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Daily Activity Pattern in Free-living European Ground Squirrels *Spermophilus citellus* (Mammalia: Rodentia) from Northwestern Bulgaria

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Abstract: The study describes the daily activity of the European ground squirrel in an experimental plot, situated in a heavily grazed pasture near the town of Knezha, Northwestern Bulgaria. Above ground activity was recorded with a visual scanning procedure in summer and autumn of 2006. In summer animals emerged on an average 1.94 h after the civil twilight at dawn and the active period lasted about 11 h. In autumn the daily activity started 3.43 h after the the civil twilight at dawn and lasted about 7.3 h. The activity pattern in summer was bimodal, while in autumn only one clearly expressed peak was observed. The influence of climatic factors (temperature, humidity and claudiness) as well as of time of the year was analysed. Activity patterns were influenced mainly by the time of the year, as it represented consecutive periods of the annual activity of the ground squirrels.

Keywords: daily activity pattern, environmental effects, European ground squirrel, souslik, *Spermophilus citellus*, Bulgaria

Introduction

The literature on daily activity patterns in small mammals is still dominated by experiments, carried out under laboratory conditions. The time budget of these animals under natural conditions still remains poorly known.

The European ground squirrel (*Spermophilus citellus* L. 1766) is ideal for indirect (for example counting of borrow entrances) and direct observation (for example, observation of daily activity) as it is diurnal and highly visible in the short grass meadows. The species has negative trend of populations and it is included as vulnerable in the IUCN Red List of Threatened Species (Amori 1996).

In Bulgaria, which is the core of their distribution (Mitchell-Jones *et al.* 1999), the ground squirrels inhabit open grasslands. Being diurnal, they search for their diet of seeds, leaves, flowers, and occasionally insects and eggs during the day. In the morning they go out when the dew is lifted, and could be seen almost until sunset (Straka 1961). Ground squirrels are real hibernators and they remain continuously underground from around August or September to March (Millesi *et al.* 1999).

In spring and summer, the animals reproduce and subsequently prepare for hibernation in autumn and winter. The reproductive cycle is accompanied by changes in physiology and behaviour (Millesi *et al.* 1998, Millesi *et al.* 1999 a, b). The energetic demands of the animals vary during the annual cycle and could affect the above ground activity patterns.

The air temperature, humidity, wind speed and cloud cover, on the other hand, have also an influence on the animals daily activity (Vaczi *et al.* 2006).

The main examination method of the daily activity is scanning the number of individuals on fixed area (Altmann 1974). At the same time, this method is also used for monitoring of the species numbers in the National Parks (Stafanov 2003).

The daily activity patterns of the European ground squirrel have been investigated only in the central parts of its range – in Hungary and Austria (Everts *et al.* 2004, Katona *et al.* 2002, Vaczi *et al.* 2006). In Bulgaria some observations have been made in the middle of the 20th century, but no description of the observation methods is available (Peshev 1955, Straka 1961). The question about the daily activity patterns of the European ground squirrel in the southern parts of its range, under climatic conditions differing from those in Hungary and Austria, remains open.

The aim of the present work was to establish above ground activity patterns of European ground squirrels throughout a part of the active season in their natural habitat. We investigated whether the daily activity pattern was affected by the external factors (e. g., temperature, humidity, wind, cloud cover).

Material and Methods

Study area

The study was carried out in 2006 in a population of free-living European ground squirrels near the town of Knezha, Northwestern Bulgaria (43°29`N; 24°05`E) on a large, heavily grazed pasture. An experimental plot of 1ha (100 x 100 m), which could be observed from a single observation position, was traced out on this pasture.

The study area is situated in the moderate-continental climatic sub-zone. The sum of summer precipitation is about 150-200 mm on an average and the temperature sum for the period with temperatures above 10°C is 3520 (Stanev *et al.* 1991).

The spring density of the European ground squirrel was estimated by counting the vertical spring holes. Counting of ground squirrel borrow entrances (holes) is quick and easy method of estimating the population density. Holes' counting without assuming linear correlation is an adequate method to detect differences in local ground squirrel densities (Katona *et al.* 2002).

European ground squirrels in this area were trapped with live traps and were marked individually with commercial hair dye. In order to avoid changes in animals' behaviour caused by altered ambient temperature perception, the head fur was not marked (Vaczi *et al.* 2006).

Environmental conditions

The environment climatic parameters were recorded every 15 minutes. The temperature (°C) and the relative humidity (%) were measured by digital thermometer/humidity meter in the shade at 1 cm above the surface (covered by grass). The temperature in a vertical borrow entrance of the ground squirrel was measured by I-buttons thermochron DS1921 (Dallas Semiconductor) in 1 m depth every 4 hours. The wind speed and the rain were recorded according to the Beaufort wind scale (0-12) and Beaufort rain scale (0-10). The cloudiness was estimated as a percentage of the sky covered with clouds. The days with heavy wind (over 4) and heavy rain (over 3) were excluded from the study as these elements strongly affect the animals' behaviour.

Observation protocol

The animals were observed using scanning procedure (Altman 1974) from one and the same observational point, from which the entire study plot is visible. An automobile was used as a shelter. In summer the scanning was carried out from 26 July till 4 August 2006 (8 days). In this time the juveniles are already weaned and are spreading out. In autumn there were 4 scan days (31 August – 3 September), which represent the period of preparation for hibernation. The observations usually lasted from 6.00 to 21.00. The study plot was scanned every 10 min for 5 min with binoculars Olympus DSP R 8x40 and telescope Exakta 20-60x70, beginning from the left side towards the right side. All the individuals and their behaviour, observed above ground in these five minutes were recorded. Two types of behaviour were recorded: foraging or non-foraging. Foraging was defined not only as visible intake of food but as presumable one coinciding either with stationary position or limited movement (step by step: no running) with the head down in the vegetation. Non-foraging was defined as all other kinds of above-ground behaviour, i.e., exploring, running, sitting, grooming, digging, scent marking and vigilance (Everts *et al.* 2004).

The light phase of an observation day was defined by the civil-twilight times at dawn (T_{CTdawn}) and at dusk (T_{CTdusk}). Phase-angle differences (ψ in h) between civil-twilight times and onset (T_{onset}) and offset (T_{offset}) of ground squirrels' activity were calculated as $\psi_{onset} = T_{CTdawn} - T_{onset}$ and $\psi_{offset} = T_{CTdusk} - T_{offset}$. The duration of the daily-activity phase (α, in hours) was calculated as the time between the first and the last observation of an animal on a particular day + 15 min to correct for the scanning frequency. (Everts *et al*. 2004).

Data were analyzed by parametric statistics as they passed Kolmogorov-Smirnov normality test. Analysis of variance (ANOVA) was used to determine the differences between the animals' numbers at different times of the day, between the phase-angle differences, the duration of the daily-activity phase, temperature and humidity. Multiple-linear-regression analysis was used for explaining variance by more than one variable. Variables with non-significant contributions to the amount of explained variance were dropped from the models (stepwise backward elimination). The effect of temperature, humidity, clouds cover and time of year on seasonal variation in timing of daily activity, ψ_{onset} and ψ_{offset} were tested. Time of year was included as categorical variable [two periods – July-August (1) and August-September (2)]. All the analyses were performed by SPSS version 14.0, SPSS Inc.

Results and Discussion

Density on the study area

The spring density on the study plot estimated by counting of the spring vertical borrow entrances, was 46-49 individuals per ha. In summer maximum 10 individuals were observed together on the plot. In autumn the maximum number of ground squirrels observed together above ground was 8.

Duration of daily activity phase

In summer the daily activity began about 8.00 EET (average temperature in 1 cm above the ground 26.4°C and average relative humidity 59.5%) with clear and calm weather. The earliest observation of ground squirrel above ground was recorded at 7.30 at 27 July 2006. Morning emergence did not correlate with the sunrise (Pearson $r = -0.048$, $n = 9$, $p = 0.902$). The activity period ended between 18.45 and 19.50 EET (average temperature in 1 cm above the ground 30.9°C and average relative humidity 40.6%).

Average α in summer was 11.16 h (sd = 0.97 h, n = 7). On average, the activity began 1.94 h after the civil twilight at dawn (sd = 0.44, n = 9) and ended 1.38 h before the civil twilight at dusk (sd=0.67, n=7).

In autumn the daily activity began about 10.00 EET (average temperature in 1 cm above the ground 17.9°C and average relative humidity 69.3%) with clear and calm weather and ended about 17.00 EET (average temperature in 1 cm above the ground 20.4°C and average relative humidity 53.8%). The latest observation of an animal above ground was recorded at 18.00 EET. As in summer, morning emergence did not correlate with the sunrise (Pearson $r = 0.189$, $n = 4$, $p = 0.879$).

Average α in autumn was 7.38 h (sd = 0.54 h, n = 3). On an average, the activity began 3.43 h after the civil twilight at dawn (sd = 0.40, n = 3) and ended 2.52 h before the civil twilight at dusk (sd = 0.09, n = 3).

The data about the phase-angle differences in autumn are similar to those reported by Everts *et al.* (2004), which have found that on average the civil twilight at dawn preceded activity onset by 3.9 h, and civil twilight at dusk followed the activity offset by 3.2 h.

The activity patterns were exclusively confined to the light phase of the day, but, as shown above, did not follow exactly the changes in civil twilights at dawn and at dusk. The activity period (α) in autumn was significantly shorter than in summer (F = 36.788, df = 1, 10; p = 0.000). Phase-angle differences in autumn were also significantly larger than in summer (ψ_{onset}: F = 21.013, df =1, 10; p = 0.001; ψ_{offset}: F = 8.114, df = 1, 10; p = 0.019).

The differences between the temperatures at 1 cm above the surface at the times of onset and offset of above ground activity between the two studied periods were significant (F = 14.274, df = 1, 10; p = 0.004 and F = 57.860, df = 1, 10; p = 0.000 relatively). Humidity in summer and in autumn did not differ significantly neither at morning nor at evening hours (F = 0.742, df = 1, 10; p = 0.409 and F = 3.797, df = 1, 10; p = 0.083 relatively), so it's likely to have no influence on the later activity onset in autumn.

The relationship between phase-angle differences (ψ_{onset} and ψ_{offset}), duration of activity phase (α) and temperature, humidity, cloud cover and season was analyzed in multiple regression models. Temperature and humidity were found to have not significant effect on the three analyzed variables. Cloudiness is likely to explain partly the variance in phase-angle difference between the civil twilight and onset of activity (Table 1). Season has the major effect on α, ψ_{onset} and ψ_{offset}. As the temperature and humidity, which are the basic characteristics of the seasons' dynamics, were excluded from the regression models, we could suggest that "season" in this case should be considered a period of ground squirrels' annual activity. So, the changes in phase-angle differences and duration of activity phase between the two periods seem to be caused mainly by endogenous factors, as it has been shown by Ashoff (1966) in many other species.

Daily activity pattern in summer

The daily activity pattern in summer is shown in Fig. 1. The visual observations showed that the above ground activity changed during the day. The activity is bimodal and significantly more ground squirrels were seen above ground in afternoon hours (16.00 – 18.00 h EET) than in forenoon hours (9.00 – 11.00 h) (1-way ANOVA, F = 5.972, df = 1, 10, p = 0.035). Such a sequence has been called an "altermans" pattern (Ashoff 1966). At midday, when the temperature rises, significantly less animals are observed (1-way ANOVA, F = 7.702, df = 1. 13, p = 0.016). This activity pattern was described by Vaszi *et al.* (2006) as bimodal daily activity pattern with a "midday siesta". The lowest activity was observed at air temperature of 32°C and relative air humidity of 30.7%. Similar activity pattern was observed by Peshev (1955) and Straka (1961).

The temperature in 1 m depth remained constant (around 20°C) over all the study period.

The fact that the afternoon peak is higher is very interesting. Similar investigations of the European ground squirrels were carried out in Hungary (Katona *et al.* 2002; Vaczi *et al.* 2006). On the grounds of average data the authors reported that the afternoon peak was smaller and more protracted, but the difference between the two peaks was not significant (Katona *et al.* 2002). Such local changes in the activity pattern are likely to result from the specific climatic features of the study region. In Hungary (the northern part of the European ground squirrel's range) the mean daily temperature in August was 21.6°C (Katona *et al.* 2002; Vaczi *et al.* 2006), while in our region of investigation (the south part of the species range) the mean daily temperature in August was 31.5°C.

Table 1. Duration of activity phase (α), phase-angle difference between the civil twilight at dusk and offset of activity (Ψ_{offset}) explained by the time of the year (season: summer – 1; autumn - 2) and phase-angle difference between the civil twilight at dawn and onset of activity (Ψ_{onset}) explained by the time of the year and cloudiness.

Dependent variable	Independent variable	Coefficient	p-value	r^2
A	Constant		0.000	
	Season	-0.901	0.002	
				0.811
Ψ_{onset}	Constant		0.848	
	Season	0.794	0.001	
	cloudiness	0.405	0.018	
				0.882
Ψ_{offset}	Constant		0.324	
	Season	0.631	0.068	0.398

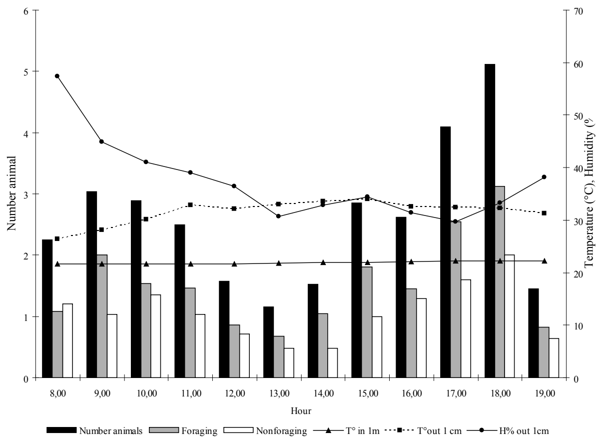

Fig. 1. Daily activity of the European ground squirrel during the summer season of 2006 in Northwestern Bulgaria.

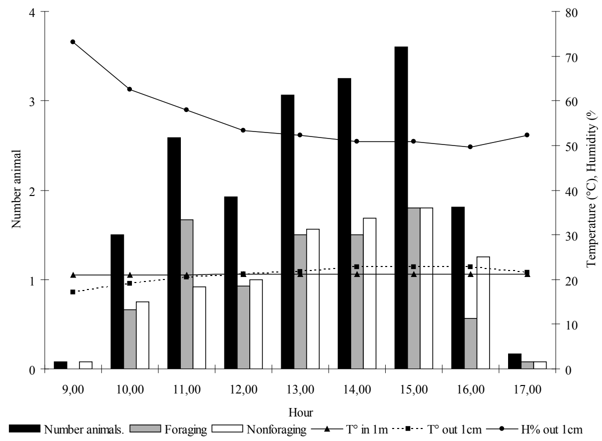

Fig. 2. Daily activity of the European ground squirrel during the autumn season of 2006 in Northwestern Bulgaria.

The observed types of behaviour were almost equally represented (58% foraging/ 42% non-foraging).

Daily activity pattern in autumn

The daily activity pattern in autumn differed from the observed in summer. Peshev (1961) has also reported that the pattern of daily activity in spring and in autumn differs from the pattern in summer. Only one, clearly expressed peak was observed between 13.00 – 15.00 h EET (Fig. 2). Only single animals remain above ground in the period 16.00 – 17.00 h EET. The comparison between the autumn peak of activity and the summer afternoon peak did not reveal any significant difference (1-way ANOVA, F = 2.127, df = 1, 7, p = 0.188).

In this period the temperature outside (in 1 cm above ground) and inside the borrow entrances (in 1 m dept) become almost equal.

In autumn the observed types of behaviour were also almost equally represented, but more (although insignificantly) animals were non-foraging (43% foraging: 57% non-foraging). In autumn (end of August – September) the ground squirrels feed mainly with seeds, which are abundant (Straka 1961). Many of the animals on the plot collected seeds, an occupation that did not take much time, if there were plenty of them. The biggest part of the time was spent carrying building materials for the nest chambers.

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Дневна активност при европейския лалугер *Spermophilus citellus* L. 1766) (Mammalia: Rodentia) от Северозападна България

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(Резюме)

Дневната активност на европейския лалугер е изследвана на експериментална площадка в района на гр. Кнежа, Северозападна България. Надземната активност е отчитана чрез визуално сканиране през лятото и есента на 2006 г. През лятото животните се появяват средно 1, 94 ч след изгрева на слънцето, като активният период продължава около 11 ч. През есента дневната активност започва 3, 43 ч. след изгрева и продължава около 7, 3 ч. Моделът на дневната активност през лятото е бимодален, докато през есента се наблюдава само един добре изразен пик. Анализирано е влиянието на климатичните фактори (температура, влажност и облачност), както и на годишния период. Най-силно влияние върху модела на активност оказва годишният период, тъй като той отразява последователните етапи от годишната активност на лалугерите.