markedly prevailed over *Apodemus flavicollis* during the afternoon checking.

The following research studies on inter and intra-species interactions have been carried out; Suchomel (2007) stated that the increase in *Clethrionomys glareolus* numbers in 2005 was most likely influenced by a low abundance of *Apodemus flavicollis*, and that in greater numbers these could have significantly restricted the population of ginger-nob by inhabiting its ecological niche. Bujalska and Grüm (2008) reported that *A. flavicollis* began breeding earlier in spring than *Clethrionomys glareolus*. In addition, bank voles appear to affect breeding of yellow-necked mice when both populations rapidly increase from April to July, since bank voles are considered to always survive better than yellow-necked mice. Bujalska et al. (2009) reported that single mature females of both species often occur in the same place, whereas local groups of such females rarely cohabit, and also that mature males of these species always avoid sites occupied by males of the other species. Kozubová et al. (2007) registered the following maximum values of *C. glareolus* density in alder forest: 42.07 ex./ha in July 2002, 1.55 ex./ha in April 2003 and 16.59 ex./ha in October 2004. Meanwhile, *C. glareolus* density in Dvorčiansky forest was 10 ex./ha in spring 2007, 163 ex./ha in summer 2007, 78 ex./ha in autumn 2008 and 8 ex./ha in autumn 2006. These authors also determined the high rate of overlapping of individual home ranges of sexually active females and males during the reproductive season at 60–86%. They also stated that the unusually high 35.6% home range overlap of sexually active females indicates some measure of tolerance between them, while the male home range overlap was very low in the mating season. It was also reported that individuals showed mutual social tolerance outside the reproductive season.

Horváth et al. (2005) observed the spatial distribution of small mammals in the *Paridi quadrifoliae-Alnetum* protected forest gradually changing into shrubbery, and also in the part of the forest where renewed reforestation occurred following logging. *Apodemus flavicollis* and *Clethrionomys glareolus* were more abundant and equally distributed in the entire alder forest study area than in the young reforested forest. The space in the protected forest is divided into *Apodemus flavicollis* sole occurrence and the joint occurrence of *A. flavicollis* and *Clethrionomys glareolus*, while *Apodemus flavicollis* was not present in the reforested area. Hiadlovská (2007) recorded the following values for species density; (1) for *A. flavicollis* in the Malé Karpaty Mts forest community: (a) in 2005, an average of 8.48 ex./ha with a maximum in July and August of 15.3 ex./ha and (b) in 2006, an average of 2.11 ex./ha with a maximum in June of 2.94 ex./ha; (2) for *A. flavicollis* in Dvorčiansky forest there were 99 ex./ha in spring 2007, 51 ex./ha in autumn 2008, 18 ex./ha in spring 2008 and 10 ex./ha in autumn 2006; and (3) for *Clethrionomys glareolus,* in 2005 there was an average of 1.21 ex./ha and a maximum of 2.34 ex./ha in August, and in 2006 the average was 3.02 ex./ha with a maximum of 5.61 ex./ha in June.

Spatial relationship analysis focused on establishing whether *Apodemus flavicollis* and *Clethrionomys glareolus* species colonized the same habitats. The spatial distribution of many species depends on the presence of topic (as in hiding) and trophic resources. However, the selective use of microhabitats for ecologically related species is a mechanism which supports the coexistence of species and also reduces negative interactions. *Apodemus flavicollis* and *Clethrionomys glareolus* either utilized different parts of the study area or they shared it in such a way that when there was high abundance of one species, there was an absolute minimum of the other. While higher home range values were recorded for *C. glareolus* than *Apodemus*, we assumed that field mice, as a more mobile species, would record higher home range values.

Interestingly, *A. flavicollis* individuals also used space vertically in the Dvorčiansky forest. Puchala (2004) and Balát, Pelikán (1959) reported the presence of *A. flavicollis* in nest boxes throughout the entire year. This species utilized these nest boxes as hiding place, shelter, food storage and as a safe place to raise offspring. We concurred with Puchala's (2004) finding that there were increased numbers of *A. flavicollis* individuals from autumn to spring.

Finally, we did not observe any *Clethrionomys glareolus* individuals in nest boxes, simply because this species is not specialized for tree climbing.

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