NOTE BRÈVE

MOVEMENTS AND ACTIVITY PATTERNS
OF RADIOTRACKED SARDINIAN WILDCATS, *FELIS SILVESTRIS LIBYCA* FORSTER, 1780

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RÉSUMÉ. — *Déplacements et activités de chats sauvages sardes* Felix silvestris libyca *suivis par radio-télémétrie*. — Pour la première fois, les déplacements et les activités de huit chats sauvages sardes Felix silvestris libyca Forster, 1780, ont été étudiés par télémétrie dans une zone protégée du sud-ouest de la Sardaigne (Monte Arcosu, province de Cagliari : 39°09'44''N, 08°52'53''E). Quatre femelles et quatre mâles ont été équipés d'émetteurs radios. Les individus ont été suivis à différentes périodes de juillet 1994 à mars 2002. En tout 4 356 localisations ont été enregistrées. Ce jeu de données a été analysé par des procédures de randomisation, avec 10 000 permutations Monte Carlo du jeu original. Les localisations d'activité ont représenté 55,6% du nombre total de relevés. Néanmoins, nous avons observé une grande variabilité individuelle dans les rythmes d'activité et dans les distances parcourues de nuit. Un individu isolé était essentiellement diurne alors que tous les autres étaient nocturnes. La distance parcourue chaque nuit par les femelles (922 m en moyenne) était inférieure à celle des mâles (1208 m). Durant les mois d'été, les chats sauvages ont montré un déclin général de leur activité et de leurs déplacement.

The activity rhythms of felids may be affected by climatic differences, distribution of prey, ecological parameters, and anthropic disturbance (Eisenberg, 1986). The wildcat *Felis silvestris* Schreber, 1777 is not homogenously well studied across its range, and while there are several populations from, e.g. Germany (Wittmer, 2001), France (Condé & Schauenberg, 1969; Condé 1972; Aubert *et al.*, 1985; Stahl, 1986; Stahl *et al.*, 1988), Switzerland (Liberek, 1999), peninsular Italy (Ragni, 1978; Genovesi & Boitani, 1993), Portugal (Fernandes, 1993), Spain (Aymerich *et al.*, 1980), Scotland (Corbett, 1979; Scott *et al.*, 1992), which have been well studied, there are many other regions where this species has been little studied. Among these poorly studied populations, those belonging to the vulnerable subspecies *Felis silvestris libyca* Forster, 1780, present in Africa, the Near East, Corsica, and Sardinia, are of special interest. In particular, the Sardinian populations of *F. s. libyca,* probably introduced by humans in prehistoric time less than 2 500 years ago (Masseti, 1993), are of interest because of their threatened status and totally unknown ecology and behaviour.

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In this paper, we analyzed the movement patterns and the activity rhythms of eight free-ranging Sardinian wildcats monitored by radio-tracking.

MATERIALS AND METHODS

STUDY AREA

The study area was the WWF-protected reserve 'Monte Arcosu'(N 39°09'44", E 08°52'53"), extended over an area of 36 km² in south-western Sardinia (Italy). The altitude ranges between 50m and 1,100m a.s.l. The area is crossed by deep valleys and furrowed by winding watercourses of a moderate flow rate and of a seasonal nature. The vegetation is typically Mediterranean with dominance of woods of *Quercus ilex*, *Quercus suber*, and Mediterranean evergreen maquis mainly composed by *Erica arborea* and *Arbutus unedo*. The climate is characterized by a hot dry summer and a wet winter with rainy and mild spring and autumn. The average annual rainfall is 487 mm. The average temperature is 15 °C with a minimum value of 6 °C in January and a maximum value of 24 °C in July.

PROTOCOL

Eight Sardinian wildcats, four adult females and four adult males, were captured by traps made up of two different box cages (40 x 30 x 120 cm each) using live quails as bait. The cats were identified according to Toschi (1965), Ragni (1981), Ragni & Possenti (1996) and Angelici & Genovesi (2003). Radio-collars (weight 55 g, TXP 2, Televilt, Sweden) were placed after immobilizing the cats with intramuscular ketamine injection (1.5 cc/kg).

The cats were monitored using a receiver (Custom electronics) and a three-element Yagi antenna. The eight cats were radio-tracked at different periods between July 1994 and March 2002. The mean radio-tracking time was 252.5 days for males and 233.75 days for females. In total, 4 356 radio-fixes was recorded (Table I). The activity and position of every animal was recorded every 15 days during 24 hour with an activity sensor installed in the radio-collars. The total, seasonal, and daily activity was calculated as the percentage of active fixes on the total number of fixes gathered in the study period.

By calculating the mean location error (Springer, 1979), it was possible to divide the study area in 36 units of 1 km² each. An animal was considered in movement when its location in two successive fixes fell in different units. The distance travelled in one night was calculated as the minimum distance between successive centres of the unit where the animal was localised.

STATISTICAL ANALYSES

In general, all statistics given here were two-tailed and with alpha set at 5%. Probability level was computed using a complete randomisation method based on Monte Carlo permutations (Good, 2000). Monte Carlo simulations were generated by the Ecosym program, with 10,000 iterations in every case. Monte Carlo simulations (= null models) of ANOVA and of Chi square test were used instead of the typical ANOVA (either parametric or non-parametric) or the typical non-parametric Chi square test. Obviously, in ANOVA tests the dependent variable is continuous, but the independent variable is discrete. The null hypothesis in usual ANOVAs (either they are one-way or 2- and 3-way designs) is that the variation among the mean of the groups is no greater than expected by chance. We provided a randomization test for a simple one-way ANOVA. The continuous data are classified into two or more categories. EcoSim reshuffles the data among those categories and then determines how much variation is expected among the means of the different categories. In EcoSim software, the input consists of a data matrix in which each row is an observation. The very first column is a set row labels that uniquely identify each observation. In this module, one of the data columns should contain the "labels" for the different categories. These labels identify the groups that the observations are classified into. Labels may be any set of alpha-numeric characters. The response variable is a continuous numeric variable contained in one of the other columns of the data matrix. The response variable can include any real number values (including zeroes and negative numbers).

In usual Chi square tests, both the dependent and the independent variable are discrete. Such data are plotted in a two-way table. Each row in the table represents one of the categories of the independent variable and each column represents one of the categories of the dependent variable. The entries in the table are the number (or percentages) of observations recorded for each category. The null hypothesis is that the response and predictor classifications are independent, so that the proportion of observations in one row of the table is the same as in any other row of the table. We performed a randomisation test for the independence hypothesis in a two-way contingency table. We provided the observed counts in each category (including zeroes), and calculated the expected values, randomised the matrix, and calculated a chi-square deviation statistic for both the observed and simulated data. A unique feature of this module is that we can change the expected values, and randomise across rows or columns of the matrix, allowing for more sophisticated tests in which expected values are generated from an external hypothesis (such as the 3:1 ratio of dominant to recessive phenotypes in a simple Mendelian cross of heterozygotes). In EcoSim software, we optionally provided input in the form of a matrix of expected values. This matrix must have the same dimensions and labels as the original data matrix, but the entries contain the expected values under the null hypothesis. The values in the

expected matrix are non-zero real numbers. It is not necessary that these values be integers (as they must in the data matrix), but they cannot include any zeroes. For the default test of two-way independence, EcoSim automatically calculates the expected values based on the marginal totals of the matrix. When appropriate, we modified these expected values to test other null hypotheses.

Based on the arguments presented above, it is evident that the trend detection power of our Monte Carlo tests is much higher than that by using the usual descriptive tests. Apart from Monte Carlo tests, all other tests were done by a SPSS (version 11.0) PC software. Non-parametric tests were used when the dataset did not fulfil assumptions of normality and homoscedasticity.

RESULTS

The wild cats were active in $55.6 \pm 2.9\%$ of the fixes (n = 8 individuals; N = 4356 fixes). Individual variability in percent of active fixes varied between 40.2% for F3 and 65.6% for F4 (Table I). Monte Carlo simulations of the observed dataset revealed no significant difference between the frequency of active versus inactive fixes in both males and females (Monte Carlo χ^2 procedure: observed index = 19.326; mean of the simulated indices = 15.034±31.30; $P_{observed < expected} = 0.815$; $P_{observed > expected} = 0.185$).

TABLE I

Descriptive parameters of the eight radio-tagged wildcats at the study area in southern Sardinia (F = female; M = male)

	F1	F2	F3	F4	M1	M2	M3	M4
Weight (kg)	2.1	2.1	1.5	1.8	2.8	2.5	2.3	2.7
Tracking period	28/07/94 15/06/95	25/07/94 05/06/95	02/08/95 20/12/95	20/09/01 15/03/02	20/08/94 15/12/94 19/05/95 07/08/95	22/11/97 08/08/98	23/09/00 02/06/01	15/10/00 26/07/01
N° radiotracking days	323	316	141	155	198	270	253	289
N° fixes	768	552	460	474	228	606	646	622
Activity (%)	57.0	50.2	40.2	65.6	50.9	62.1	55.0	63.1

The circadian activity rhythms of the cats revealed an higher activity level during the early hours of the night, and a reduced activity in the warmer hours of the day (Figure 1). Monte Carlo simulations of the daily activity patterns revealed that the activity level was significantly higher from 19-20 h to 23-24 h, and significantly lower from 09-10 h to 13-14 h, than any other daily intervals (Monte Carlo ANOVA procedure: Pseudo-F analysis, observed index = 95.853, mean of the simulated indices = 50.757 ± 2.581; P < 0.002). However, the same Monte Carlo analysis revealed no significant intersexual differences in the observed patterns (Pseudo-F analysis, observed index = 56.322, mean of the simulated indices = 51.437 ± 3.178; P = 0.316). A single male showed prevalently diurnal habits (Figure 2), but this fact could not be interpreted statistically due to the too low sample sizes (n = 8 individuals), and is therefore considered preliminarily as a unusual behaviour.
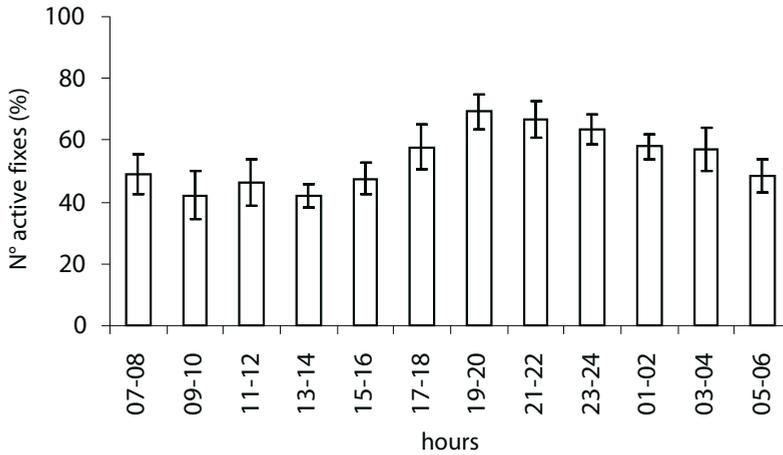
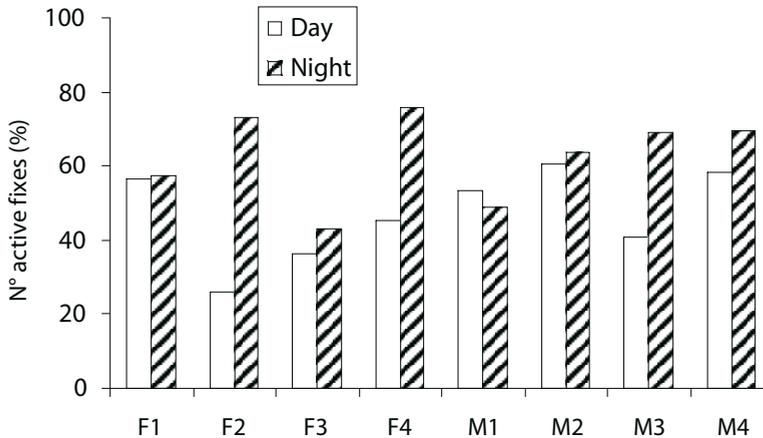Figure 1. — Circadian activity rhythms of the wildcats (mean ±S.E.).

Figure 2. — Day/night activity rhythms of the male (M) and female (F) wildcats.

Wildcats were active in about 75% of the total fixes. Monte Carlo simulations revealed that moving was significantly more frequently associated with active fixes than any other type of activity (Monte Carlo χ^2 procedure: observed index = 1.608; mean of the simulated indices = 14.851 ± 30.79; P < 0.00001). The linear distance travelled by night varied in females from a minimum 840 m (F1) to a maximum 1,200 m (F4), and in males from a minimum 768 m (M2) to a maximum 1,536m (M4). On average, the distance travelled per night by females was less than that of males, and also the minimum distance travelled by the females in a night was on average less than that travelled by the males (females: 992.0 ± 90.5 m; males: 1208.0 ± 175.5). These intersexual differences attained statistical significance after 10,000 Monte Carlo simulations of the actual dataset (Monte Carlo ANOVA procedure: Pseudo-F analysis, observed index = 68.134, mean of the simulated indices = 44.646 ± 30.151; P < 0.01).

Percent of active fixes dropped in summer compared to the other three seasons, and the difference between summer and the other seasons was statistically significant after 10,000 Monte Carlo randomisations of the real dataset (Monte Carlo χ^2 procedure: observed index = 2.159; mean of the simulated indices = 6.895 ± 14.24; P < 0.044; see Figure 3A). Concurrently, also the mean distance travelled per night dropped during summer in a statistically significant

way (Monte Carlo ANOVA procedure: Pseudo-F analysis, observed index = 39.212, mean of the simulated indices = 21.444 ± 17.35; P < 0.032; Figure 3B).
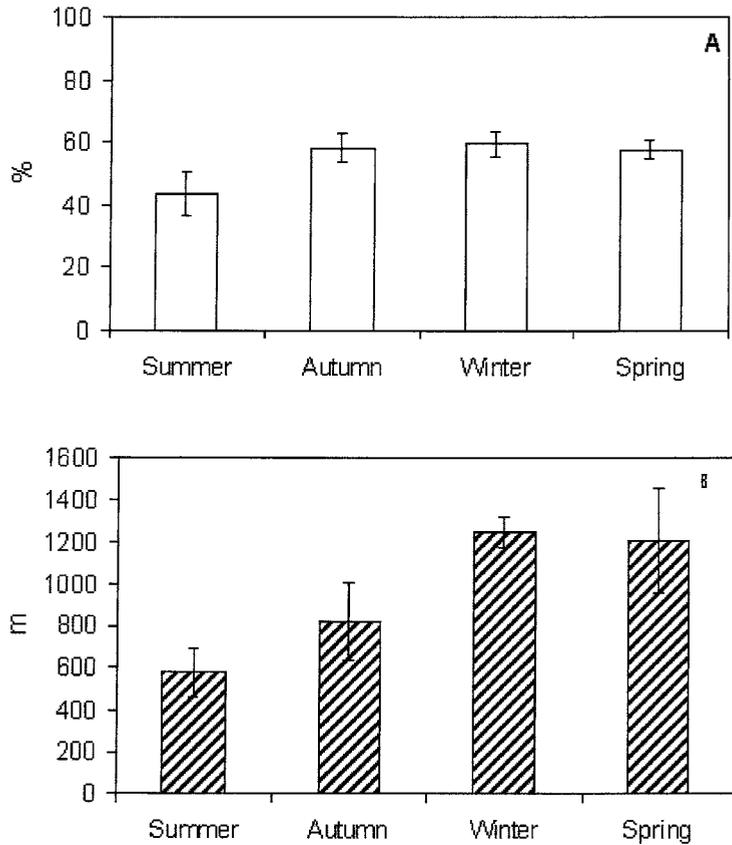

Figure 3. — Seasonal average activity (**A**), and seasonal average distance covered in night movements.

DISCUSSION

Activity rhythms in predators (including mammals as well) are determined especially by prey rhythms, but influenced also by other ecological variables, including interactions with other sympatric species (e.g., Kleiman & Eisenberg, 1973, Seidensticker *et al.*, 1973, Corbett, 1979, Stahl *et al.*, 1988, Eisenberg, 1986). Unfortunately, the feeding habits of the Sardinian wildcat are still unknown from a quantitative point of view, but presumably it feeds mainly on the small mammals (rodents, insectivores), lagomorphs, and birds of the Mediterranean maquis (Puddu & Viarengo, 1993). Thus, it is likely that the night activity of the wildcats follows directly the needs of capturing nocturnal prey, as indeed observed in other congeneric species from elsewhere (e.g., Condé, 1972; Aymerich *et al.*, 1980; Aymerich, 1982), as well in many other felid species (e.g., Schaller 1972; Corbett, 1979; Beltrán & Delibes, 1994). The prevalently diurnal activity of a single individual in our sample is not very surprising, given that in the closely related *Felis silvestris* diurnal activity was observed regularly during the winter months, this fact being probably a response to food shortage (Corbett, 1979). In this regard, it seems plausible that also the reduced activity exhibited during summer simply reflects the reduced number of night hours at that season, rather than a true shift in activity intensity by wildcats.

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