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Short Note

Activity patterns of European ground squirrels (*Spermophilus citellus*) in a cultivated field in northern Greece

Dionisios Youlatos[1,*], Yiorgos Boutsis[1], John D. Pantis[2] and Helena Hadjicharalambous[3]

[1] Department of Zoology, School of Biology, Aristotle University of Thessaloniki, Thessaloniki, Greece, e-mail: dyoul@bio.auth.gr
[2] Department of Ecology, School of Biology, Aristotle University of Thessaloniki, Thessaloniki, Greece
[3] Greek Biotope/Wetland Center, The Goulandris Natural History Museum, 14th Km Thessaloniki-Mihaniona, Thermi, Greece

*Corresponding author

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In continental Europe, ground-dwelling squirrels are represented by the alpine marmot *Marmota marmota* (Linnaeus 1758) and the European ground squirrel or souslik *Spermophilus citellus* (Linnaeus 1766). The latter species generally inhabits short grass open habitats (Krystufek and Vohralik 2005) and ranges from the Czech Republic southward to northern Greece and European Turkey, and from Austria eastward to Ukraine divided into two main populations (Krystufek 1999): the Pannonian population, inhabiting central Europe and extensively studied (Grulich 1960, Millesi et al. 1998, 1999a,b, Krystufek 1999, Huber et al. 1999, 2001, 2002, Katona et al. 2002, Everts et al. 2004), and the Balkan population which involves the marginal populations of northern Greece, for which little is known (Ruzic 1978, Boutsis 2002, Krystufek and Vohralik 2005, Ozgurt et al. 2005).

Greek populations can be especially important, as they are found at the periphery of the southern border of the range of the species and inhabit the highly seasonal and dry hot conditions of the Mediterranean basin. Thus, they may exhibit behavioral traits differing from that of conspecifics dwelling in northern latitudes (Ruzic 1978), in a way similar to North American species with equally wide latitudinal ranges (Jenkins and Eshelman 1984, Michener and Koeppl 1985, Elliott and Flinders 1991, Bartels and Thompson 1993). In this context, the present study aims to provide original data on dates of emergence from hibernation, activity periods, immergence into hibernation, and aboveground activity and behavior of adult European ground squirrels in north-central Greece. Such data may offer a basis for comparisons among European populations, and are becoming increasingly vital as populations are rapidly declining across Europe, due to continuous urbanization and ongoing agriculture, compelling the establishment of a conservation action plan (Hellenic Zoological Society 1992, Krystufek 1999).

The study site (22°59′06″ E, 40°32′09″ N), 3 ha of an alfalfa field, is owned by the Aristotle University of Thessaloniki and is located in the municipality of Thermi, 14 km east of Thessaloniki, in the prefecture of Macedonia, northern Greece. The site alternates between wheat and alfalfa every 2 and 4 years, respectively; it was cultivated with alfalfa during the period 2000–2003, wheat during 2004–2005 and was replaced again by alfalfa in 2006. We collected behavioral data during the three active seasons when alfalfa was cultivated in the site (2002, 2003 and 2006). The study site was inhabited by a small isolated population of European ground squirrels. We avoided trapping and adhered to direct observations with a pair of binoculars. Focal individuals were identified by (a) mapping the burrow exits they used and (b) specific pelage markings discerned by acquired experience through continuous observations. Adult males were distinguished by enlarged scrotal testes. The sex of adult reproductive females was assigned during the mating period, when swollen external genitalia were visible, and dates of reproductive states were determined tentatively by signs of pregnancy, enlargement of nipples, and emergence of litter, considering eventual errors. In total, 10 adult females and 10 adult males were used as focal individuals. Raw focal behavioral data were aggregated for each individual over each period, and we calculated percentages of aboveground activity and behaviors. Percentages for each sex over each period are presented as means$\pm$1 SD. Prior to statistical analysis, we tested data for homogeneity of variance using the Levene's test (Zar 1996). Subsequently, significance of differences in mean percentages of different behavioral categories, and in mean dates of emergence from and immergence into hibernation was calculated with one-way analysis of variance (ANOVA), using unequal HSD post-hoc tests (Zar 1996). All statistical analyses were performed with SPSS 11.0 (SPSS Inc., Chicago, USA).

Based on our data from three active periods, adult male European ground squirrels emerged from hibernation significantly earlier than adult females (Table 1, $p=0.011$). The same sequence was observed in Austria (Millesi et al. 1999a) and in North American species (Streubel and Fitzgerald 1978, Jenkins and Eshelman 1984, Zegers 1984, Michener and Koeppl 1985, Elliott and Flinders 1991, Bartels and Thompson 1993, Eshelman and Sonnemann 2000). This sequence most likely enables males to complete sexual maturity aboveground and increase reproductive opportunities (Holekamp and Sherman 1989, Michener 1992).

Table 1 Mean (±SD) and range of dates of adult female and adult male activity periods based on data from focal individuals for the active seasons 2002, 2003 and 2006 in northern Greece.

	Females[a]	Males[b]
Emergence from hibernation	22 Mar ±9 days	9 Mar ±8 days
	5 Mar 2002–30 Mar 2006	25 Feb 2002–18 Mar 2003
End of mating	1 Apr ±8 days	1 Apr ±8 days
	23 Mar 2002–10 Apr 2006	23 Mar 2002–10 Apr 2006
End of gestation	25 Apr ±6 days	
	14 Apr 2002–1 May 2003	
Litter emergence	30 May ±8 days	
	14 May 2002–6 Jun 2006	
Immergence into hibernation	21 Jul ±6 days	6 Aug ±10 days
	8 Jul 2002–28 Jul 2006	19 Jul 2002–17 Aug 2006
Sampled animals (n)	10	10

[a]We identified four activity periods for focal females: (i) mating: emergence from hibernation to end of mating, (ii) gestation: end of mating to end of gestation, (iii) lactation: end of gestation to litter emergence and (iv) post-weaning: litter emergence to immergence into hibernation.
[b]We identified three activity periods for focal males: (i) mating: emergence from hibernation to end of mating, (ii) post-mating: end of mating to litter emergence and (iii) pre-hibernation: litter emergence to immergence into hibernation.

In northern Greece and Turkish Thrace (Ozgurt et al. 2005), both sexes emerged from hibernation slightly earlier than in Austria (Millesi et al. 1999a) and the Bulgarian Black Sea coast (Krystufek and Vohralik 2005). Similar findings were also reported for North American *S. richardsonii* (Michener 1977), *S. columbianus* (Murie and Harris 1982) and *S. lateralis* (Bartels and Thompson 1993), where animals in lower latitudes emerge from hibernation earlier than conspecifics from higher latitudes. This pattern has been frequently related to the warmer air temperatures that occur earlier in southern latitudes (Michener 1977, 1979).

Adult males immerged into hibernation significantly later than adult females (Table 1, $p=0.001$) in northern Greece and Austria (Millesi et al. 1999a). This sequence was also observed in *S. elegans* (Zegers 1984), *S. parryii* (Buck and Burnes 1999) and *S. armatus* (Eshelman and Sonnemann 2000) in North America. Delayed immergence into hibernation by males may be related to fat storage increase or fat storage use delay (Millesi et al. 1999a). Interestingly, Ruzic (1978) reported an inverse sequence in F.Y.R. Macedonia, similar to most North American species (Streubel and Fitzgerald 1978, Jenkins and Eshelman 1984, Michener and Koeppl 1985, Elliott and Flinders 1991, Bartels and Thompson 1993).

In northern Greece, Bulgaria, F.Y.R. Macedonia and European Turkey (Ruzic 1978, Krystufek and Vohralik 2005, Ozgurt et al. 2005) immergence into hibernation occurred earlier than in central Europe (Millesi et al. 1999a). This latitudinal pattern, equally observed in *S. tridecemlineatus* (Streubel and Fitzgerald 1978) and *S. richarsonii* (Michener and Koeppl 1985) in North America, is usually related to higher ambient temperatures and drop of food quality and water content that may inflict early hibernation on ground squirrels (Ruzic 1978, Michener and Koeppl 1985, Schwanz 2006). This may also be the case for northern Greece, where the active period appears to be shifted to the less dry months permitting the exploitation of more valuable food sources. However, the fact that *S. lateralis* hibernates earlier in higher latitudes (Bartels and Thompson 1993) demonstrates the complexity of hibernation onset.

Males spent significantly more time aboveground than females during the mating period (Table 2, $p=0.003$). Females were more active during the post-weaning period compared to male pre-hibernation period ($p=0.0005$), which coincided temporally (Table 2). Similarly, increased aboveground activity has also been recorded for parous female *S. columbianus* and was associated with the greatest energetic demands of early post-weaning

Table 2 Mean percentages (±SD) of total aboveground activity, feeding (manipulation and ingestion of food items), vigilance (bipedal alert postures), locomotion (body displacement) and other aboveground behaviors of adult male and female European ground squirrels in northern Greece during the different periods of active seasons of 2002 (111 h of observation), 2003 (227 h of observation) and 2006 (192 h of observation).

	Males			Females			
	Mating	Post-mating	Pre-hibernation	Mating	Gestation	Lactation	Post-weaning
Feeding[a]	25.1±4.5	40.5±8.2	41.9±6.8	48.9±4.7	25.4±3.8	47.4±6.6	22.0±2.6
Vigilance	62.5±1.7	45.1±6.7	39.0±5.5	45.5±5.7	68.2±4.6	46.3±7.9	65.9±4.6
Locomotion	4.4±1.5	3.5±1.8	3.9±1.5	3.2±0.9	3.0±1.2	3.1±2.0	6.6±2.4
Other[b]	7.9±3.8	10.9±3.7	15.2±4.1	0.2±0.1	1.8±1.0	1.4±0.6	4.2±3.8
Total aboveground activity	52.1±4.4	59.8±4.3	42.9±8.1	40.9±3.8	51.4±4.2	39.9±5.0	53.7±4.3
Sampled animals (n)	10	10	10	10	10	10	10

Percentages of aboveground behaviors were calculated on the basis of aboveground data excluding non-visible data.
[a]Focal animal data (Martin and Bateson 1994) at 1-min intervals during 3 h sessions/day focusing on different individuals per session.
[b]Involves quadrupedal crouch, burrow maintenance, social interactions, self-grooming, rubbing, marking and play.

(MacWhirter 1991). The low aboveground activity recorded for males during the pre-hibernation period may also be associated with restricted food availability or with avoidance to exposure to relatively high ambient temperatures and solar radiation (McCarley 1966, Michener and Koeppl 1985, Elliott and Flinders 1991, Katona et al. 2002, Everts et al. 2004).

During aboveground activity, vigilance and feeding were the dominant behaviors in all periods for both males and females (Table 2). These behaviors also dominate aboveground activity of ground squirrels in central Europe (Everts et al. 2004) and North America (Streubel and Fitzgerald 1978, Holekamp and Nunes 1989, MacWhirter 1991, Michener and McLean 1996, Eshelman and Sonnemann 2000). In general, rates of vigilance were particularly high for both sexes. This may be related to the relatively small size of the study population that may have entailed frequent individual bouts of vigilance for predator detection (Manno 2007). High vigilance in mating males (Table 2, $p=0.0001$) could be correlated with monitoring of estrous females, as well as of potential competitors (Manno 2007). On the other hand, increased vigilance in gestating and post-weaning females may be related to protection of both unborn and emerged offspring, contributing to overall reproductive success (MacWhirter 1991, Huber et al. 1999, Millesi et al. 1999b).

Adult females engaged in high percentages of feeding during mating and lactation (Table 2). High feeding rates during lactation have also been recorded in central Europe (Everts et al. 2004) and North America (MacWhirter 1991) and were related to the high energetic demands of lactation (Holekamp and Nunes 1989, Kenagy et al. 1989, MacWhirter 1991, Michener and McLean 1996). This may further explain the low percentages of vigilance during that period, as the two behaviors can be mutually exclusive (Arenz and Leger 2000). Males exhibited high percentages of feeding both during postmating and pre-hibernation in northern Greece (Table 2) and central Europe (Everts et al. 2004), a pattern associated with fat storage, necessary for survival over winter (Millesi et al. 1999a). Similar behaviors have been recorded for *S. beldingi* (Jenkins and Eshelman 1984) and *S. richardsonii* (Michener and McLean 1996) in North America.

Although the present data derive from a small, isolated population inhabiting a cultivated field, we believe that they should be considered as indicative of the marginal Southern populations inhabiting the Mediterranean plains. Furthermore, the present study demonstrated some differences between Balkan and Pannonian populations, as well as between different areas within the Balkan population. Such differences underline the behavioral plasticity of the species enabling it to adapt to divergent conditions across a wide latitudinal range. The rapid decline and the vulnerability of the species in northern Greece, due to large-scale urbanization and ongoing agricultural practices, prompts for further studies in different habitats in order to determine priorities for the elaboration of a conservation action plan.

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