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Short Communication

Winter locomotor activity patterns of European hares (*Lepus europaeus*)

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ABSTRACT

In this study, activity patterns of the European hare (*Lepus europaeus*) were analyzed during winter using global positioning system (GPS) collars on 24 hares in two study areas located in central Italy. We programmed the collars to collect 12 location points per day, for a duration of three months. Results show two distinct phases of activities related to the day–night cycle. The daytime phase is characterized by inactivity at the form while the second phase is characterized by movements. Males were more active than females, showing a constant locomotor activity during the whole night. Females showed two peaks of activity during the night with a reduction in the middle of this time period. The comparison between females of the two study areas showed difference in interfix distance in particular around sunset and sunrise. In fact the minimum daily movement between the two areas shows that foraging sites of area B are more distant than those of area A. The recent possibility to apply GPS collars on small–medium mammals provides a powerful instrument to study the behavioral ecology of the European hare, and consequently promote an effective population management strategy for the species conservation.

In the last 30 years, European hare (*Lepus europaeus*) activity patterns have been studied in north and central Europe (Homolka 1986; Pépin and Cargnelutti 1994; Reitz and Léonard 1994; Holley 1986, 2001; Rühe and Hohmann 2004; Schai-Braun et al. 2012). These authors describe unanimously the European hare as a species with two distinct activity phases, the first during the night, characterized by active behavior while the second covers mostly the daylight resting at the form. Recent studies have shown that this description is true when the night time period is long enough to meet the ecological requirements of the species. In fact during summer, when nights are short, the activity can be prolonged even in daylight hours (Holley 2001; Schai-Braun et al. 2012). Studies based on distances between rest and foraging sites showed significant differences between sexes, (Angelici et al. 1999). However, little is known about the activity pattern in southern Europe where the southern limit of the species distribution is found (Trocchi and Riga 2005). Thus, we focused our research on the study of European hare locomotor activity patterns during winter in two study area in central Italy. To accomplish this study, we applied GPS collars to 24 hares for three months during the winter and early-spring season of 2008.

The study was carried out in two protected areas of Tuscany (Italy): A (43°33′ N, 11°11′ E;) and B (43°00′ N, 11°46′ E;). The climate is Mediterranean, with the minimum temperature in January (3°) and the maximum in July (21°). Annual precipitations range between 600 and 700 mm and are concentrated in spring and autumn. The average relative humidity is 73% with a minimum in July and a maximum in November.

Study area A (516 ha, 300 m a.s.l.) was characterized by woodland (30%), vineyards and olive groves (30%), winter cereals (17%), fallow fields (11%), scrub land and hedges (6%), and meadows (6%). The average field size was 1.5 (±0.2 SE) ha. Study area B (834 ha, 475 m a.s.l.) was characterized by ravines, originated from clayey ground, and winter cereals (38%), woodland (18%), scrub land (14%), meadows (9%), fava bean (6%), pasture (10%) olive groves (2%) and fallow fields (3%). The average field size was 4.4 (±0.6 SE) ha.

On 4 January 2008 we captured 12 adult hares in area A (5 males and 7 females), and on 19 January 2008 we captured 20 hares but we decided to tag only 12 adult females in area B using nets. Hares were tagged with GPS collars (Tellus mini – Televilt, weight 74 g) scheduled to acquire the position every 2 h for 98 days. Hares were immediately released in the same place where they were captured.

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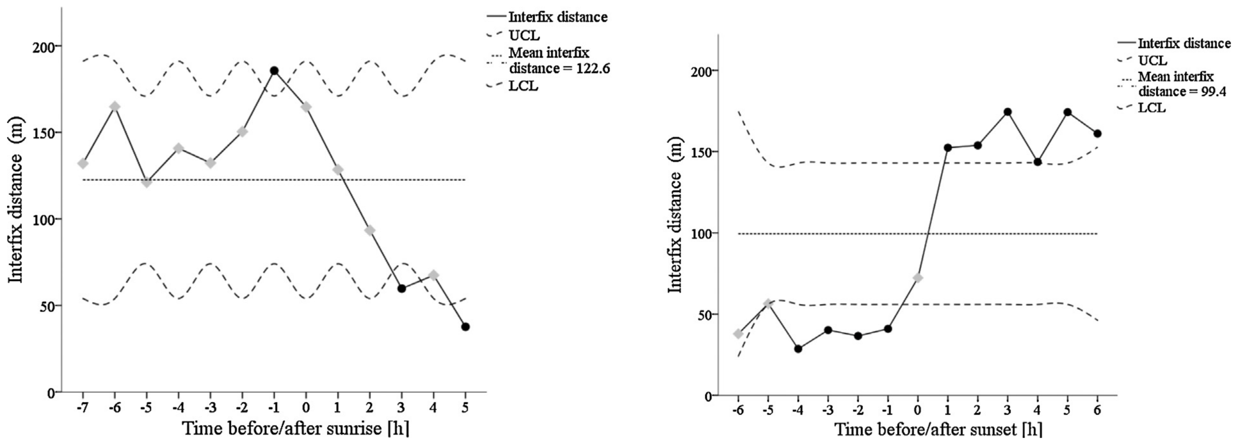

Fig. 1. Locomotor activity of hare males in area A, in relation to the time of sunset and sunrise described by control chart.

GPS location error was previously estimated by calculating the Euclidean distance, a test measurement and the true location of the collar in the field. Location accuracy was then estimated in ±15 m from the real position. Hare densities were estimated by means of spotlight counts (Langbein et al. 1999). In area A we estimated 24.6 hares/100 ha compared to area B with 27.5 hares/100 ha.

In both study areas hunting was strictly forbidden throughout the year. At the end of May hares were recaptured, collars recovered and data downloaded.

To analyze the locomotor activity patterns of hares we measured the interfix distance between two consecutive locations collected every two hours, 12 times per day. From January to March data were arbitrarily grouped in 6 blocks of 14 days. Night time was assumed as the time period from sunset to sunrise, and daytime was defined from sunrise to sunset.

In the two study areas the sunrise shifted from 7.30 a.m. in January to 5.54 a.m. in April. Sunset shifted from 4.50 p.m. in January to 6.35 p.m. in April. To investigate hares movements during the study period the distance covered by animals was analyzed using control charts (Morrison 2008). Control charts are useful to represent the consistency of a stream of data over time. The use of control-charts is justified due to the presence of a time pattern in the data. Control charts are used, particularly, to verify the presence of stationary data or trends that describe the development of the investigated phenomenon in time. Moreover, in cases in which standard deviation or deviation from the median value can be calculated, identification of outliers samples in time can be also performed by using confidence limits. This consistency is characterized by a stream of data falling within the control limits based on the upper control limit (UCL) or lower control limit (LCL), using 3 standard deviations (3 sigma) from the mean. Wald–Wolfowitz test was applied to compare firstly the activity of males versus females in area A and subsequently females in area A versus females in area B.

In order to define the minimum daily movement of hares, we measured (a) the distance between daytime distances of successive days (day to day distance, DDD) using fixes collected in the time bands from 11 a.m. to 03 p.m.; (b) the distance between daytime fixes (11 a.m.–03 p.m.) and successive night-time fixes (11 p.m.–03 a.m.) (day to night distance, DND) (Reitz and Léonard 1994; Rühe and Hohmann 2004). Variation of day-to-day and night-to-day distances were analyzed using the GLM repeated measure procedure. This technique is used to provide an analysis of variance when the same measurement is made several times on each subject or case. Factors between-subjects, as the belonging to different geographical areas, the sex and the type of measure (DDD or DDN), were also considered.

The aim of this application was to test the null hypothesis of the effects of both between-subjects factors and within-subjects factors. The significance levels of the *F* test was used to interpret the results. All statistical analyses were performed using PASW 18 (Chicago, Illinois, USA), with a minimum level of significance of $p < 0.05$. Land use and interfix distance were analyzed using ArcGis 10 (ESRI Inc., Redlands, USA).

During this study the radio beacons of 1 hare in area A and 3 hares in area B were lost. Then the analysis was performed for 11 hares in area A (4 males and 7 females) and 9 females in area B. The mean number of satellites used for the location of the fixes was 5 (±0.15 SE). That is, the number of GPS-fixes taken per animal ranged from 185 to 963 with an average of 801 (±41 SE). This resulted in a total of 18,439 fixes and thus a total of 14,349 interfixes distances available for analysis (3678 for males, 10,671 for females).

Locomotor activity of hares starts at sunset and ends in the early morning when they return to the form. Males In area A show an intense locomotor activity throughout the night (Fig. 1), while females show only two peaks of activity. The first activity peak occurs during the 3 h around sunrise and the second peak happens during the three hours after sunset, with a reduction of activity in the middle of the night (Fig. 2). In the study area B female locomotor activity is concentrated at night and it is characterized by two peaks of activity following a similar pattern observed in the study area A (Fig. 3).

In area A, the comparison of the locomotor activity between males and females showed, according to control charts, that males have a significant higher locomotor activity than females 3 h before sunrise ($p < 0.01$), 2 h after sunrise ($p < 0.05$), and 4, 5 and 6 h after sunset ($p < 0.01$, $p < 0.01$ and $p < 0.05$ respectively). Comparing the activity of females in the two study areas we observed that females in the study area B have a significant higher locomotor activity than those in the area A, in particular at 1 and 4 h after sunset ($p < 0.01$, $p < 0.01$ respectively) as well as 1 h before sunrise ($p < 0.01$). Based on the analysis of the minimum daily movement in area A, we observed a statistical difference between DDD and DND ($F = 14.67$, $p < 0.01$). More specifically, hares yielded a mean of 114 m in successive day fixes DDD and a mean of 190 m in successive day and night fixes DND (Fig. 4). However no significant difference were observed in DDD and DND between sexes ($F_{1,16} = 0.84$, $p = 0.37$) and among the considered fortnights ($F_{5,80} = 1.05$, $p = 0.39$). In area B the minimum daily movement of females in DDD and DND differs significantly (DDD: $\bar{x} = 112$ m, DND: $\bar{x} = 316$ m; $F_{1,13} = 47.14$,

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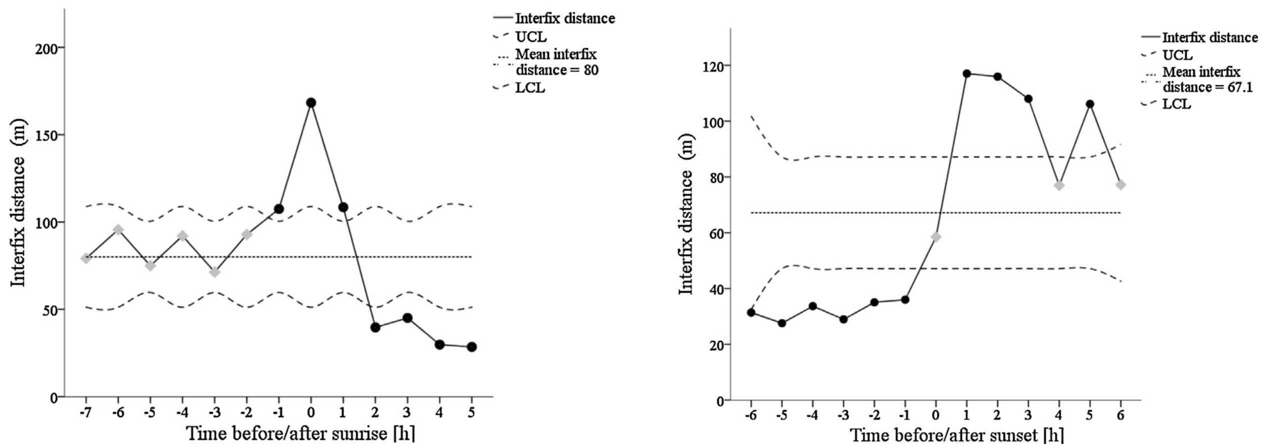

Fig. 2. Locomotor activity of hare females in area A, in relation to the time of sunset and sunrise described by control chart.

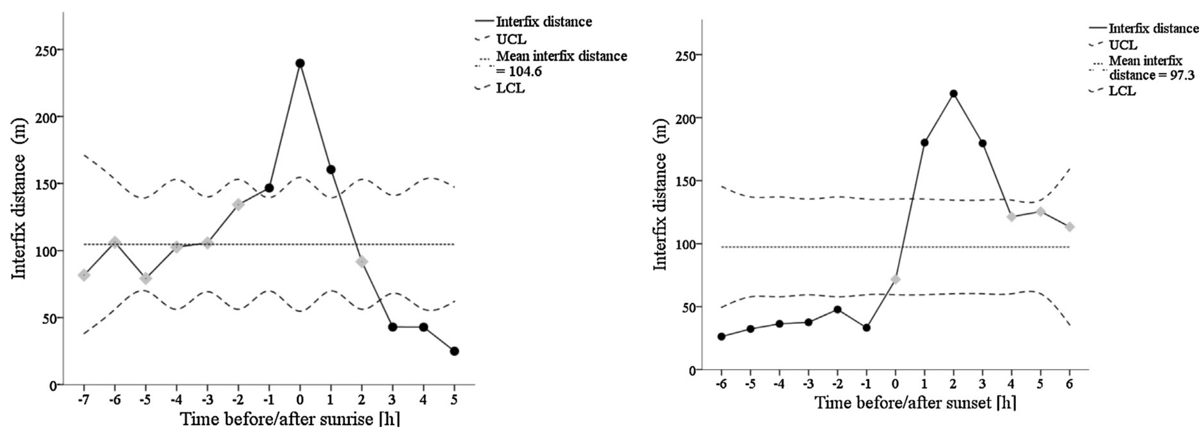

Fig. 3. Locomotor activity of hare females in area B, in relation to the time of sunset and sunrise described by control chart.

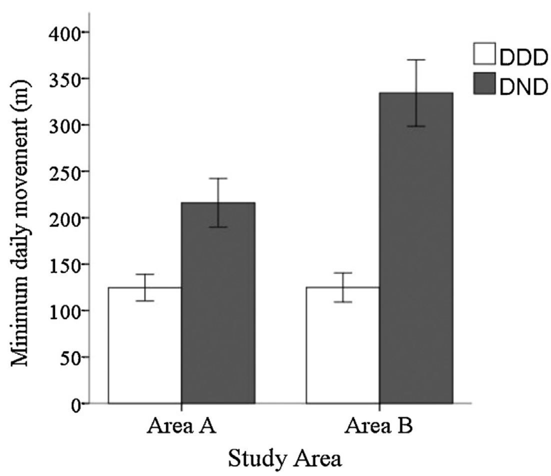

Fig. 4. Mean distance (±SE) between day fixes of successive days (DDD), and between a day fix and successive night fix (DND).

$p < 0.01$) (Fig. 4), but no significant differences were observed in DDD and DND among fortnights ($F_{5,65} = 1.21$, $p = 0.31$). Finally we observed a marginally significant difference between females in the two study area ($F_{1,25} = 3.98$, $p = 0.057$) and a significant interaction between the study area and the minimum daily movement ($F_{1,25} = 6.11$, $p < 0.05$). Indeed, DND remains higher in female of area B (Fig. 4).

Our results confirmed that the European hares are active during the night and tend to be inactive during the day as described in another species of the same genus (*Lepus townsendii*, Rogowitz, 1997). The locomotor activity of the European hare starts at sunset for both sexes. Unlike previous studies, we showed a difference between sexes in locomotor activity patterns: while males maintain an intense activity throughout the night, females greatly reduce their movements in the middle of the night. This results was observed during the peak of reproductive season and it is well known that females in estrous attract resident and satellites males (Flux 2009). This consideration leads us to suppose that males carried greater distances to find receptive females. The comparison between females of the two study areas showed difference in interfix distance in particular around sunset and sunrise. This result could be related to the environmental diversity of the two study areas. In fact, fields in area B and land parcels are much larger than those of area A and resting sites are much more distant from foraging sites. In agreement with this hypothesis and from the comparison of the minimum daily movement of DND between the two areas, our results show that foraging sites of area B are more distant than those of area A. Considering the fidelity of the resting site by day to day distance (DDD), our results suggest that European hares might change their daytime forms on the basis of an anti-predator behavior, in order to limit the amount of detectable olfactory cues, as already observed by Angelici et al. (1999). In conclusion we observed that males are more active than females during winter nights, in correspondence, and probably in relation, with the peak of reproductive season in Southern Europe (Trocchi and

Riga 2005). The observed differences of distance from foraging sites among females in the two considered study areas suggest that ecological variables must be taken into account when studying the behavior of a species on larger geographical scale.

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