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A new method based on indirect evidences to infer activity pattern in moles. A test on the blind mole in Central Apennines

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Abstract. The study of activity patterns in subterranean mammals has been poorly explored in subterranean insectivores. This is especially true for the rare and elusive blind mole *Talpa caeca*. A field work devoted to collect data on life history traits of the blind mole was run in a montane pasture in Southern Italy (1549 m a.s.l.). Plastic barrel-like traps were placed in actively used mole tunnels and checked regularly at 6 h intervals for two sessions of nine consecutive days, for a total 1500 trap-nights. No moles were captured alive, but signs of mole activity at trap sites (traps filled with ground) were regularly recorded. A video recorded inside a trap confirmed that moles fill the traps with soil as part of trap avoidance behavior. Activity at trap sites was analyzed as a binomial variable, considering the rate of filled traps vs. the number of armed traps at each 6 h trap-checking intervals. Activity showed a polyphasic pattern typical of moles, but differently from other species, activity was more concentrated in the central part of the day (12.00–18.00). Results suggest a specific adaptation to local environmental conditions and body size.

Key words: *Talpa caeca*, circadian rhythms

Introduction

Because of their limited exposure to light and the regression of some of the structures able to perceive it, highly specialised subterranean mammals offer interesting insight in the study of the role of light as external regulator of rhythms (see for example Cooper et al. 1993).

The study of activity patterns in subterranean mammals has been traditionally addressed to rodent species (see among the others Nevo et al. 1982, Bennet 1992, Rado et al. 1993, Davis-Walton & Sherman 1994, Ben-Shlomo et al. 1995, Lovegrove & Papenfus 1995, Oster et al. 2002, Zelová et al. 2009, Lövy et al. 2013), while little is known about the activity patterns of subterranean insectivores (Godfrey 1955, Mellanby 1967, Harvey 1976, Gorman & Stone 1990, Loy et al. 1992, Hennicke 1997, Macdonald et al. 1997, Borroni et al. 1999). This lack of data is mostly related to the many difficulties in capturing, handling and monitoring subterranean insectivores. This is especially true for rare and elusive species like the blind mole *Talpa caeca*, for which no data are available on either spatial or temporal organization.

The blind mole is the smallest among the five moles occurring in Europe, i.e. *T. europaea*, *T. romana*, *T. stankovici*, *T. occidentalis*, and *T. caeca*. It is endemic to south-eastern Europe, where it is found with fragmented and scattered populations in the western Alps, the Apennines, and the Balkan peninsula, from sea level to 2000 m, although it is more frequent above 1000 m (Kryštufek 1999, Loy 2008). In Italy the range of the blind mole overlaps with both *T. europaea* and *T. romana* in north-central and south-central regions respectively, even if it is rarely found syntopic (Mitchell-Jones et al. 1999, Loy 2008).

To partially fill the gap of knowledge on the biology of the blind mole we planned a study of a wild population recently found in a montane area of south-central Italy (Scaravelli & Mancini 2005). Following a procedure successfully adopted in the study of other mole species (Gorman & Stone 1990, Loy et al. 1994a, b, Beolchini et al. 1996) the study was devoted to live capture the animals and fit them with a radiotrasmmitter. We failed in capturing live moles, but the use of a standardized trap-checking schedule allowed gathering first indirect information on the activity patterns in this elusive mole.

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Table 1. Example of data used to analyze activity rhythms based on indirect signs. Data refer to the results of one day. Each time interval represents a trap-checking session (traps were checked at the end of the interval, i.e. at 6.00, 12.00, 18.00, 24.00). Grey cell = trap found filled with soil; white cell = trap found empty.

Day	Trap ID	00.00-6.00	6.00-12.00	12.00-18.00	18.00-24.00
6	1				
6	2				
6	3				
6	4				
6	5				
6	6				
6	7				
6	8				
6	9				
6	10				
6	11				
6	12				
6	13				
6	14				
6	15				
6	16				
6	17				
6	18				
6	19				

Table 2. Differences in cumulative frequencies of traps found filled at each 6 h interval check. * = $P < 0.05$.

	Night (6.00) 66/475 (<i>ft/at</i>) (14 %)	Morning (12.00) 64/392 (<i>ft/at</i>) (16 %)	Afternoon (18.00) 74/385 (<i>ft/at</i>) (19 %)	Evening (24.00) 33/248 (<i>ft/at</i>) (13 %)
Night (6.00) 66/475 (<i>ft/at</i>) (14 %)	$\chi^2 = 0.0$			
Morning (12.00) 64/392 (<i>ft/at</i>) (16 %)	$\chi^2 = 1.0$	$\chi^2 = 0.0$		
Afternoon (18.00) 74/385 (<i>ft/at</i>) (19 %)	$\chi^2 = 4.4^*$	$\chi^2 = 1.1$	$\chi^2 = 0.0$	
Evening (24.00) 33/248 (<i>ft/at</i>) (13 %)	$\chi^2 = 0.048$	$\chi^2 = 1.1$	$\chi^2 = 3.8^*$	$\chi^2 = 0.0$

Material and Methods

Field work was run in a montane botanical garden located at 1549 m a.s.l. (Giardino della Flora Appenninica, Capracotta, southern Italy), where an isolated population of *T. caeca* was discovered in 2005 (Scaravelli & Mancini 2005) (longitude 14.276761°, latitude 41.845014°). Between 2009 and 2011 many attempts were made in the same locality to capture live specimens to fit with radio transmitters (Ramacciato 2008), both using a technique successfully adopted by one of the authors with *T. romana* (Loy et al. 1994a, b, Beolchini et al. 1996), and by testing many other trapping methods specifically designed for this species (Ramacciato 2008). All these attempts failed to capture live specimens of *T. caeca*, and only two dead specimens were trapped. Despite traps failed to capture live moles, many traps were found filled with ground by the moles at each traps check. A remote

video recording obtained by the means of a webcam placed into a trap allowed to observe an adult blind mole exploring the trap, running away, and then filling the trap with soil. Trap filling was often accompanied by a side tunnel dug to bypass the trap. This behaviour was also observed in *T. romana* by one of the authors (A. Loy pers. comm.). Traps filled with soil by moles were easily distinct from signs left by the subterranean voles that are often found in mole's tunnels, as contrary to the latter mole fill up and compact the soils into the trap. Traps filled up with soil were then considered as evidence of moles being active within the time interval between two successive checks. Based on these observations and considering that moles are solitary and highly territorial, patrolling their tunnel system during their active polyphasic bouts (Gorman & Stone 1990, Loy et al. 1994a), we run a field work specifically devoted to detect and quantify moles'

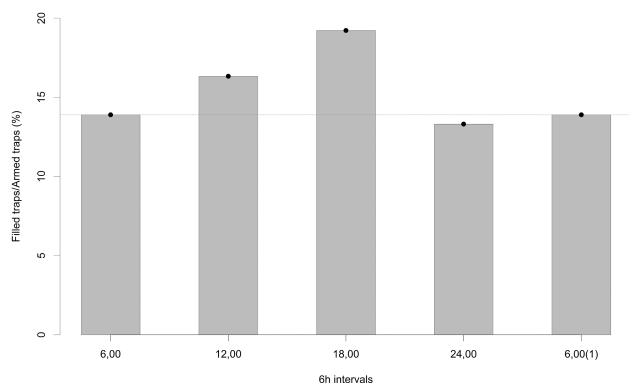


Fig. 1. Cumulative frequency of traps found filled with ground at each 6 h control. Results of test for differences among 6 h intervals are reported in Table 2.

daily activity based on evidences of activity found at the trap sites at each control.

Two field sessions were run in May-June 2009. Plastic barrel-like traps with no bait were placed in actively used mole tunnels and checked regularly at 6 h intervals (6.00, 12.00, 18.00, 24.00) for a total 18 days. The two field sessions were coupled and the data gathered were pooled because the time shift

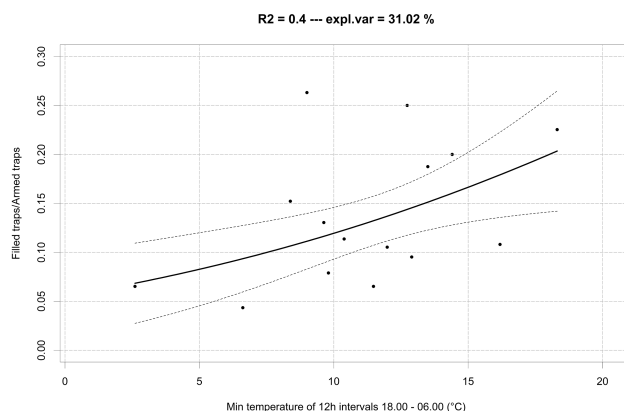


Fig. 2. Relationship between minimum air temperature of the day and activity during the second part of the day (18.00-6.00). Dashed black lines indicate the 95 % confidence interval of the estimate.

between the two sessions was very short (4 days). A new trap was placed in proximity of each new soil mount found in the study area. Thus the number of active traps progressively increased from 19 (day 1) to 46 (from day 14). Traps found completely filled with soil at each check were considered as a sign of mole activity occurred during the previous 6 h. Traps filled with ground were cleared and replaced at the same

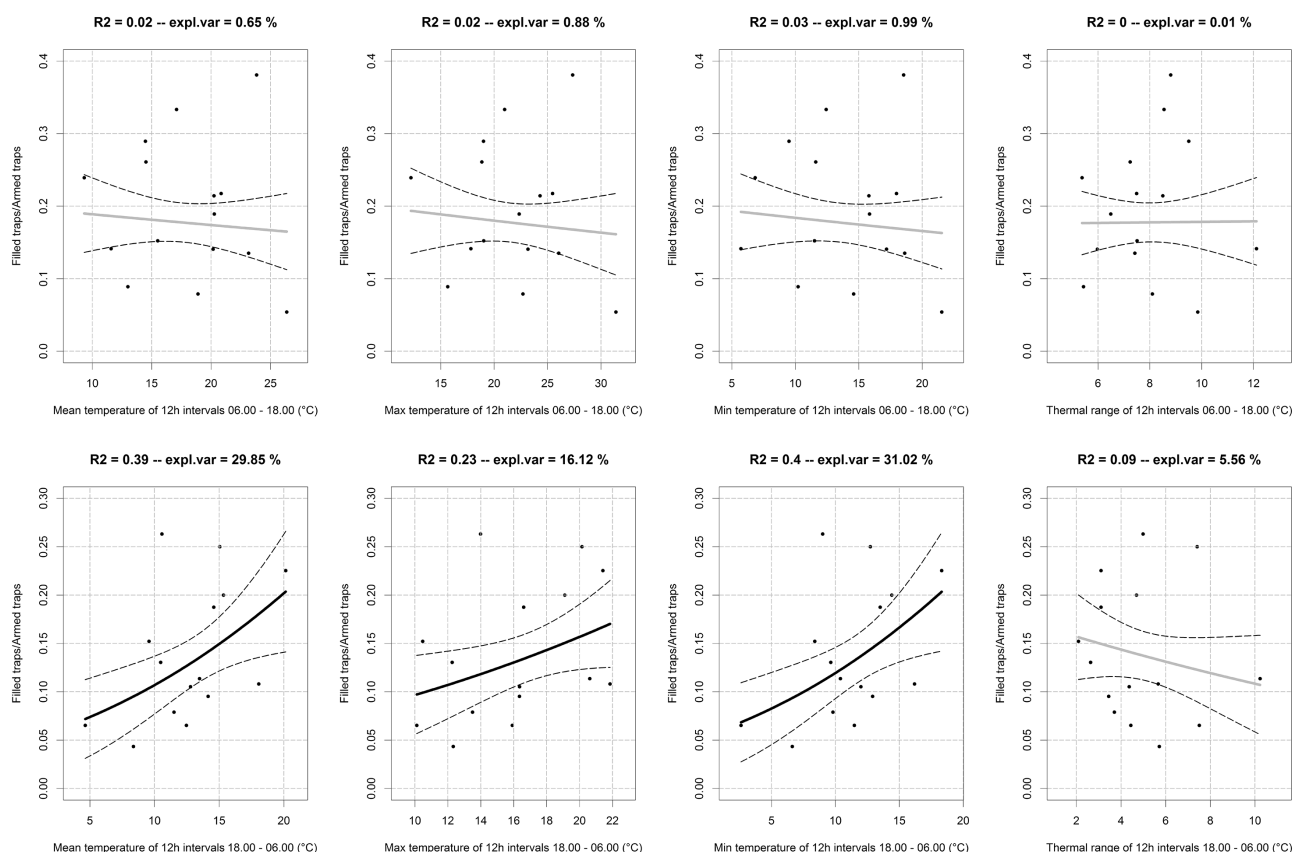


Fig. 3. Relationship between mean, max, min air temperature and diurnal thermal range of the day and activity during the first (6.00-18.00) (upper line) and the second part of the day (18.00-6.00) (lower line). Solid black curves indicate a statistically significant relationship; dashed black lines indicate the 95 % confidence interval of the estimate.

site. Activity was analyzed as a binomial variable, considering the rate ft/at , where ft is the number of filled traps (*successes*) and at the number of armed traps (*attempts*), at each interval. Differences in cumulative activity rates among 6 h time intervals (6.00, 12.00, 18.00, 24.00), calculated as the ratio between the total number of filled traps and the total number of armed traps (ft_{total}/at_{total}) were tested for differences between proportion data (Newcombe 1998). A generalised linear model (GLM) with a binomial distribution of errors and a clog-log link function was also used to investigate the relationship between the temporal variation of activity rhythms cumulated at 12 h intervals (6.00-18.00 and 18.00-6.00) and mean, max and min air temperature and diurnal thermal range. Climatic data were collected from the nearest meteorological station located at 1.4 km from the study area (www.capracottameteo.it). To assess the goodness-of-fit of each model we computed both the explained variance, calculated as the ratio of the difference between null and residual deviance to null deviance, (Zuur et al. 2009), and the Nagelkerke's adjusted R^2 (Nagelkerke 1991). Test for differences in proportions data and generalized linear models were performed with the R package "stats" (R Development Core Team 2013); the Nagelkerke's adjusted R^2 was calculated with the R package "MuMIn" (Burnham & Anderson 2002).

Results

A total 1500 trap-nights were performed during 18 days of trapping. No moles were captured alive but one adult female of *T. caeca* was found dead in a trap. Table 1 reports an example of how data were structured to analyze activity rhythms based on indirect signs (traps filled with ground), each record representing a trapnight.

Fig. 1 shows the cumulative activity detected in the study area at each 6 h intervals. Activity was significantly larger in the afternoon (12.00-18.00) than during morning (6.00-12.00), evening (18.00-24.00), or night (24.00-6.00). No significant differences between activity during morning (6.00-12.00) and afternoon (12.00-18.00) were found (Table 2).

Activity from 18.00 to 6.00 showed significant relationships with mean air temperature ($p < 0.01$; explained variance = 29.85 %; $R^2 = 0.39$) and max air temperature ($p < 0.05$; explained variance = 16.12 %; $R^2 = 0.23$), whereas the most robust relationship resulted with the minimum air temperature ($p < 0.01$; explained variance = 31.02 %; $R^2 = 0.40$) (Fig. 2). Activity during most of the daylight (6.00-18.00) was

not significantly related with any of the environmental variables (Fig. 3).

Discussion

Despite no live moles were captured during 18 trapping days and 1500 trap-nights, the temporal occurrence of indirect signs at trap sites was used as an index of moles being active within each trap-checking interval. The frequency of traps filled with ground among intervals suggests that *T. caeca* in the study area substantially shows a polyphasic activity similarly to other mole species (Gorman & Stone 1990, Loy et al. 1994b, Borroni et al. 1999), with some activity detected during morning, evening and night. Nevertheless, our evidences also suggested the species to be preferentially active during the daylight, with a significant peak of activity in the warmest part of the day, from 12.00 to 18.00. Moreover, the significant relationship between the minimum external temperature and the decrease of activity during the second part of the day (18.00-6.00) suggests that this small sized species might be more influenced by the temperature daily cycle compared to the other two large moles *T. romana* and *T. europaea*.

Sensitivity to the external temperature in the blind mole could also be stressed by the high altitudes at which this species usually occurs (Kryštufek 1999, Loy 2008), and the low depth of their tunnel systems (Gorman & Stone 1990). In fact, tunnel depth in the study area varied between 10 and 20 cm, while those of larger species usually vary from 20 cm to 1 m (Gorman & Stone 1990, Loy 2008). A susceptibility to low temperature would be consistent with the two specimens found dead into the traps despite the very tight 6 h control intervals (see also Ramacchiato 2008) successfully adopted in studies on other species (Loy et al. 1994a, b).

Temperature is known to have a strong influence in insectivore mammals like moles, where high metabolic rate coupled with the small size and the digging metabolic rate (Zelová et al. 2010) increase their energetic demand (McNab 1966, 1979). This effect might be even more relevant in the blind mole that is the smallest sized among the European species (Kryštufek 1999, Loy 2008). In fact, the role of energy metabolism in maintaining the thermal homeostasis of endotherms and in shaping activity rhythms depends on the efficiency of heat conservation in the body, which is, in turn, a function of body mass and thermal conductance (McNab 1980, 2002, 2010, Schmidt-Nielsen 1995, Schleucher & Withers 2001, Wooden & Walsberg 2002). Therefore, temperature loss might

represent an important constraint for the blind mole. Shifting the activity peak toward the warmest part of the day could therefore represent an adaptive response to the cold climate found in most of the species range. Nevertheless, we cannot exclude that the moles were active even when no evidences were found at trap sites, and that more data and evidences are needed to confirm the activity pattern of the blind mole derived from our data, as well as the relationships between daily activity, temperature and metabolic demand. Anyhow, based on previous knowledge on the biology of these subterranean insectivores, we are quite confident that our results represent a first reliable

glance on the temporal organization of the blind mole worth to be further explored in the future. Furthermore, we believe that the indirect method proposed in this study could represent a useful approach to bypass the remarkable difficulties encountered in the study of wild populations of the elusive mole species.

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