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Structure and Variability of Alarm Calls of European Ground Squirrel *Spermophilus citellus* L. 1766 (Mammalia: Rodentia) from Western Bulgaria

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Abstract: The structure and variability of alarm call of European ground squirrel (*Spermophilus citellus* L. 1766) from two populations in West Bulgaria are studied. The registered alarm calls may consist of two separated phases: at 8 kHz and 12 kHz respectively. Both phases can be fused or emitted continuously with maximum interval of 32.90 ms between them: probably they are produced by two independent acoustic sources. A phenomenon of concentration of the maximum energy of the call in the second harmonic is observed. The durations of the phases have high degree of variation, but the total length of the call in the studied populations has similar values. The total duration of alarm call is more than 100 ms, while the maximum registered value can exceed twice the minimum. The frequency characteristics (highest, lowest frequency and frequency with most energy of both phases) have low degree of variability and they clearly and statistically significantly distinguish the studied populations.

Key words: alarm call, sound analysis, *Spermophilus citellus*, Bulgaria

Introduction

The genus *Spermophilus* Cuvier, F. 1825 includes 31 recent species inhabiting Europe, Asia and North America. The European ground squirrel (*Spermophilus citellus* L. 1766) is diurnal rodent and occurs in loosely structured populations throughout Central and South-East Europe. Its area of distribution has two clearly distinguished parts: Pannonian and Balkan, separated by the Carpathian Mountains (Ruzič 1978). In Bulgaria the species occurs patchy almost in the whole country up to 2500 a.s.l. The few mountain populations are isolated in Vitosha, Rila, West and Central Stara Planina Mountains. (Peshev *et al.* 2004). The species has negative trend of populations and it is included as vulnerable in the IUCN Red List of Threatened Species (Amori 1996).

Many rodents, including genus *Spermophilus*, in case of danger emit alarm calls related to their social and diurnal life (Shelley, Blumshtein 2005). *S. citellus* frequently produces a typical alarm call, heard by human ear. The sound communication in some species of *Spermophilus* is relatively well studied (Eiler, Banack 2004, Nikol`skii 1984, Slobodchikoff *et al.* 1998, Shelley, Blumshtein 2005). Nikol`skii (1979) published the only known spectrograms of alarm calls of one free-living and one captive *S. citellus* from Moldova. Georgiev *et al.* (2004) studied 16 alarm calls emitted by a single individual near Kalchevo village (North-East Bulgaria). These investigations, based on restricted

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number of recordings, give only incomplete characteristics of the alarm call of *S.citellus*.

The aim of the present study is to make comparative analysis of design and variability of alarm calls in two separate populations of *S. citellus* from West Bulgaria.

Material and Methods

We recorded alarm calls of free-living *S. citellus* at two locations:

Ponor Mountain part of West Stara Planina Mountains – N 43° 04.62`, E 23° 15.89`, 1249 m a. s. l. The recordings were made from 09.00 h to 12.00 h on 20.07.2006 in sunny and calm weather. A total of 22 alarm calls were registered.

Kremikovtsi residential district of Sofia city - N 42˚ 47,45`, E 23° 29,50`, 689 m a. s. l. The recordings were made from 09.00 h to 12.00 h on 17.08.2006 in sunny and calm weather. A total of 53 recordings were made.

The same human was used as a common stimulus to elicit alarm calls at two colonies. Alarm calls were recorded using a portable Pettersson D 240 detector and audio-type recorder Sony VM-D6C. We analyzed the calls using BatSound 3.1 software for Windows in time expansion (10 X). The frequency components were measured from the Fast Fourie Transform (FFT) power spectrum, size 256 and 512, Hanning window. We measured the following call parameters: total call duration (DUR) (ms), duration of the first call phase (DUR I) (ms), duration of the second call phase (DUR II) (ms), inter-phase interval (IPI) (ms), frequency with most energy of the first phase (FREQ I) (kHz) and of the second phase (FREQ II) (kHz), highest and lowest frequencies of the first phase (FMAX I and FMIN I) and of the second phase (FMAX II and FMIN II) in kHz, bandwidth (BDWTH) of the first phase as FMAX I – FMIN II (kHz) and respectively for the second phase. If harmonics was present, values of the fundamental were taken. In cases with fused I and II phases, the coefficient of variation of IPI has not been evaluated.

We calculated descriptive statistics and analyzed correlations using Statistica version 5.0 software for Windows.

Results

The measured parameters of the call features and their coefficient of variation (CV) are presented in Table 1 for the two studied populations.

The alarm calls consist of two phases at different frequencies in 52 cases in Kremikovtsi population and 11 cases in the Ponor population. The half of the registered calls in the Ponor Mountain consist of a single phase at the lower frequency (FREQ I = 8.02 kHz) (Fig. 1 a, b), while in the Kremikovtsi region only one call was expressed with a single phase at the higher frequency (FREQ II = 12.48 kHz). In some cases the I and the II phases can be fused (Fig. 1 c). Both phases of the call have low frequency modulation, determined by their BDWTH values, as the second one is more modulated (Table 1). In most cases the different number of harmonics is well presented (Fig. 2 a - d). A three-peak power spectrum presentation characterizes both phases (Fig. 3 a, b). The different shapes of wave presentations (Fig. 1 b, c, Fig. 4 a - f) illustrate well the variability in duration and the relative power of both phases.

In the studied populations we established very low degree of variation of frequency characteristics of both phases. The coefficient of variation of the second phase has values from 3 to 5 % higher than the first one. The total duration of alarm call as well as its phases varies in large scale. DUR II of calls of Ponor population has the highest coefficient of variation (38.69 %). The degree of frequency modulation in both phases is also high: from 20.05 % in BDWTH II of the Kremikovtsi population to 31.25 % in BDWTH I of the Ponor population. In some cases we can observe quasiconstant frequency of the phases (Fig. 1 a, b, Fig. 4 b), while in others the initial or terminal part of the phases is obviously frequency modulated (Fig. 2 b, Fig. 4 e, f).

Significant differences (in $p<0.05$) between both populations are established in three of the less variable features of alarm call: FREQ I, FMAX I и FMIN II (Fig. 5 a - d). These frequency characteristics clearly and statistically significantly distinguish the studied populations.

The biggest differences can be observed in de-

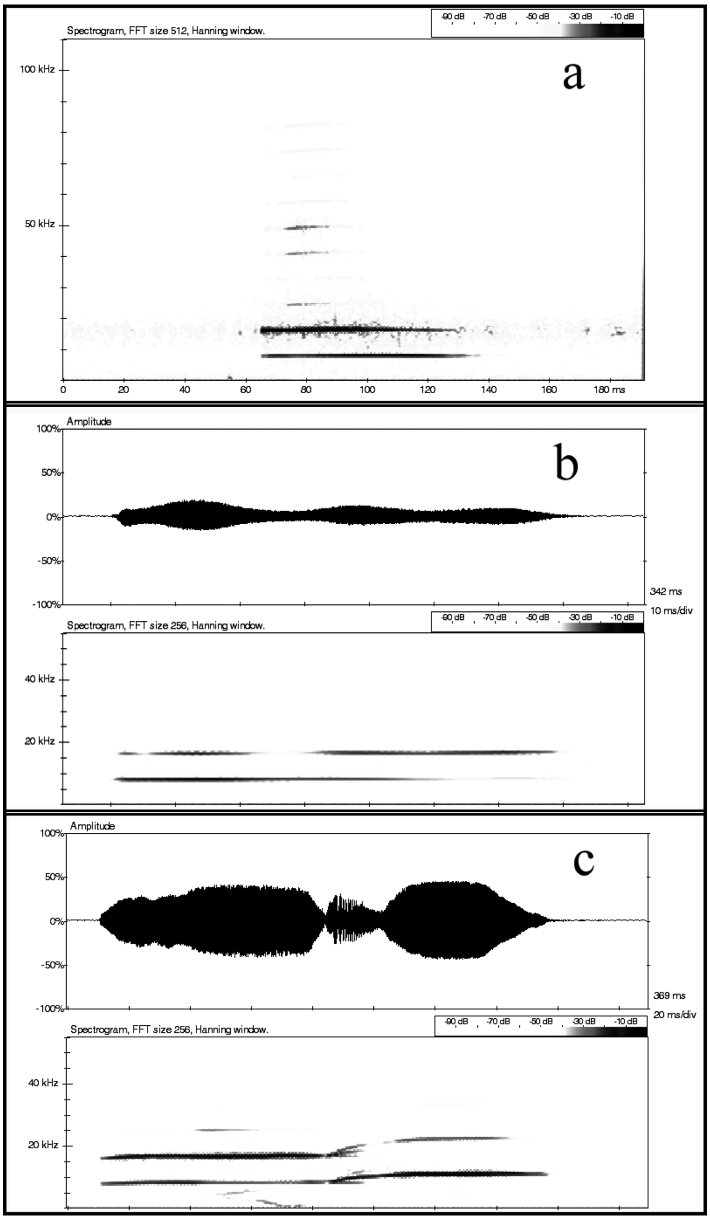

Fig. 1. a, b – Sonogram of single phase calls of individuals from Ponor Mountain; c – Sonogram and wave presentation of a fused I and II phases.

gree of frequency modulation of the second phase numerically expressed by the values of BDWTH II (Table 1, Fig. 5 d). The frequency modulation of this phase of call in animals from Kremikovtsi varies in large scale from 1.86 kHz to 5.00 kHz, while the maximum BDWTH II in animals of the Ponor Mountain is only 3.5 kHz. Even if the total duration of alarm call in both populations has relatively high degree of variation, their minimum, maximum and mean values are very close (Table 1).

Discussion

In the two studied specimens of European ground squirrel from the easternmost part of the area of species distribution (Moldova), Nikol`skii (1979) established that the main energy of call is about 7 kHz and the harmonics are low expressed. The frequency is not modulated or weakly modulated. In the studied animals from Bulgaria the two phases of signal contrast to that from Moldova: the first phase has main frequency of about 8 kHz, while the second is concentrated about 12 kHz. The fact that emissions

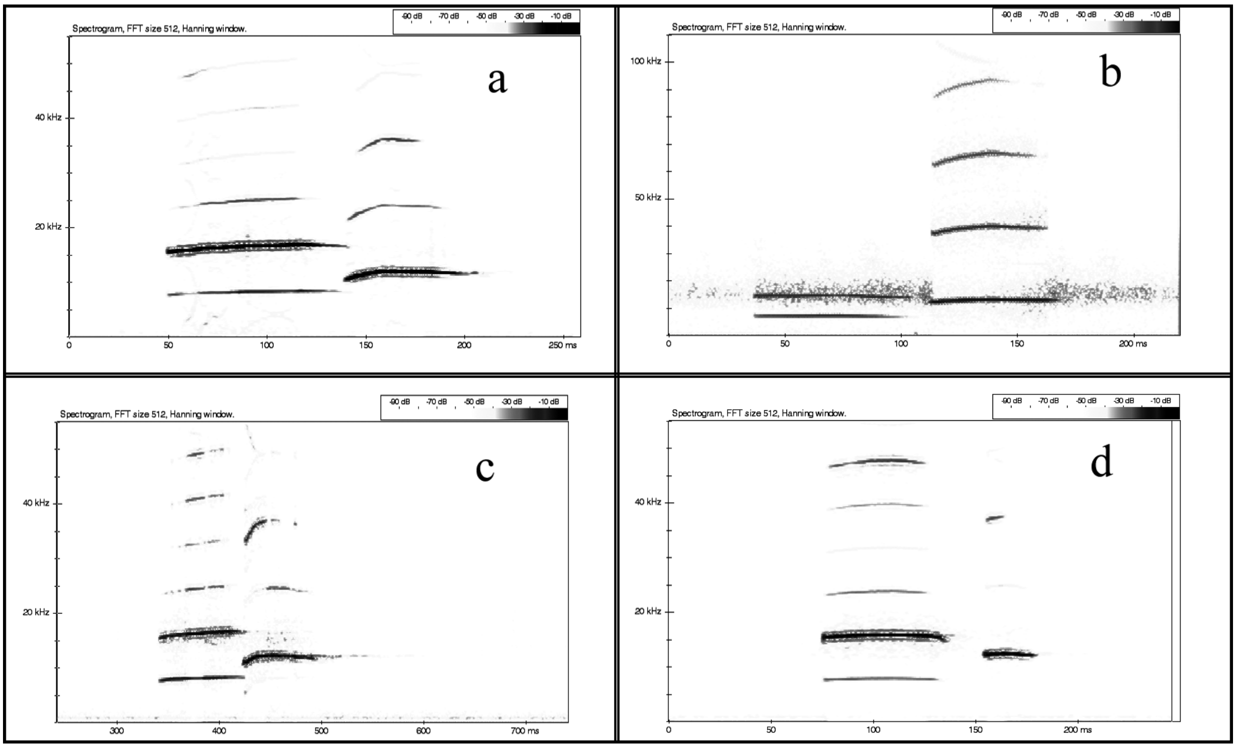

Fig. 2 a, b, c, d – Sonograms of alarm calls with well expressed harmonics.

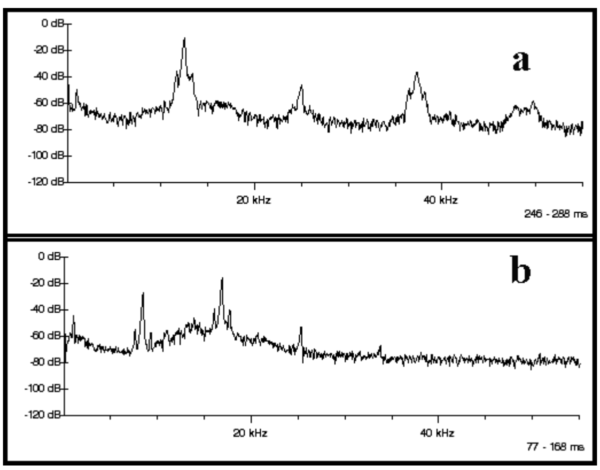

Fig. 3 a, b – Three-peak power spectrum presentation

of both phases can overlap in time (Fig. 1 c) gives us reason to suppose the existence of two independent acoustic sources. Similar structure of alarm calls, consisting by two independent phases has been established by NIKOL'SKII (1979) in *S. xanthoprymnus* (BENNETT, 1835) and *S. pygmaeus* (PALLAS, 1779). The author also considers that these two time-independent phases of the call are produced by two independent acoustic sources. The phenomenon of concentration of the maximum energy of the call in the second harmonic, established by NIKOL`SKII (1979) in *S. suslicus* (GULDENSTAEDT, 1770), is a frequent case in both studied populations of *S. citellus* (Fig. 1 a, Fig. 2 a, b). The main energy of the call in the only specimen studied from North Bulgaria is concentrated about 8 kHz (GEORGIEV *et al.* 2004). The same is the frequency of the first phase in our individuals.

Sciurids often show predator specificity and have specific call type for avian, reptilian, and mammalian predators (EILER, BANACK 2004, NIKOL`SKII 1984, SLOBODCHIKOFF *et al*. 1998). Many animals have geographical variation or dialect differences in their vocalizations. These differences combined with social behaviour and isolation can contribute to speciation (EILER, BANACK 2004).

Conclusions

1. In the studied populations of *S. citellus* from Bulgaria the registered alarm calls can consist of two separated phases at 8 kHz and 12 kHz respectively. Signals with only single phase at one of two main frequencies are registered.

2. Both phases can be fused or emitted continuously with maximum interval of 32.90 ms between them

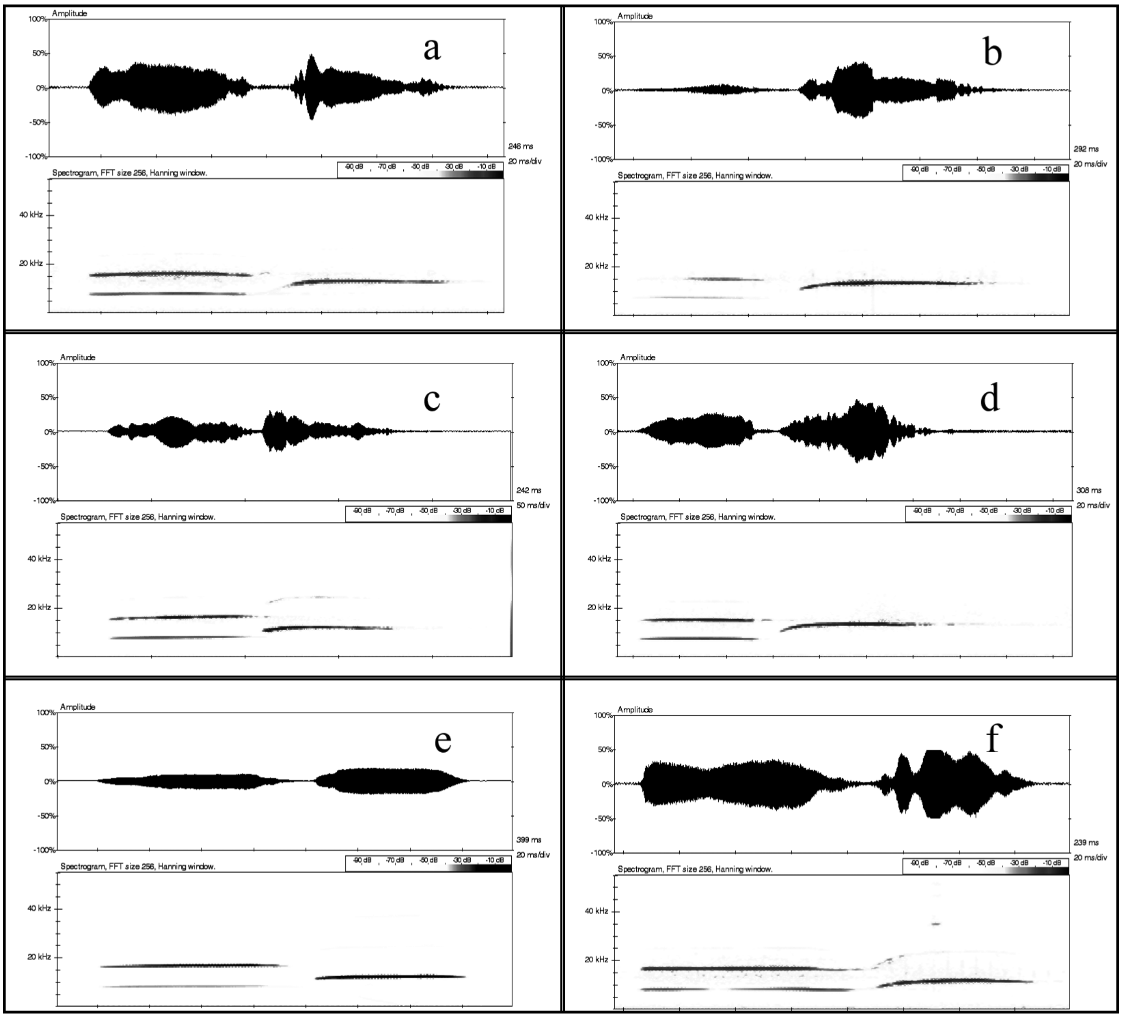

Fig. 4 a, b, c, d, e, f – Sonograms and wave presentations, illustrating the variability of alarm call in studied populations.

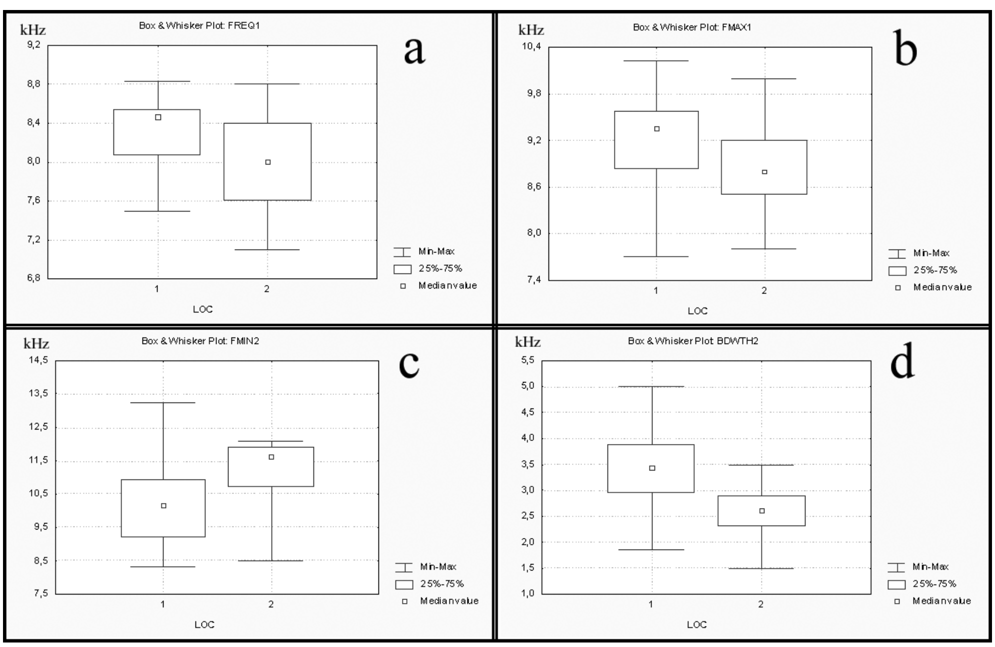

Fig. 5 a – Distribution of FREQ I values in Kremikovtsi (1) and Ponor (2) populations; b – Distribution of FMAX I values in Kremikovtsi (1) and Ponor (2) populations; c – Distribution of FMIN II values in Kremikovtsi (1) and Ponor (2) populations; d – Distribution of BDWTH II values in Kremikovtsi (1) and Ponor (2) populations.

Table 1. Main parameters of alarm call of *Spermophilus citellus* (L.) from Bulgaria.

Call features	Kremikovtsi population						Ponor population					
	No of cases	Mean	Min	Max	SD	CV (%)	No of cases	Mean	Min	Max	SD	CV (%)
DUR I (ms)	52	69.54	29.20	92.60	13.68	19.67	22	67.23	38.20	97.20	15.27	22.71
FREQ I (kHz)	52	8.30	7.49	8.83	0.33	4.09	22	8.02	7.10	8.80	0.49	6.11
FMIN I (kHz)	52	7.29	6.44	8.09	0.34	4.65	22	7.10	6.30	8.20	0.60	8.45
FMAX I (kHz)	52	9.19	7.71	10.22	0.57	6.20	22	8.86	7.80	10.00	0.53	5.98
BDWTH I (kHz)	52	1.89	0.82	2.69	0.49	26.32	22	1.76	0.70	2.60	0.55	31.25
DUR II (ms)	52	65.40	23.80	129.90	21.52	32.90	11	79.85	24.50	127.50	30.89	38.69
FREQ II (kHz)	52	12.36	11.15	15.33	0.95	7.68	11	12.70	10.80	13.60	0.87	6.92
FMIN II (kHz)	52	10.28	8.33	13.24	1.21	11.77	11	11.13	8.50	12.10	1.05	9.52
FMAX II (kHz)	52	13.72	11.82	16.97	1.33	9.77	11	13.70	11.30	15.10	1.14	8.32
BDWTH II (kHz)	52	3.44	1.86	5.00	0.68	20.05	11	2.57	1.50	3.50	0.52	20.62
IPI (ms)	52	9.65	0.00	24.50	7.73	-	11	8.39	0.00	32.90	11.70	-
Total DUR (ms) (DUR I + DUR II + IPI)	52	144.58	103.30	193.10	20.53	14.20	11	153.58	101.50	197.50	30.46	19.83

and probably they are produced by two independent acoustic sources.

3. The durations of the phases have high degree of variation, but the total length of the call in the studied populations has similar values.

4. The total duration of alarm call is more than 100 ms, while the maximum registered value can exceed twice the minimum.

5. The frequency characteristics (highest, lowest frequency and frequency with most energy of both phases) have low degree of variability and they clearly and statistically significantly distinguish the studied populations.

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References

Amori G. 1996. *Spermophilus citellus*. – In: IUCN 2006. 2006 IUCN Red List of Threatened Species. [Cited 2006 Oct 8]; Available from: http://www.iucnredlist.org.

Eiler K. C., S. A. Banack 2004. Variability in the alarm call of golden-mantled ground squirrels (*Spermophilus lateralis* and *S. saturatus*). – *Journal of Mammalogy*, **85** (1): 43-50.

Georgiev A., S. Keppler, H. Haas 2004. A preliminary investigation into the alarm-calling behaviour of European sousliks (*Spermophilus citellus*). – In: Behavioural ecology excursion to Bulgaria 2004. Project report of the European souslik working group. Online: http://www.geocities.com/thesousliks.

Nikol`skii A. A. 1979. Species specificity of alarm call in sousliks (*Citellus, Sciuridae*) of Eurasia. – *Russian Journal of Zoology*, **58** (8): 1183-1194. (In Russian, English summary).

Nikol`skii A. A. 1984. Sound signals of mammals in the evolutionary process. Moscow (Science). 199 p. (In Russian).

Peshev Tz., D. Peshev and V. Popov 2004. Fauna Bulgarica. 27. Mammalia. Sofia, Publishing House of the Bulgarian Academy of Sciences “Marin Drinov”. 633 p. (In Bulgarian).

Ruzič A. 1978. *Citellus citellus* (Linnaeus, 1766) – Der oder das Europaische Ziezel. – In: Niethammer J., F. Krapp (eds.). Handbuch der Säugetiere Europas, Wiesbaden, Akademische Verlagsgesellschft, 123-144.

Shelley E. L., D. T. Blumshtein 2005. The evolution of alarm communication in rodents. – *Behavioral Ecology*, **16** (1): 169-177.

Slobodchikoff C. N., S. H. Ackers and M. Van Ert 1998. Geographic variation in alarm calls of guennison’s prairie dogs. – *Journal of Mammalogy*, **79** (4): 1264-1272.

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Структура и изменчивост на звука на тревога при европейския лалугер *Spermophilus citellus* L. 1766 (Mammalia: Rodentia) от Западна България

Й. Кошев, И. Пандурски

(Резюме)

Изследвани са структурата и изменчивостта на звука на тревога на лалугера (*Spermophilus citellus* L.) от две популации в Западна България. Регистрираните звуци могат да се състоят от две отделни фази: съответно на честоти от 8 kHz и 12 kHz. Двете фази мога да бъдат слети или да бъдат издавани последователно с максимален интервал между тях от 32.90 ms, и вероятно се продуцират от два независими акустични източника. Наблюдаван е и феномен на концентрация на максималната енергия на звука във втората хармонична. Продължителността на фазите има висока степен на изменчивост, но общата дължина на звука при изследваните полуации има сходни стойности. Общата продължителност на звука на тревога надвишава 100 ms, а максималната регистрирана стойност може да надвишава два пъти минималната. Честотните характеристики (най-висока и най-ниска честота и честота с най-голяма енергия на двете фази) имат ниска степен на изменчивост и най-ясно и статистически достоверно различават двете популации.