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Ecology and space use in a relict population of the European Ground Squirrel (*Spermophilus citellus*) at the north-western edge of its distribution range

Ekologie a prostorové uspořádání v reliktní populaci sysla obecného (*Spermophilus citellus*) na severozápadní hranici areálu jeho rozšíření

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Abstract. The study is focused on demography and space use in an isolated population of European ground squirrel (*Spermophilus citellus*) living on the periphery of its distribution range. Data were collected during the three year period using standard mark-recapture method combined with frequent observations in a defined 2 ha area. Abundance varied from 4.0 ind./ha in spring 2004 to 17.5 inds./ha in summer 2003. Similarly, the number of burrow entrances per individual varied from 5.6 to 32.2. The sex ratio in adults varied inconsistently and in juveniles was male biased. Death loss during the hibernation was the main part of inter-year mortality rate, particularly in juveniles. Entering into hibernation occurred gradually starting with adult females immerging first, then adult males and finally juveniles. Males emerged from hibernation approximately two weeks before females. The hibernation was longest in adult females followed by adult males and shortest in juveniles of both sexes. Body mass among adults varied from 145–430 g for females and 250–520 g for males. Comparisons revealed significant differences in body mass between the sexes in both age categories (adults and juveniles). The home range size varied from 2.126 to 5.395 m^2 in adult males and from 1.031 to 3.161 m^2 in adult females. Home ranges overlapped both inter and intra sexes. Results seems to be consistent with data from other European ground squirrel populations, but it should be pointed out that the demographical characteristics observed are usually close to upper limiting (mortality, body mass) or lower limiting values (density, survival).

Key words. *Spermophilus citellus*, demography, timing of seasonal activity, home range, body mass.

INTRODUCTION

The European ground squirrel, *Spermophilus citellus* (Linnaeus, 1766) inhabits some parts of central Europe and the Balkans. Its distribution range extends from western Ukraine in the East to Greece and European Turkey in the South. The north-western edge of its geographic range lies in the Czech Republic (Ružić 1978, Mitchell-Jones et al. 1999). Due to major changes in agriculture and landscape management starting in the late fifties of the 20th century, the European ground squirrel lost major parts of its habitat in the Czech Republic and consequently, its abundance has decreased (Anděra & Hanzal 1995, Cepáková & Hulová 2002). The species is now included in the Red List of critically endangered vertebrate taxa of the Czech Republic (Anděra & Červený 2003), and it is also protected by the Act on Nature Conservation and Land-

scape Protection no. 114/1992 Code against killing, habitat destruction and human disturbance (executive ordinance ME CZ n. 395/1992 Code).

The main aim of this study was to document all basic life-history traits of *S. citellus* living under extreme conditions. These conditions were represented by (1) a small population size (at the time of the study the maximum estimated abundance was 250 individuals), (2) complete isolation of the population on the periphery of the distribution range of the species (the nearest reported *S. citellus* occurrence was about 50 km far to the East) and (3) relatively high elevation (600 m) and mainly Atlantic climate with the average annual rainfall of 600–750 mm (Quitt 1971).

The study was focussed on parameters that are reported to be characteristic of all ground-dwelling sciurid species and at the same time vary across latitude, altitude and habitat type, such as body mass changes, timing of annual cycle and mortality (Michener 1984). The aim was to enable future comparison of these parameters with data reported from different parts of the species' range (Millesi et al. 1999, Danila 1982, Ružić 1978, Straka 1963, Grulich 1960). Knowledge on life history and behaviour of *S. citellus* under extreme conditions will help to find out ecological requirements and constraints of this species.

MATERIAL AND METHODS

The studied *S. citellus* population inhabits the golf range of Olšová Vrata, 5 km south-east of Karlovy Vary, Czech Republic (50° 12' N, 12° 55' E; altitude 550–607 m). The total area of the golf range is 47.2 ha, including 27.1 ha of lawns. The rest of the area consists of ponds, remnants of former forest and shrubs. The golf range is surrounded by a forest, a long-grass meadow and a highway.

The *S. citellus* were observed and trapped during three whole active seasons (March to October), from 2002 to 2004, the special attention was focused on 2.0 ha study plot in the central part of the ground squirrel colony. Occasional trapping and observations were performed in 2000, 2001, 2005 and 2006. Ground squirrels were live-trapped using snares attached at burrow entrances. All burrow entrances at the study plot were marked by metal tags with numbers and recorded on a map of the area. Animals were marked with subcutaneous transponder chips (Datamars, T-IS 8010 FXD-B) injected in the back of a neck.

At capture, each animal was identified, weighed (PESOLA scale, ±2.5 g) and the place of the capture (number of burrow entrance) was recorded. Individuals were categorized according to sex and age: adults (males and females after first hibernation and older) and juveniles (males and females before first hibernation). Reproductive status of male ground squirrels was also recorded. Males were defined as reproductive if they had dark scrotal pigmentation and descendent testes. Immergence body mass was defined as body mass of an individual captured <10 days before immergence into hibernation. Emergence body mass was defined similarly as body mass <10 days after emergence from hibernation. Mass loss during hibernation was calculated as the difference between immergence body mass and emergence body mass, and the proportional loss was the percentage of immergence mass lost. Furthermore, body-mass gain (g/day) in juveniles, adult males before hibernation and females during gestation were calculated. Absolute body-mass gain (v) was calculated with $v=(m_{t1}-m_{t2})/(t_1-t_2)$ and relative body-mass gain (r) with $r=(m_{t2}-m_{t1})/(m_{t1}+m_{t2})\times 0.5$, where m = body mass (g), t = time of capture (days). Thus it was possible to compare values measured in variable time periods.

It was impossible to measure length of active season and hibernation for a sufficient number of individuals from each age and sex category. Therefore, duration of active season was calculated as the period between observation or capture of the first and the last animal of the respective age and sex active above ground. Duration of hibernation was calculated using the same method, conversely. Data on their first and last presence above ground were recorded only for limited number of individuals. Mortality was calculated as the difference between the number of *S. citellus* individuals immerging into hibernation and the number of individuals emerging from hibernation next spring. Mortality during the active season was recorded

only on the base of direct observations, found carcasses and reports of the golf- range staff. To minimize errors due to emigration of individuals from the central study plot, trapping was also performed on the rest of the golf range. Small sample sizes in analyses were caused mainly by high mortality of animals and also by limited observation time.

Size of the home range was calculated using method of the minimum convex polygon on the base of at least 10 independent observations or recaptures of each individual. The size and spatial distribution of home ranges was assessed using the ArcMap™ 9.1 software (ESRI Inc.).

Due to small sample size, body-mass data were statistically analyzed by Mann-Whitney U-test. When individuals were measured repeatedly in a particular phase, the mean value for each individual was used.

RESULTS

Abundance and sex ratio

In 2002, the population on the study plot consisted of 10 adults and 15 juveniles (5 ad. and 7.5 juvs./ha). The number of individuals increased slightly to 13 adults and 22 juveniles (6.5 ad. and 11 juvs./ha) in 2003. In 2004, the abundance of ground squirrels at the study plot declined to only 5 adults and 3 juveniles (2.5 ad. and 1.5 juvs./ha). Number of burrow entrances per individual changed rapidly with abundance; however the overall number of entrances remained nearly constant (Table 1). During the summer 2002, the size of the whole studied population was estimated to be ca 250 individuals and it rapidly declined to ca 150 in 2003 and merely 30 individuals in 2004.

Sex ratio (proportion of males) in adults was balanced (0.50 males) in 2002, slightly male biased (0.62) in 2003 and female biased (0.33) in 2004. The sex ratio among juveniles varied from 0.60 in 2002 to 0.50 in 2003 and 0.67 in 2004.

Mortality

Differences between sex ratio in adults and juveniles indicate that mortality varies with age and sex. During the active seasons in 2002 and 2003, 20% of adult females were found dead (2 from a total of 10 individuals), but no adult males (n=13). During hibernation, mortality of

Table 1. Variation in the number of burrow entrances per individual at the study plot
Tab. 1. Variabilita počtu vchodů do nor a počtu jedinců na studijní ploše

period / období	No. of individuals / počet jedinců	No of burrow entrances / počet vchodů do nor	burrow entrances per individual / počet vchodů na jedince
April–May 2002	10	156	15.6
June–July 2002	25	156	6.2
August–September 2002	23	156	6.8
April–May 2003	12	167	13.9
June–July 2003	30	167	5.6
August–September 2003	23	167	7.3
April–May 2004	6	161	26.8
June–July 2004	5	161	32 2

adult females was 25% (i.e. 1 from a total 4 ind.) in winter 2002–2003 and it increased considerably to 80% (i.e. 4 from a total 5 ind.) in winter of 2003–2004. Mortality of adult males during hibernation in 2002–2003 and 2003–2004 was 20% (i.e. 1 from a total 5 ind.) and 87.5% (i.e. 7 from a total 8 ind.), respectively. Among juveniles, 11.1% (i. e. 1 from a total of 9 ind.) of the males died during the active season of 2002, but no any female (n=6). Similarly, in 2003 mortality was observed only in juvenile males (18.2%, i.e. 2 from a total 11 ind.) but no any female (n=11). During their first hibernation, 83.3% of the females (i.e. 5 from a total 6 ind.) and 87.5% of the males (i.e. 7 from a total 8 ind.) died in 2002–2003, whereas the percentages increased to 90.9% of the females (i.e. 10 from a total 11 ind.) and 100% of the males (n=9) in 2003–2004.

Timing of hibernation and active season

Emergence from hibernation occurred first in adult males in all years studied (2002 to 2005). Adult females emerged from hibernation on average 15.5 days later (range 14–19 days) (Table 2). Juveniles emerged from their natal burrows consistently in the middle of June in all study years (Table 2).

Duration of active season was recorded for several individuals only. Among adults they were two males in 2002 (160 days and 162 days), one male in 2003 (151 days) and one female in 2005 (89 days). Among juveniles, one male and one female (siblings) were observed in 2002

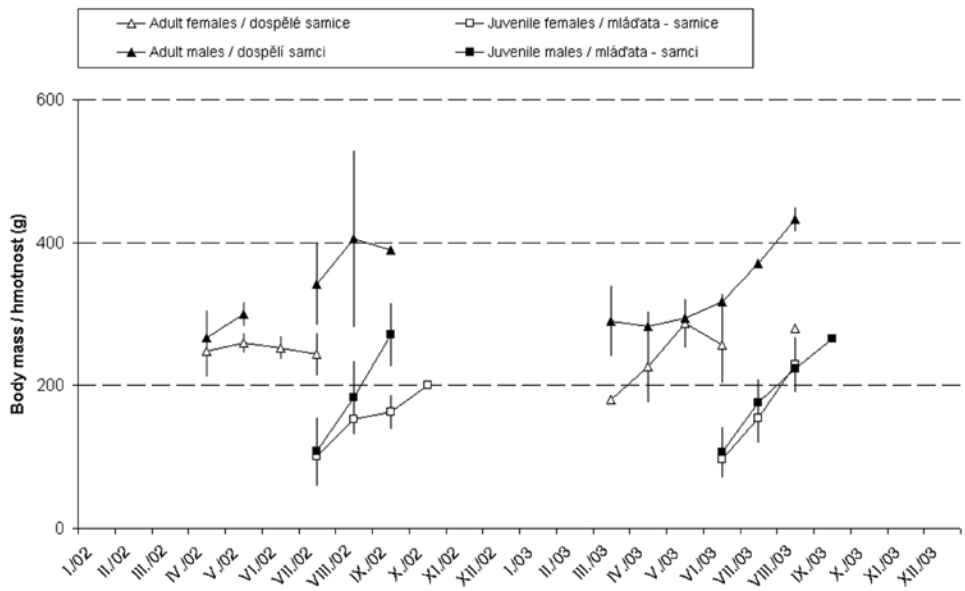

Fig. 1. Body mass of European ground squirrels (mean ± SD) by age and sex during seasons 2002 and 2003.
Obr. 1. Hmotnost (průměr ± SD) jednotlivých pohlaví a věkových skupiny sysla obecného v sezónách 2002 a 2003.

Table 2. Timing of emergence from hibernation and immergence into hibernation. Duration of the active season and hibernation (in brackets) in days is based on first and last observation of animals of each group; E = emergence (first observation), I = immergence (last observation)
Tab. 2. Ukončení a počátek zimního spánku v jednotlivých sezónách; data označují konec a počátek zimního spánku; pod nimi je v počtu dnů uvedena délka období aktivity (resp. hibernace) na základě prvních a posledních pozorování jedinců příslušných skupin; E = první pozorování v sezóně, I = poslední pozorování v sezóně

year / rok age, sex / věk, pohlaví	2002 E	I	2003 E	I	2004 E
adult males / dospělí samci	4 March 187 (190)	6 September	16 March 174 (205)	5 September	29 March
adult females / dospělé samice	18 March 136 (243)	1 August	31 March 136 (247)	14 August	17 April
juvenile males / mláďata samci	17 June 106 (181)	30 September	13 June 89 (201)	9 September	13 June
juvenile females / mláďata samice	17 June 120 (174)	14 October	13 June 102 (207)	22 September	13 June

to be active for 108 and 112 days, respectively. Two juvenile females observed in 2003 were active for 69 days.

The longest active season (based on emergence of the first and immergence of the last animal of each sex and age) was observed in adult males, followed by adult females and juveniles (Table 2). Almost no sex difference in duration of the active season was observed in juveniles.

Mean duration of hibernation in adult males was 213 days (205–226; n=4) in winter 2002–2003. In 2003–2004, one adult male hibernated for 232 days. Two juvenile females hibernated each for 246 days, one in 2002–2003, and the other in 2003–2004. Duration of hibernation recorded in one juvenile male was 202 days in winter 2002–2003. Data on duration of hibernation in adult females were not available. However, according to of the timing of the active season, hibernation is longest in adult females, followed by juveniles and adult males (Table 2).

Body mass

Body mass among reproductive individuals varied from 145 g for females after emergence from first hibernation to 520 g for adult males before hibernation. Comparisons revealed significant differences between the sexes in both age categories (Fig. 1). At emergence, adult males were heavier than adult females (adult males, median 313 g, range 280–360 g, n=8, versus adult females, median 235 g, range 145–300 g, n=14; Mann–Whitney U-test: $U=2.50$, $p<0.001$). Differences in adult body mass at immergence were also highly significant (adult males median 445 g, range 365–520 g, n=11, versus adult females, median 320 g, range 230–430 g, n=11; Mann-Whitney U-test: $U=5.00$, $p<0.001$). Body mass of adult males decreased to an annual minimum during mating (males after reproduction period, median 270 g, range 250–300 g, n=10, versus males at emergence – see above; Mann-Whitney U-test: $U=4.00$, $p<0.005$, see Fig. 2).

Body mass of juvenile males at emergence from their natal burrow were not significantly different from those of juvenile females (juvenile males, median 95 g, range 45–145 g, n=13,

versus juvenile females, median 85 g, range 35–145 g, n=13; Mann-Whitney U-test: U=72.00, p>0.05). However, before immergence into hibernation juvenile males were already significantly heavier than juvenile females (juvenile males, median 245 g, range 200–330 g, n=18, versus juvenile females, median 210 g, range 155–300 g, n=19; Mann-Whitney U-test: U=102.00, p<0.05). Mean body-mass gain calculated for juvenile males was 1.44 g/day

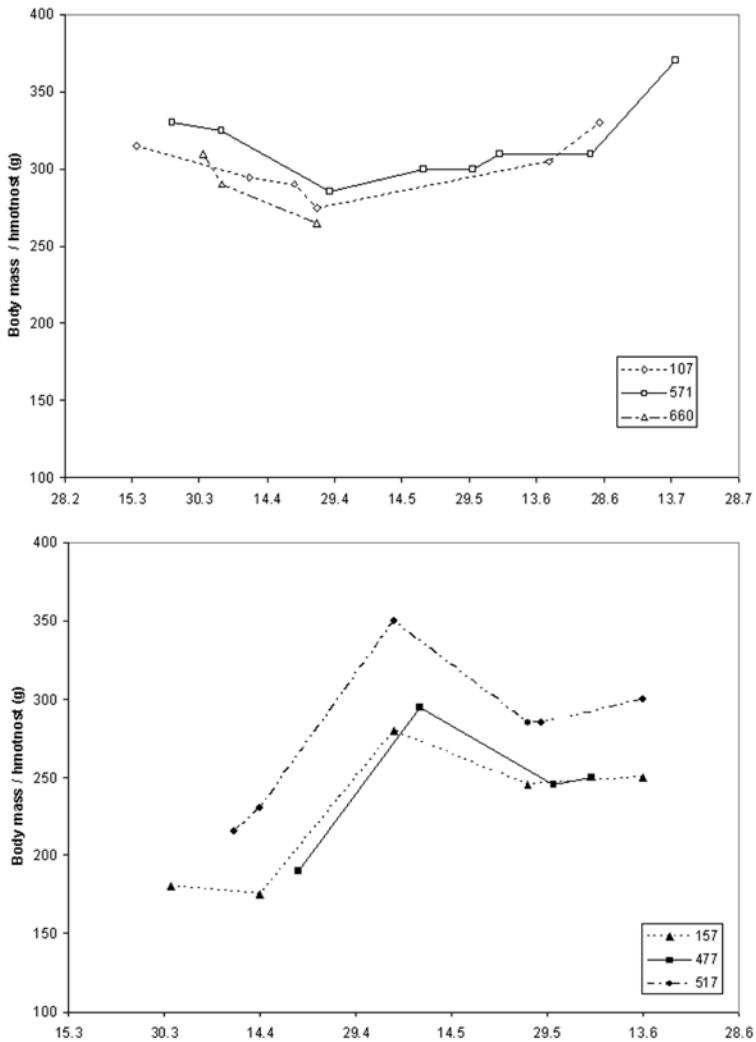

Fig. 2. Body-mass changes in three adult males (above) and three adult females (down) during the reproduction period.
Obr. 2. Změny hmotnosti během období rozmnožování u tří dospělých samců (nahoře) a tří dospělých samic (dole).

(range 0.83–2.03 g/day, n=3) in 2002 and 1.66 g/day (range 0.85–2.22 g/day, n=4) in 2003. Their relative body-mass gain during this period was 4.78% and 4.80% of the body weight, respectively. Body-mass gain of juvenile females was more variable then in juvenile males and attained higher percentages (2002 – mean 0.77 g/day, relative 4.83%, range 0.25–1.11 g/day, n=3; 2003 – mean 2.26 g/day, relative 5.70%, range 0.48–3.41 g/day, n=9), but the Mann-Whitney U test did not reveal any significant difference between sexes (U=34.00, p>0.05).

Body-mass gain of adult males during the pre-hibernation fattening was 2.08 g/day, 4.20% (range 1.09–2.43 g/day, n=3) in 2002 and 2.76 g/day, 4.55% (range 2.27–3.15 g/day, n=3). Body-mass gain of adult females during gestation was 5.31 g/day 11.44% (range 5.00–5.53 g/day, n=3, see Fig. 2). Individual body-mass loss of adult males during hibernation calculated as the difference between immergence and emergence body mass of particular individual, was 25.18% (median 110 g, range 55–145 g, n=5). Body-mass loss, calculated as difference between mean immergence and emergence body mass, of adult males was higher than of adult females (29.7%, 132 g, and 26.6%, 85 g, respectively).

Reproduction

Shortly after emergence, males became sexually active (descendent testes and dark scrotal pigmentation). In 2002, one from five observed males showed no signs of reproductive activity. As tis individual had the lowest body mass, it was probably a yearling. Descendent testes and dark scrotal pigmentation were first observed on 8th March (four days after emergence from

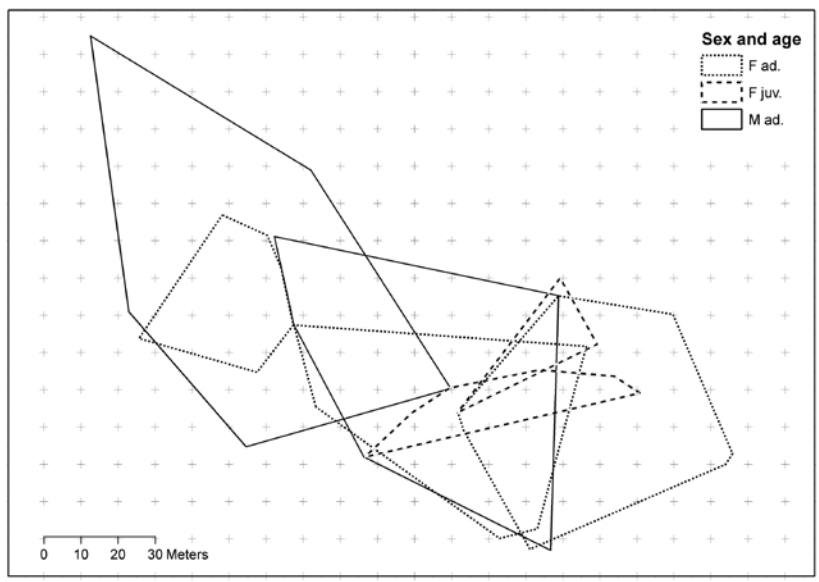

Fig. 3. Home-range size and overlap in 7 individuals of *S. citellus* observed at the study plot in 2003.
Obr. 3. Velikost, prostorové uspořádání a překryv domovských okrsků sedmi jedinců sysla obecného na studijní ploše v roce 2003.

hibernation) and last on 3 May 2002, thus males were sexually active for 57 days. In 2003, all six males observed on the study plot were sexually active. First male with the dark scrotal pigmentation and descendent testes was observed on 21 March 2003 (four days after emergence from hibernation) and last on 19 May, thus the period of male sexual activity lasted for 59 days. Despite frequent observations I did not notice any copulation above ground. In several cases two or three different males were captured in the entrance of a particular female's burrow within four hours. During the period of reproductive activity agonistic interactions between adult males and scars on their skin were observed frequently.

Home-range size

Home-range size varied with sex and age. Adult males had the largest home ranges (mean 3.577 m^2, range 2.126–5.395 m^2, n=4). Home ranges of adult females had approximately half the size of adult males (mean 1.874 m^2, range 1.031–3.161 m^2, n=5). Home-range of juvenile females was even much smaller (mean 451 m^2, range 239–689 m^2, n=3). Spatial overlap of home ranges was observed both inter and intra sexes (Fig. 3). Data were not sufficient to analyse space use of juvenile males.

DISCUSSION

Population density of *S. citellus* (individuals per ha) exhibits considerable variations among localities as well as temporal variations within a single site (Hoffmann et al. 2003, Mrlíková 1999, Kosnar 1979, Ružić 1978). Relations between climatic conditions and density of *S. citellus* reported by Ružić (1950) show that populations inhabiting sites with the Atlantic climate exhibit lower densities than those in sites with more continental climate. Low density, even before the population crash, recorded in present study plot probably confirms this relation, but similar low densities were reported also from a population near Vienna with more continental climatic conditions (Hoffmann et. al 2003, Table 3). Sauer (1976) and Turrini et al. (2008) reported high densities of *S. beldingi* and *S. citellus*, respectively, in highly productive habitats (alfalfa field).

The number of burrow entrances is sometimes used for estimation of ground squirrel abundance (Kalabuchov 1953, Cincotta et al. 1987, Weddell 1989, Váczi pers. comm.), however it is reported to be a poor estimator of ground-squirrel densities (Powell et al 1994, Van Horne et al. 1997). Grulich (1980) reported 1.5 to 10.0 entrances belonging to one burrow in Czech and Slovak populations of *S. citellus*. My observations revealed considerable fluctuation in number of entrances per one *S. citellus* specimen (5.6–32.2). The values reported for *S. pygmaeus* are even higher than my data: 25 to 45 burrow entrances for adult males and 15 to 20 for adult females (Soldatova 1962). Considering this variability, I recommend a careful interpretation of the number of burrow entrances, or use of different estimation method, such as that described in Hubbs et al. (1999). Usually, the birth sex ratio of most mammal species is very close to 1:1, with a slight male bias, and deviations typically develop later on (Krebs & Davies 1993). In *S. citellus*, the sex ratio is often biased towards females among adults (Grulich 1960, Ružić 1978, Hoffmann et al. 2003). Similarly my results show a higher proportion of juvenile males in two from three studied years, however adult sex ratio varied rather inconsistently. The most probable explanation for this is the small size of the focal population and observed sample, which can be easily subject to random events (Begon et al. 1990). However, a higher proportion of males in the adult population was also reported from some Czech (Mrlíková 1999), Balkan

Table 3. Variation of density in the *S. citellus* colonies; PD = population density (ind./ha), LO = length of observation (years)
Tab. 3. Variabilita hustoty jedinců v koloniích sysla obecného; PD = hustota osídlení (jedinci/ha), LO = doba pozorování (roky)

locality / lokalita	PD	LO	reference / zdroj
Olšová Vrata, Bohemia, Czech Rep.	4.0–17.5	3	this study
Kolín, Bohemia, Czech Rep.	46.8–142.6	1	Kosnar 1979
Bílý Újezd, České Středohoří, Bohemi, Czech Rep.	21.8–111.8	2	Kosnar 1979
Mimoň, Bohemia, Czech Rep.	6.0–15.6	2	Mrlíková 1999
Langenzersdorf, Austria	6.3–61.0*	8	Hoffmann et. al 2003
Dolovo, S Banat, Serbia	18.0–48.0*	3	Ružić 1978
Neradin, Krušedol, Banatska Palanka, Serbia	4.0–88.0	5	Ćirović et al. 2008

* non juveniles only / počítáni pouze dospělí jedinci

(Ružić 1965) and Moldavian (Danila 1982) localities. A shift towards a higher proportion of females is primarily caused by higher mortality of males (Schmutz et al 1979, Millesi et al. 1999, Hoffmann et al. 2003). I presume that in a small population, a biased sex ratio does not necessarily reflect increased male mortality, but is mostly due to random events. Future studies should focus on a comparison of sex ratios in small and large *S. citellus* populations.

The inter-year mortality rates observed in present study are similar to previously reported data from Moldavia (Danila 1982) and from Austria (Millesi et al. 1999), however, the mortality pattern was completely different. Contrary to highest mortality rate during the active season reported by Millesi et al. (1999), in the present study the main proportion of mortality was observed during hibernation. The mortality during the active season reported by Millesi et al. (1999) was mostly caused by predation, conversely during this study occurrence of predators on the study site was not observed. A possible explanation of this discrepancy can be that high predation pressure positively affects body condition of ground squirrels before hibernation. The absence of predators probably allows individuals with poor body condition to start the hibernation, however, they are not able to survive until next spring.

High rate of mortality during 2003–2004 winter was probably caused by rapid snow melting and consequent flooding of ground squirrel burrows. Similar population crash was described by Hoffmann et al. (2003) from population near Vienna, thus these events affecting ground squirrel populations seem to be quite common. Susceptibility of *S. citellus* to extreme weather conditions such as torrential rain was observed by Havelík (2002).

The timing of emergence, immergence and length of active season (Tables 2 and 4) corresponds with findings in other populations (Millesi et al. 1999, Grulich 1960, Ružić 1978). The early emergence of adult (reproductively active) males is probably necessary to complete spermatogenesis, which is not possible at low body temperature during hibernation torpor (Janský 1980, Michener 1984, 1992). In contrast to observations by Millesi et al. (1999), some adult males in present study did not show descendent testes earlier than four days after they left hibernacula. Similar behaviour is reported in males of *S. xanthoprymnus* in Anatolia (Gür & Gür 2005). The period of euthermic body temperature should probably play a role in the process of spermatogenesis. Adult females and one non-reproductive male emerged synchronously circa 14 days after adult males. This interval is somewhat shorter than it was reported from a locality near Vienna

Table 4. Duration of hibernation in some populations of *Spermophilus citellus* (days)
Tab. 4. Délka hibernace u některých populací sysla obecného (dny)

locality / lokalita	adults / dospělí (♂ / ♀)	juveniles / mláďata (♂ / ♀)	reference / zdroj
Czech Republic, Olšová Vrata	190–205 / 243–247	181–201 / 174–207	this study
Austria, Vienna	159–212 / 207–265	177–217	Millesi et al. 1999
Serbia, South Pannonia	210–225	150–165	Ružić 1978

(Millesi et al. 1999). In contrast to Grulich (1960), in present study adult females immerged earlier than adult males, i.e. in the same order that was reported by Millesi et al. (1999). This discrepancy probably originates when Grulich (1960) took up information about sex differences in the timing of hibernation onset from former studies focused on different species.

The later immergence of adult males *S. citellus* is considered to be exceptional within the genus (Michener 1984), where adult males typically immerge before or at the same time as adult females (e.g., *S. richardsonii*: Michener 1984, Michener & Locklear 1990, *S. beecheyi*: Holekamp & Nunes 1989). Probably only in *S. parryii* (McLean & Towns 1981) and *S. beldingii* (Verts & Costain 1988) the immergence occurs in the same order as in *S. citellus* and no sex differences in immergence date were observed in *S. armatus* (Slade & Balph 1974) and *S. tridecemlineatus* (McCarley 1966). Male *S. citellus* may probably postpone immergence into hibernation as long as possible to preserve their fat stores for the following spring, when the mating period requires good physical condition (Michener 1984). According to Millesi et al. (1999), however, the necessity to store energy does not account for the later immergence. Juveniles immerge as the latest, probably because they need both to grow and to build up fat stores for their first hibernation (Millesi et al. 1999).

The body mass of adult *S. citellus* recorded in this study probably belongs to the highest documented values ever. In comparison to populations from lower latitudes and altitudes (Austria and Serbia) one could interpret it as the Bergmann's rule as already has been suggested by Grulich (1960). However, Zammuto & Millar (1985) found the opposite relation in *S. columbianus*, as well as Blois et al. (2007) in *S. becheeyi*. Future studies should focus on the comparison of more populations from the whole *S. citellus* distribution range to prove validity of this rule and to reject the possibility that the described situation was caused by inbreeding, founder effect or genetic drift.

The sex difference in juvenile body mass at immergence is a first display of the sexual dimorphism in adults, which is considered to be typical of polygynous species where males have to compete (directly or in ritual interactions) for females (Ridley 1999). This phenomenon has been well documented in *S. citellus* by observation of male fights and decrease of their body mass during the mating period (Grulich 1960, Kosnar 1979, Millesi et al. 1999, this study – see Fig. 2). The size of a territory (actively protected part of the home range) in a dense population of *S. citellus* observed by Kosnar (1979) varied only between 16 to 80 square meters in males and 15 to 72 in females. Home-range size of *S. citellus* calculated by Turrini et al. (2008) was related to productivity of environment: 0.176 ha in a highly productive (alfalfa meadow) and 0.555 ha in a sparse environment (secondary steppe). Values obtained in present study were intermediate and probably reflect moderate productivity of the golf range area.

Results of the present study seem to be consistent with data from other *S. citellus* populations, but it should be pointed out that the demographical characteristics observed in present study are usually close to upper limiting (mortality, body mass) or lower limiting values (density, survival). Limiting values of demographical characteristics are usually observed in small populations where the effects of random events are sometimes more visible then long-term population trends. The occurrence of random events can also indicate depression of population fitness and susceptibility to the extinction (Smith 1974, 1980, Lomolino 1984). Loss of heterozygosity in the studied population, as was observed by Hulová & Sedláček (2005) should provide genetic evidence of this phenomenon.

SOUHRN

Příspěvek shrnuje výsledky tříletého studia populační biologie a prostorové organizace v izolované populaci sysla obecného na okraji jeho areálu rozšíření. V letech 2002 až 2004 byla pomocí trvalého značení a zpětných odchytů sledována část populace sysla na golfovém hřišti v Olšových Vratech u Karlových Varů. Celková početnost populace, která byla v roce 2002 odhadnuta na 250 jedinců, poklesla na 150 v roce 2003 a na pouhých 30 jedinců v roce 2004. Populační hustota se pohybovala od 4,0 (na jaře 2004) po 17,5 jedinců na hektar v létě 2003. Počet vchodů do nor připadající na jednoho jedince se měnil v rozpětí od 5,6 do 32,2 a byl sezónně i meziročně značně proměnlivý, avšak celkový počet vchodů zůstával téměř konstantní. Poměr pohlaví mezi dospělými jedinci kolísal v intervalu 0,33 až 0,62 samců, u mláďat byl vyrovnaný nebo posunutý ve prospěch samců (0,5 až 0,67). Nejvyšší míra mortality byla zaznamenána v období zimního spánku, kdy byla v zimě 2002/2003 zjištěna 30% úmrtnost dospělých jedinců a 85,7% úmrtnost mláďat. V zimě 2003–2004 dosáhla mortalita 80% u dospělých jedinců a 95,5% u mláďat. V období aktivity byla mortalita zaznamenána pouze u dospělých samic (20% v obou sezónách 2002 a 2003) a mladých samců (6,7% v roce 2002 a 18,2% v roce 2003). Hmotnost dospělých samců byla signifikantně větší než hmotnost dospělých samic a to jak v období před, tak i po ukončení zimního spánku. Zjištěné hmotnosti se pohybovaly se v rozmezí 145 až 430 g u dospělých samic a 250 až 520 g u dospělých samců. Střední hodnota hmotnosti dospělých jedinců po ukončení hibernace byla 313 g u samců a 235 g u samic, před jejím nástupem pak 445 g u samců a 320 g u samic. Hmotnosti mláďat se signifikantně lišily až v době před hibernací, kdy byla zjištěna vyšší hmotnost u mláďat samčího pohlaví. Při opuštění mateřské nory nebyl mezi hmotností samců a samic zjištěn signifikantní rozdíl. Velikost domovských okrsků dospělých samců se pohybovala od 2126 do 5395 m^2, u dospělých samic od 1031 po 3161 m^2. Překryv domovských okrsků byl zjištěn jak mezi pohlavími, tak i v rámci obou pohlaví. Výsledky této studie se shodují s obdobnými daty z jiných částí areálu rozšíření sysla obecného, je však nutné zdůraznit, že hodnoty zjištěné u studované populace se ve většině případů blíží hodnotám limitním – a to někdy minimálním (např. přežívání, hustota populace), jindy maximálním (mortalita).

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