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Circadian activity patterns and nocturnal resting sites of Eurasian badgers (*Meles meles* L.) in a rural area of western Switzerland

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Circadian activity patterns and nocturnal resting sites of Eurasian badgers (*Meles meles* L.) in a rural area of western Switzerland. - A preliminary investigation of badger (*Meles meles* L.) activity patterns and nocturnal resting sites was conducted in a rural area of western Switzerland. Data were collected by radio-tracking one male and seven females for short periods, between spring and autumn, over the years 1999-2002. Badgers were active (essentially on surface) in 80.9% of nocturnal radio-locations, whereas diurnal activity (mainly underground) was recorded in 41.1% of fixes. Badgers started overground activity on average (± SD) 1.00 ± 0.75 h after sunset and ceased 1.50 ± 1.75 h before sunrise. The duration of activity periods varied between 2.50 and 9.75 h and was not correlated with night length. Nocturnal resting occurred in 63% of nights, with a mean resting bout duration of 0.50 ± 0.25 h. Badgers generally rested in the feeding patch they had been using, only joining a burrow in 3.2% of cases. Our results suggest that, in rural areas, the choice of nocturnal resting sites is largely influenced by foraging activity.

Keywords: Eurasian badger - *Meles meles* - activity rhythm - nocturnal resting sites - time budget - sett - agricultural area - western Switzerland.

INTRODUCTION

Eurasian badgers (*Meles meles* L.) are semi-fossorial mustelids which show extreme plasticity in their diet and socio-spatial organization (recent review *in* Do Linh San, 2006). Until the 1990s, most studies on the behavioural ecology of badgers had been conducted in Great Britain, where these medium-sized carnivores often live at high density and form territorial groups (e.g. Rogers *et al.*, 1997; Macdonald & Newman, 2002; Palphramand *et al.*, 2007). However, considering the large diversity of habitats found in Europe and the potential of detecting interesting intraspecific variation in some major behavioural parameters, several research projects were then carried out throughout the continent, often dealing with the spatial ecology of badgers (e.g. Broseth *et al.*, 1997; Hofmann *et al.*, 2000; Revilla & Palomares, 2002; Kowalczyk *et al.*, 2003b; Rosalino *et al.*, 2004; Do Linh San *et al.*, 2007a).

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Badger activity rhythms have also been investigated, with studies conducted in habitats as diverse as suburban environments (Harris, 1982; Cresswell & Harris, 1988), forest ecosystems (Kowalczyk *et al.*, 2003a), mountainous regions (Do Linh San *et al.*, 2007b) and semi-arid areas of southern Europe (Rodríguez *et al.*, 1996; Rosalino *et al.*, 2005). However, considering that agricultural landscapes constitute the main badger habitat in western and central Europe, relatively little attention has been paid yet to the activity patterns of rural badgers (Zabala *et al.*, 2002; Gosczynsky *et al.*, 2005) and virtually nothing is known of their temporal behaviour in landscapes dominated by cereal farming. Furthermore, although the literature generally contains information on activity and time budgets, few authors studied the repartition between overground and underground activity/rest (Do Linh San *et al.*, 2007b) or the choice of nocturnal resting sites (Harris, 1982).

The purpose of this work was therefore to describe the circadian activity patterns of badgers in an agricultural region typical of western Europe (Broye region, Switzerland). We radio-tracked badgers between spring and autumn to determine i) the onset, duration and offset of their activity period(s), ii) their activity types and iii) the occurrence, number, duration and temporal distribution of resting bouts during their activity period(s). We also determined in which habitat types nocturnal rest took place, and if this occurred over- or underground.

STUDY AREA

This research was carried out in the Broye, a rural region located in western Switzerland (46°52' N, 6°56' E). The landscape of our 74-km^2 study area is generally flat with small hills ranging in elevation from 430 to 725 m. Open fields devoted to farming activity (mainly cereals, tobacco, beets and potatoes) cover 73% of the total area. Only 15% of the region is represented by forest patches, copses, hedges and a long stretch of riverine forest along the south bank of Lake Neuchâtel. Infrastructures and residential areas occupy 9.9% of the study area, whereas the remaining 1.3% is covered by marshland. The climate is characterized by cold, dry winters with average winter temperature and precipitation of 1.6° C and 141.0 mm, respectively. Summers are hot with average temperature and precipitation of 20.4° C and 272 mm, respectively. During the study period, annual average temperature was 9.9° C and total annual precipitation averaged 944 mm (data collected at the Meteorological Station of Payerne).

MATERIAL AND METHODS

Trapping and radio-tracking

Between July 1999 and July 2002, eight badgers (Table 1; F20 was captured twice) were neck-snared at six breeding setts (burrows) in the study area. Badgers were anaesthetized with an injection of ketamin hydrochloride, weighed, sexed and aged following Stubbe (1965). Each animal was fitted with an activity-monitoring transmitter (Wildlife Materials, Murphysboro, IL, USA and Biotrack, Wareham, Dorset, UK; frequency: 148-149 MHz) weighing 90-120 g and released at the capture site after a period of recovery of one to three hours.

TABLE 1. Sex, age at capture, group affiliation, tracking period, and number of nocturnal continuous radio-tracking sessions for the badgers under study

Individual	Sex	Age	Group affiliation	Tracking period (dd.mm.yy)	No. of tracking days	No. of nocturnal tracking sessions
F36	Female	Cub[1]	Forel Lac	30.07.99 – 01.08.99	3	1
F37	Female	Adult	Forel Lac	29.07.99 – 26.08.99	29	3
F19	Female	Adult	Chevroux	09.04.00 – 03.06.01	167[2]	0[3]
F20 (a)[4]	Female	Adult	Morens, Payerne	30.04.00 – 19.08.00	112	4[5]
F20 (b)[6]	Female	Adult	Payerne	19.05.01 – 30.06.01	43	2
F22	Female	Adult	Morens	28.04.01 – 23.06.01	57	3
F45	Female	Cub[1]	Rueyres	12.08.02 – 03.11.02	84	3
F46	Female	Adult	Cugy	29.03.02 – 06.08.02	131	10
M14	Male	Subadult	Cugy	03.06.02 – 21.07.02	49	1
Total		—	—	—	675	27

[1] Cubs were 6 to 10-month old when radio-tracked, and therefore almost adult-sized. [2] No tracking data were collected over the period October 2000 to March 2001. [3] F19 could not be tracked with enough accuracy at night, as the collar signal was too weak (probable material defect). [4] F20 moved from Morens's to Payerne's social unit during the tracking period. [5] One additional emergence time was collected for this individual. [6] F20 was retrapped in 2001 and equipped with a new radio-collar.

RADIO-TRACKING AND DETERMINATION OF ACTIVITY PATTERNS

Activity of radio-tagged badgers was recorded by means of a portable telemetry receiver (Yaesu, Model FT-290RII distributed by A. Wagener, Cologne, D) and a 3-element folding antenna. Collared individuals could only be monitored for short time periods (from three days to five months and a half), from spring to autumn, because they were killed on the road (N = 2), their collar slipped off (N = 2) or their transmitter failed prematurely (N = 4).

In this paper, the terms "day"/"diurnal" and "night"/"nocturnal" refer to the time intervals between sunrise and sunset, and sunset and sunrise, respectively. Activity rhythms of badgers under study were evaluated with i) 568 punctual activity fixes recorded between 08:00 and 20:00, and ii) 987 activity fixes collected during 27 nocturnal continuous radio-tracking sessions (Table 1). Generally one, but sometimes up to three diurnal activity fixes (morning, midday, afternoon) were recorded on the same day for a specific animal. Nocturnal radio-tracking sessions started about one hour before sunset, and ended approximately one hour after sunrise or when badger overground activity ceased. Variations in radio-signal pulse rate were used to determine whether badgers were moving (active) or not (inactive). The marked variations in signal intensity and a combination of the triangulation and homing techniques (Priede & Swift, 1992) were employed to establish if badgers were located over- or underground. As during nocturnal tracking sessions activity fixes were taken every 15 min (while monitoring the signal for between 2 and 5 min), badgers were therefore considered as either active or inactive for 15-min periods. We distinguished four categories of behaviour while radio-tracking badgers: i) overground activity (animal active on surface), ii) underground activity (animal active in a sett), iii) overground resting (animal inactive on surface), iv) underground resting (animal inactive in a sett).

The activity period (AP) was defined as the span of time between the first emergence and the final return to a sett. Here again, emergence and return times could be determined owing to the drastic variations (increase and decrease, respectively) in radio-signal intensity, the change in pulse rate (faster and slower, respectively) and the use of the triangulation and homing techniques. As some badgers used overground resting sites to spend the day, start and end of their APs were defined as the time corresponding to the last (evening) or the first (morning) location in the resting place, respectively. To limit biases due to the tracking of badgers in these two different conditions, and because of the sampling regime adopted, average values were rounded off to the nearest 15 min. Due to the small sample size, activity data were pooled over all individuals. For this reason and because of the strong bias in sex ratio (one male for seven females; Table 1), the results presented in this paper must be considered with some caution, and only constitute a preliminary description of the circadian activity patterns of badgers living in the Broye region.

Data analysis

Figures are reported as the mean ± SD. For the purpose of seasonal comparisons, activity data were attributed to one of the three following periods: spring (April-May), summer (June-July) and autumn (August-October). Hourly variations in the proportions of the different types of activity were investigated with a Chi-square test of homogeneity. Kruskall-Wallis and Mann-Whitney U tests were used to compare seasonal variations in activity parameters. A possible association between AP duration and night length was investigated with a Spearman's rank correlation.

RESULTS AND DISCUSSION

Like most European wild carnivores (Macdonald, 1995), the badger is essentially crepuscular and nocturnal. Observations made in the Broye region do not depart from this pattern. Indeed, over the study period, badger activity periods (APs; N = 27) started on average 1.00 ± 0.75 h after sunset and ended 1.50 ± 1.75 h before sunrise. As a whole, 93% of APs started after sunset and 89% of them ceased before sunrise. However, as reported in other studies (Zabala *et al.*, 2002; Kowalczyk *et al.*, 2003a; Rosalino *et al.*, 2005; Do Linh San *et al.*, 2007b), we recorded large variations in the start and cessation of APs: the onset of APs occurred from 0.50 h before to 4.00 h after sunset, whereas APs ceased from 5.50 h before to 1.25 h after sunrise. Consequently, the duration of APs was also very variable, ranging from 2.50 to 9.75 h, with an average of 6.75 ± 1.75 h. APs were significantly shorter in spring (5.25 ± 1.75 h; N = 11) than in summer (7.25 ± 1.00 h; N = 10; Mann-Whitney U test, $p < 0.01$) and autumn (8.25 ± 1.00 h; N = 6; $p = 0.001$). However, as sample size is very small and biased toward females, the latter results would require to be confirmed by a more exhaustive study involving several individuals of both sexes.

Badger activity rhythms have been shown or hypothesized to be affected by many factors, among them night length, vegetation cover, climatic conditions and food availability (Neal & Cheeseman, 1996). Although no significant correlation was found between AP duration and night length in our small sample (Spearman's rank correlation, $p > 0.05$), food availability, in conjunction with other factors, probably affected

badger activity rhythms. Indeed, in summer, badgers showed a tendency to start and end their APs earlier (in average 0.50 h) than during other seasons. In addition, emergences and returns by daylight were almost exclusively registered during the dry summertime, when night length is shortest, food availability low (Fischer *et al.*, 2005) and vegetation cover denser (Do Linh San, 2004).

Basic data on badger activity budget have been collected in different habitats, and the regional variations observed are probably related to the above-mentioned factors, notably food availability and climatic conditions (Kowalczyk *et al.*, 2003a). In the food-rich suburbs of Bristol (UK), nocturnal activity ranged from 35 to 65% between April and October (Harris, 1982). In rural and forested areas of Poland (cold regions), as well as in Portugal (low food availability, arid climate), nocturnal activity recorded from spring to autumn varied from 35 to nearly 100% (Kowalczyk *et al.*, 2003a; Goszczynsky *et al.*, 2005; Rosalino *et al.*, 2005). In the Swiss Jura Mountains (cold region), diurnal activity averaged 3% and nocturnal activity 57%; these annual figures, however, are largely influenced by the lower activity levels recorded during winter (Do Linh San *et al.*, 2007b). In the Broye region, the activity budget was similar during the night (80.9%; N = 1000 fixes) but much higher during the day (41.1%; N = 555). The lowest level of activity (8.7%) was observed between 13:00 and 13:59, whereas activity peaked (93.9%) between 21:00 and 21:59 (Fig. 1). During the day, badgers rested in 46.5% of the cases in a sett, whereas 12.4% of the locations corresponded to animals resting on surface. Overground daybeds were generally located in rape, wheat and maize fields (Do Linh San, 2004). These results contrast with data collected in a nearby semi-rural area (Saint-Blaise–Cressier–Thielle), where no badger was found resting above ground during the day (Weber & Ferrari, 2005). In the latter study site, the proportion of agricultural surfaces (40%) is almost twice smaller than in the Broye region (73%), what might partly explain the differences observed, if badgers specifically require the protection of crops to rest overground during the day. Although diurnal activity was unexpectedly high, it mostly took place in a sett (29.7% of diurnal fixes) rather than overground (11.4%). In addition, diurnal activity on surface was associated to movements of badgers in their overground daybeds, and was not the result of foraging activity (with the above-mentioned exception of early mornings and late afternoons). At night, badgers were mainly active on surface (62.9% of nocturnal locations), while underground activity was only recorded in 18% of fixes. Rest indifferently took place in a burrow (11.4%) or above ground (7.7%). However, when considering the behaviour of badgers solely during APs (N = 775), rest occurred on surface (7.8% of fixes) rather than underground (0.1%). Underground activity (2.4%) was rare too, as compared with the 89.7% of the time devoted to overground activity. The observed hourly proportions of the different activity types varied in a highly significant way (Chi-square test of homogeneity, $\chi^2 = 924.0$, df = 69, $p < 0.001$; Fig. 1).

Whereas badgers are active during the whole AP in many parts of Europe (Kruuk, 1989; Kowalczyk *et al.*, 2003a; Goszczcynski *et al.*, 2005; Rosalino *et al.*, 2005), other studies, like the present one, highlighted that badger nocturnal activity may be interspersed with resting periods (e.g. Zabala *et al.*, 2002; Do Linh San *et al.*, 2007b). In our study area, rest was recorded in 63% of APs. The number of resting

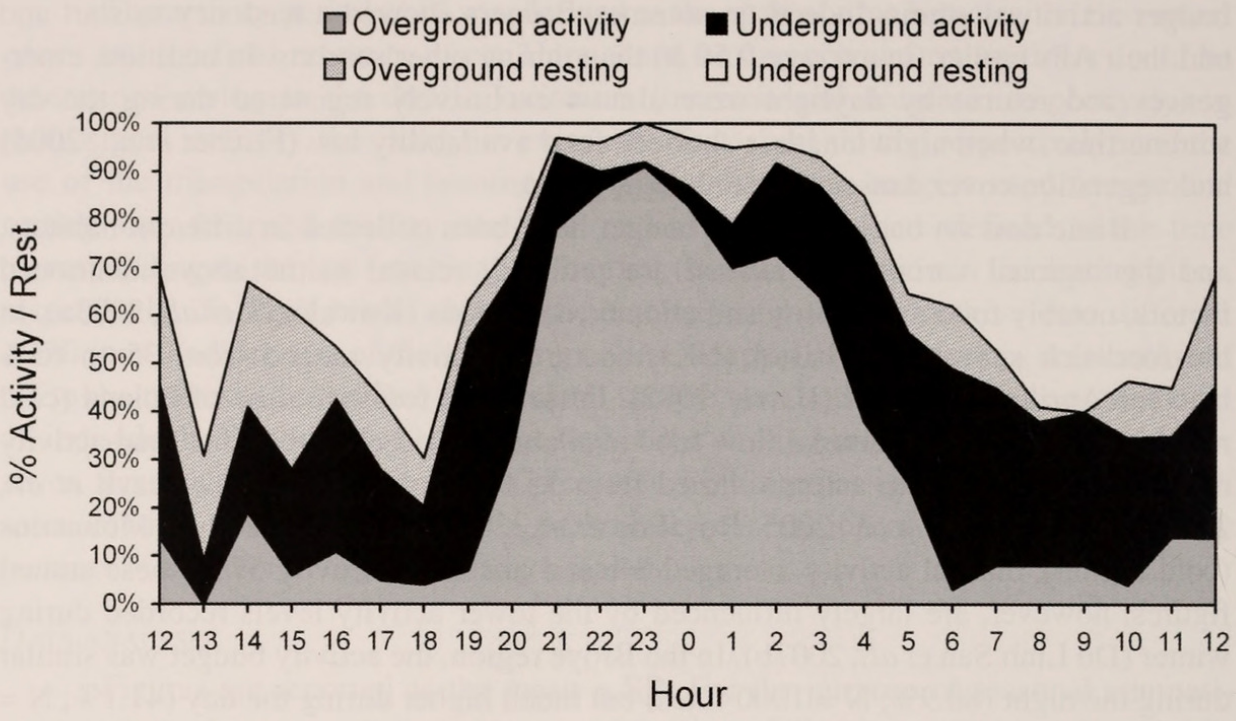

FIG. 1

Circadian activity rhythm of badgers from the Broye region expressed as proportions (%) of the four major activity types according to one-hour classes and for which on average 65 ± 37 fixes (range: 22-126) were recorded. The overall 1555 activity fixes were collected between 29 March and 3 November over the years 1999 to 2002.

bouts per AP (1.15 ± 1.13; range: 0-4; N = 27), their duration (0.50 ± 0.25 h; range: 0.25-2.00 h; N = 31) and the total time allocated to nocturnal resting (0.50 ± 0.75 h per AP; range: 0-2.75 h; N = 27) was very stable between seasons (Kruskall-Wallis test, $p > 0.1$). Both the occurrence of resting bouts and the number of 15-min periods of inactivity peaked between 01:00 and 01:59 (Fig. 2).

A single study provided data on the choice of nocturnal resting sites. In suburban Bristol, Harris (1982) found that badgers mainly rested underground (77.3%) during the night, either returning to the main sett, joining an outlying sett or taking shelter under sheds and summerhouses. Resting places on surface, under bushes or hedges, were used less frequently (22.7%). The results obtained in the Broye region diverge from this pattern. Indeed, nocturnal rest mainly took place above ground in cultivated fields (77.4% of the recorded nocturnal resting bouts; N = 31) such as rape, wheat and maize plantations. Forests/forest edges (12.9%), hedges and bushes (3.2%) and pastures (3.2%) were less frequently used during periods of rest. These observations are in agreement with habitat selection data of foraging badgers in the study area. The same radio-tracked individuals indeed positively selected rape, wheat and maize plantations during their feeding periods (Do Linh San, 2004). Therefore, it seems that the choice of nocturnal resting sites is largely influenced by foraging activity. Indeed, nocturnal rest intervened in 77.4% of the cases in a patch that had been previously and/or was subsequently actively exploited for food during at least 0.25 h (maximum: 2.25 h). In the remaining 22.6% of situations, animals moved to a particular location to rest, among them only once in an outlying sett (3.2%). Further studies

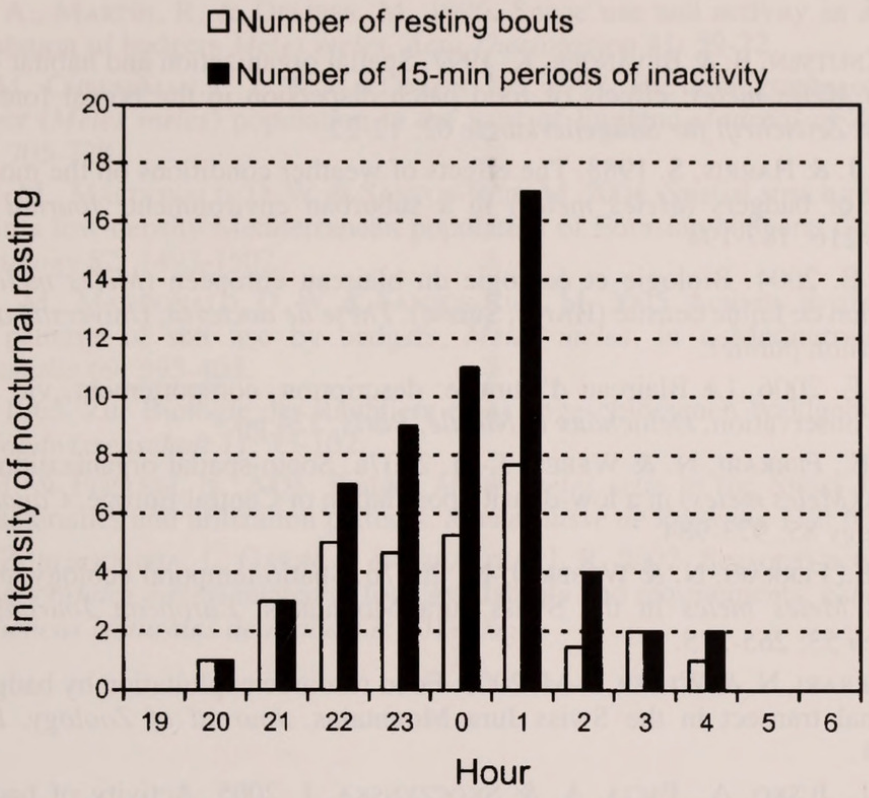

FIG. 2

Distribution of the 31 resting bouts and 56 15-min periods of inactivity recorded during badger activity periods. Tracking sessions (N = 27) were conducted between April and October over the years 1999 to 2002.

are needed to establish if the choice of nocturnal resting sites is primarily determined by badger foraging activities, and to establish if departures from such a postulated general pattern is possibly influenced by human presence and disturbances, or other (perceived) threats. If so, this could explain why the suburban badgers studied by Harris (1982) preponderantly use setts to rest during the night. In addition, this behaviour might be favoured in badger populations possessing small home ranges (as is the case in the suburbs of Bristol), where returning or moving to a sett to rest at night probably requires only little time and energy. Because adult females represent the vast majority of fixes (Table 1) collected in the Broye region, it is also possible that this unusual resting behaviour is influenced by the reproductive status of this sex, and not representative of the local badgers as a whole.

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