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Activity timing of southern water vole (*Arvicola sapidus* Miller, 1908) in a Mediterranean river

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Resumen

El conocimiento de las alternancias entre actividad/descanso durante ciclos de 24 h es importante para comprender la forma en que las especies interaccionan con el medio y, a la vez, puede proporcionar herramientas para desarrollar medidas de conservación adecuadas. El conocimiento sobre esta alternancia de actividad y reposo es escaso en la rata de agua *Arvicola sapidus*, un roedor endémico de la península Ibérica y Francia. El presente estudio tiene como objetivo contribuir al conocimiento de los patrones de actividad/reposo hora a hora, mediante la cuantificación de las distancias recorridas (asociadas a actividad) para diferentes individuos de *Arvicola sapidus* en un tramo del río Montsant, utilizando la técnica del radioseguimiento. Los resultados han mostrado que la rata de agua se comporta como una especie catemeral. La aproximación al patrón de actividad obtenida mediante datos sobre la frecuencia de actividad en intervalos de una hora mostró una menor resolución que la aproximación obtenida a partir de las distancias medias recorridas en intervalos de una hora. Los individuos que ocupaban un hábitat subóptimo recorrieron una distancia media por hora mayor que la de los individuos que ocupaban un hábitat óptimo. La actividad se ha relacionado con las condiciones de hábitat. Estas consideraciones ayudarían a explicar por qué la fragmentación y destrucción del hábitat se configuran como las principales causas de regresión de la rata de agua, así como la importancia de la conservación del hábitat para favorecer el mantenimiento de la especie.
Palabras-clave: actividad, *Arvicola sapidus*, distancias recorridas, hábitat, radioseguimiento.

Abstract

Knowledge of the alternation between activity and rest during the 24 h daily cycle is important in order to understand how species interact with the environment and can also provide tools for designing appropriate conservation measures. At present, little is known about this alternation in *Arvicola sapidus*, an endemic rodent restricted to the Iberian Peninsula and France. This study aims to extend our knowledge of this rodent's hour to hour activity/rest patterns by using radiotelemetry to quantify the distances travelled (associated with activity) by individual southern water voles along a stretch of the Montsant River. The results showed that the southern water vole's behaviour is cathemeral. The use of data of frequency of activity in one-hour intervals to assess the activity pattern showed a lower resolution than the use of data of the mean distances travelled in one-hour intervals. The individuals occupying a suboptimal habitat travelled a greater mean distance per hour than individuals occupying an optimal habitat, indicating that their activity was related to the habitat conditions. These considerations may help to explain why fragmentation and habitat destruction are emerging as the main cause of the decline of the southern water vole, and underline the importance of habitat conservation to encourage the maintenance of the species.
Key words: activity, *Arvicola sapidus*, distances travelled, habitat, radiotelemetry.

Introduction

The southern water vole *Arvicola sapidus*, Miller 1908 (Rodentia, Cricetidae) is an arvicolid species whose distribution is restricted to the Iberian Peninsula and France (Saucy 1999). Generally occupies the banks of stable watercourses and bodies of water with moderate stream widths and depths, together with gently sloping banks and a soft substrate with both abundant herbaceous vegetation (mainly helophytes) and moderate to low levels of tree and shrub cover (Mate *et al.* 2013). This species shows a cathemeral activity rhythm (it is active during both day and night), with a bimodal pattern (Pita *et al.* 2011).

The two basic behavioural phases in the life of any animal are activity and rest. During activity, associated with movement, a variety of vital tasks that are essential to ensure fitness are performed. The most obvious is foraging, but exploration, search for mates or conspecifics, together with both patrolling and defence of the home range are also indispensable (Halle 2006). Rest, associated with a lack of translational movement of the animal, is more than just "non-activity"; important social interactions occur during rest, as well as recovery. During rest periods, animals primarily perform what is often called "comfort behaviour", such as eating, sleeping, grooming, playing, lactation and care of young, or establishing relationships with other group members (Halle & Stenseth 2000a).

Knowledge of the alternation between activity and rest is important to understand how species interact with the environment and what the factors affecting their life history are (Bunnell & Harestad 1990, Larrucea & Brussard 2009), and at the same time this can provide tools to help develop appropriate conservation measures (Hwang & Garselis 2007). Factors such as the energy expenditure, thermoregulation, stress or response to either predators or competitors can all modify activity time (Halle & Stenseth 2000a). Activity patterns in turn influence the basic behaviour of the animal, such as social interactions or caring for offspring. When it comes to endangered species, it is important to know when foraging activities take place, or when the predation risk is greatest, and also when surveys might be most effective (Larrucea & Brussard 2009). Knowledge of this alternating activity and rest during the 24 h daily cycle in the southern water vole is scarce. The present study therefore aims to contribute to knowledge of hour to hour activity/rest patterns by quantifying the distances travelled (associated with activity) by different individual southern water voles along a stretch of the Montsant River, using radiotelemetry.

Study area and methods

The Montsant River (41º10'-41º18' N and 0º45'-0º53' E, Tarragona, Spain) has a typically Mediterranean torrential regime, with strong fluctuations in flow that cause large seasonal changes. Along the river there are herbaceous communities which alternate with quite fragmented riparian forest communities. For a complete description see Mate *et al.* (2013).

Four adult voles were caught with a single-entry live cage traps with a tilting door (30x15x14cm). According to the quantitative characterization of optimal, suboptimal and hostile areas (Mate *et al.* 2013), two individuals, A_1 ♀ 235 g and A_2 ♂ 240 g, occupied an optimal habitat (UTM: 31T 313552 4574455); and the other two, A_3 ♀ 217 g and A_4 ♂ 275 g, occupied a suboptimal habitat (UTM: 31T 313396 4574432). In the Montsant River, habitat selection by southern water vole can be explained by a combination of interrelated environmental conditions, rather than a single habitat characteristic: the riparian vegetation (bankside vegetation cover), the characteristics of the banks (slope and penetration resistance of soil) and the characteristics of the watercourse (water depth and width) (Mate *et al.* 2013). A radio transmitting collar (Pip Ag393, Biotrack Ltd., Wareham, Dorset, UK) was fitted to each specimen, after sedation with isoflurane (IsoFlo®, Esteve Veterinaria-Abbott Laboratories, Barcelona, Spain). The sedation was carried out using a portable anaesthetic machine (McKinley, Everest Tecnología Veterinaria Médica, Molins de Rei, Spain), and the protocol was supervised by a veterinary practitioner from the Wildlife Service of the Autonomous Government of Catalonia. The animals were localized using a Sika receiver (model S/N701 W, Biotrack Ltd., Wareham, Dorset, UK) and a manual Yagi antenna (Lintec Antennas, Goring-by-Sea, West Sussex, UK). Locations were determined by multiple triangulation of the observer's position with the river, as water voles usually move along the stream. At each location, the position (UTM) was measured using a Garmin GPS eTrex® (Garmin, Romsey, Hampshire, UK). The captures and radio tracking were carried out during the summer of 2011 with the required authorizations from the General Directorate of the Natural Environment and Biodiversity, of the Autonomous Government of Catalonia. The monitoring was conducted hour by hour for 5 days (A_1,A_2: July 19th to 23th, and A_3, A_4: July 25th to 29th).

The records were grouped into four periods based on information on the times of sunrise and sunset (National Geographic Institute, Spanish Ministry of Development): dawn (from one hour before to one hour after sunrise), dusk (from one hour before to one hour after sunset), diurnal (between sunrise and sunset), and nocturnal (between dusk and dawn) (Lucherini *et al.* 2009), hourly data given in Universal Time Coordinated (UTC). For each individual, the UTM coordinates allowed an assessment of the distances travelled in one-hour intervals and a calculation of the activity (associated with movement). Specifically, for the interval starting in hour i and ending in hour i+1, and locations (x_i, y_i) and (x_{i+1}, y_{i+1}), the distance travelled was estimated as:

$$d_{(i,i+1)} = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$

In this context, activity was shown when the distance travelled in intervals of one hour was greater than the GPS location error (5 m). The relative frequency of one-hour intervals with activity detected was used to estimate the mean activity of each period/individual. On the other hand, the activity was also related with the distance travelled. The mean ($\bar{D}$) and standard deviation (s) of the distances travelled corresponding to one-hour intervals allowed us to estimate the mean distance travelled for each period/individual and its precision ($\bar{D} \pm 1.96 \bullet s \sqrt{n}$, where n is the sample size in the time slot considered). The General Linear Model was used to determine the significance of the differences in the distances travelled. A two-factors model (habitat and time slot) was used for all the records with detected activity, and a one-factor model (habitat) was used when considering only daytime records. With small sample sizes at dusk and dawn we pooled the records from dawn, dusk and night as "extended nocturnality".

Results and discussion

A total of 119 records were obtained for each individual. The frequency of activity associated with movement and the distances travelled in one-hour intervals showed that the southern water vole behaves as a cathemeral species in the Montsant River (Fig. 1). The adaptation of the southern water vole to being active during all the hours of the day and night is consistent with what has been observed elsewhere (Saint Girons 1973, Gosálbez 1987, Pita *et al.* 2011): it alternates short periods of activity and rest over a 24-hour cycle (Daan & Slopsema 1978, Halle & Stenseth 2000b, Ylönen & Brown 2007). This behaviour could be explained by the fact the diet of the southern water vole follows a vegetarian dietary pattern that is rich in cellulose and low in energy and consequently requires frequent foraging activity (Gębczyṅski 2006, Halle 2006, Ylönen & Brown 2007). This distribution of activity over time could be also related with strategies aimed to reduce predation risk and interspecific competition (Halle 2006).

The approaches considered (activity associated with movement and distances travelled) lead to the same general conclusions, but differ in detail. The detection of movement in most of the one-hour intervals suggested an almost uniform pattern of activity (Fig. 1a), probably because the arvicoline can make multiple short-haul movements within the one-hour intervals. By contrast, the distances travelled showed different intensities of movement over time (Fig. 1b). This approach to the activity pattern is consistent with the patterns obtained from data provided by photo-trapping in the Montsant River (Mate *et al.,* unpublished), and from data provided by telemetry in open plains of southwest Portugal (Pita *et al.* 2011).

The results showed that individuals occupying a suboptimal habitat travelled a greater mean distance per hour than individuals occupying an optimal habitat (with records of all time slots: $F= 13.21$, $p= 0.0003$; with only daytime records: $F= 21.60$, $p< 0.0001$). Mean distance travelled was estimated at 32.03 m/h in suboptimal habitat (A_3: 33.8 ± 5.5 m; A_4: 30.1 ± 5.0 m), and at 18.93 m/h in optimal habitat (A_1: 22.4 ± 3.6 m; A_2:15.9 ± 1.6 m). Moreover, no significant differences were observed in the mean distances travelled per hour in different time slots ($F= 0.19$, $p= 0.9047$). The descriptive results for individual and time slot are shown in Table 1.

Rodents adapt their behaviour in order to minimize energy consumption and risk of predation, as well as to maximize the time available for foraging and resting (Sibly 2000, Halle 2006, Ylönen & Brown 2007). Differences in distances travelled per hour for the two couples studied were related to the availability of resources. So, when food resources

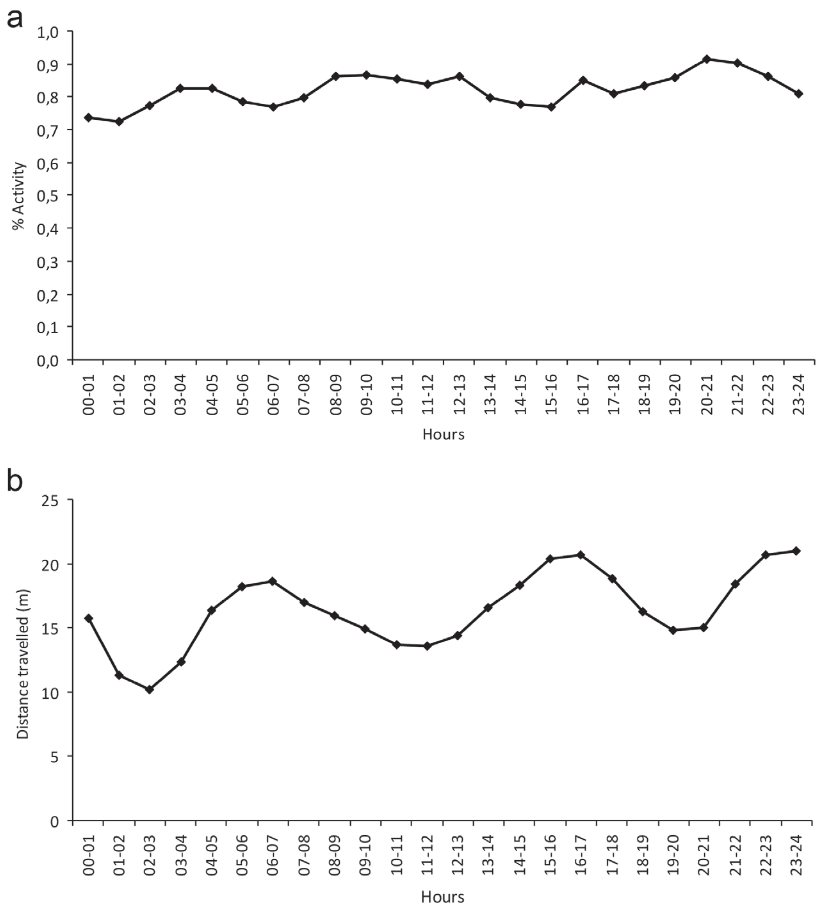

Figure 1. Hourly activity: a) relative frequency of activity detected in one-hour intervals; b) mean distance travelled in one-hour intervals.

Table 1. Mean distances covered (m) and frequency of activity (%) by individual in time slot. (reg: total number of records; mov: number of records in which movement was observed).

	♀ A1				♂ A2			
	reg	mov	distances (m)	activity (%)	reg	mov	distances (m)	activity (%)
extended nocturnality	56	41	22.3 ± 5.2	73.2 ± 11.6	55	46	15.7 ± 2.2	83.6 ± 9.8
dusk	9	6	28.9 ± 13.8	66.7 ± 30.8	9	6	15.5 ± 4.8	66.7 ± 30.8
night	35	24	22.6 ± 7.6	68.6 ± 15.4	35	29	14.1 ± 2.7	82.9 ± 12.5
dawn	12	11	18.2 ± 7.0	91.7 ± 15.6	11	11	17.5 ± 5.0	100.0
diurnality	63	43	22.4 ± 5.1	68.3 ± 11.5	64	49	16.7 ± 2.4	78.6 ± 10.4
TOTAL	119	84	22.4 ± 3.6	70.6 ± 8.2	119	95	15.9 ± 1.6	79.8 ± 7.2

	♀ A3				♂ A4			
	reg	mov	distances (m)	activity (%)	reg	mov	distances (m)	activity (%)
extended nocturnality	56	51	32.0 ± 8.9	91.1 ± 7.5	55	46	29.1 ± 7.4	83.6 ± 9.8
dusk	11	10	27.8 ± 14.9	90.9 ± 17.0	8	8	21.9 ± 8.2	100.0
night	36	32	32.8 ± 12.5	88.9 ± 10.3	38	32	31.0 ± 10.0	84.2 ± 11.6
dawn	9	9	33.9 ± 19.0	100.0	9	6	28.5 ± 16.9	66.7 ± 30.8
diurnality	63	59	35.4 ± 6.8	93.7 ± 6.0	64	56	31.0 ± 6.7	87.5 ± 8.1
TOTAL	119	110	33.8 ± 5.5	92.4 ± 4.8	119	102	30.1 ± 5.0	85.7 ± 6.3

become scarce or dispersed (less optimal habitats), the animals are forced to cover greater distances daily in search of food, thus incurring increased energy expenditure and assuming a greater risk of predation (Owen-Smith 2003). Most of the daily energy consumed by arvicolines is metabolized to maintain the functioning of the body. The ambient temperature and the proportion of time spent on displacement modify the metabolic rates of the animals and affect the level of heat loss due to respiration (Delany 1981).

All these considerations may help to explain why fragmentation and habitat destruction are emerging as the main cause of the decline of the southern water vole (Román 2007, Rigaux *et al.* 2008). They also stress the importance of habitat conservation to encourage the maintenance of the species (Román 2007, Mate *et al.* 2013, Pita *et al.* 2013).

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