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Seasonal and circadian changes in activity rates of adult farm blue foxes

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The present paper reports systematic activity rates obtained from year-round video recordings of farmbred blue foxes (*Alopex lagopus*) housed singly in conventional wire-mesh cages (107 cm wide x 110 long x 70 cm high). Subjects were 9 males and 13 females. Mean whole-year activity rates were slightly higher in males (394 ± 116 min/24 h; mean ± SD) than females (349 ± 111 min/24 h). Significant ($P<0.001$) seasonal variations were found in the activity rate of both sexes. Females were most active in May (539 ± 157 min/24 h) and males in June (471 ± 128 min/24 h). Lowest activity rates were in September. Activity rates of males, in particular, tended to increase at the approach of the breeding season in March. Seasonal activity patterns of farmed foxes resembled that of foxes living in the wild. Circadian activity was concentrated on farm work hours (0800–1600) in winter, but not in summer. Typically farmed blue foxes were most active between sunrise and sunset. Diurnal pattern of farmed foxes is markedly different to wild foxes which typically exhibit a more nocturnal pattern of activity.

Key words: behaviour, daily active time, farm foxes, fur farming, yearly variations

Introduction

The farm-life history of the blue fox, a colour mutation of the arctic fox (*Alopex lagopus*), is over 70 years old. However, there still exists a lack of systematic knowledge on many behavioural traits of this species in captivity. For instance, rate and pattern of their activity requires more clarification. Comparisons between captive and wild conditions are particularly scarce. The need for more comprehensive data has emerged when attempting to develop housing environment for farmed foxes towards a more functional and natural direction (Braastad 1992, Bakken et al. 1994, Harri et al. 1995, Jeppesen 1996).

The classic study on captive foxes' activity and behaviour was conducted with two arctic foxes housed in a ground enclosure throughout the year (Tembrock 1958). The foxes in that

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study exhibited seasonal variations in activity rate with highest levels occuring at the onset of the breeding season and lowest ones during autumn. Much later, Korhonen and Alasuutari (1994, 1995) documented occasional observations on the behavioural activity of group-housed arctic blue foxes in ground enclosures with parallel results. As concerns the actual fur farm conditions, Korhonen (1988) conducted visual observations on the seasonal activity rates of five male blue foxes kept in conventional wire-mesh cages under a shed. Activity rates of these foxes also showed year-round variations, being most pronounced in summer. Furthermore, video recordings on the breeding activity of farmbred blue foxes have demonstrated that activity rates increase from January to March (Korhonen and Niemelä 1995). Thus, there exists evidence that farmed blue foxes obviously exhibit annual variations in activity rates. Recently, Mononen et al. (1996) and Rekilä et al. (1996) presented some additional activity data derived from short-term video recordings made during one month. Their results suggest that the activity of farm blue foxes follows a clear circadian rhythm, with foxes being most active during work time (0800–1600). Korhonen (1988) previously reported observational data which also indicated that circadian activity of farm blue foxes often concentrates on daylight hours and work times. The results of Tembrock (1958) also revealed a distinct relationship between activity and circadian light rhythm. In that study arctic foxes were least active between 1000 and 1600. In conclusion, there are several short-term studies which have reported activity patterns of foxes in captivity, but there is still a lack of systematic information from whole-year recordings.

The objective of the present behavioural study was to provide more comprehensive data on activity patterns of blue foxes under typical cage conditions. Specific aims were to quantify (1) amount of activity, (2) extent of seasonal and circadian variation in activity rate, and (3) effect of conventional farmwork and light hours on activity rate. In addition, comparisons between sexes were made.

Material and methods

Subjects and general managements

Experiments were carried out at the Fur Farming Research Station, Kannus, western Finland (63.54° N, 23.54°E), from January to December 1993. Outdoor on-farm conditions are shown in Figure 1. Subjects were originally 9 adult male and female blue foxes born May 1992, randomly selected from the research farm breeding group which was comprised 60 females and 20 males. However, due to disturbances in female activity recordings caused by breeding, four additional non-mated females (born May 1992) were included from April onwards. Breeding occurred during March and April. Nine of the total 13 females became pregnant and, therefore, their cages were fitted with wooden whelping nestboxes (40 cm wide x 70 cm long x 40 cm high) from May to July. Males were not provided with nestboxes throughout the study. Test animals were housed singly in wire mesh cages, measuring 107 cm wide x 110 cm long x 70 cm high each. Each cage contained a wooden platform (made of 22 x 125 mm board) measuring 107 cm in length x 30 cm in width. The bottom of the platform resembled a V shape (type name: Wood V, cited by Korhonen et al. 1996). The distance of the platform from the cage roof was 23 cm. Platforms were placed in cages crosswise. Platforms were cleaned of faeces and urine weekly. All experimental animals remained in good health throughout the study period.

Fresh-mixed fox feed manufactured by the local feed kitchen (Kannus Minkinrehu Ltd.) was supplied daily at 1300 from a feed machine. Feed primarily contained slaughter-house offal, fish and cereals. Fox feed allowances (range 250 to 450 g/d) were adjusted according to the seasonal recommendations of the Finnish Fur Breeders' Association's feeding standards (Berg 1986). Feeding was omitted on Sundays. Water was freely available from an automatic dispenser when ambient temperature was above 0°C. Wa-

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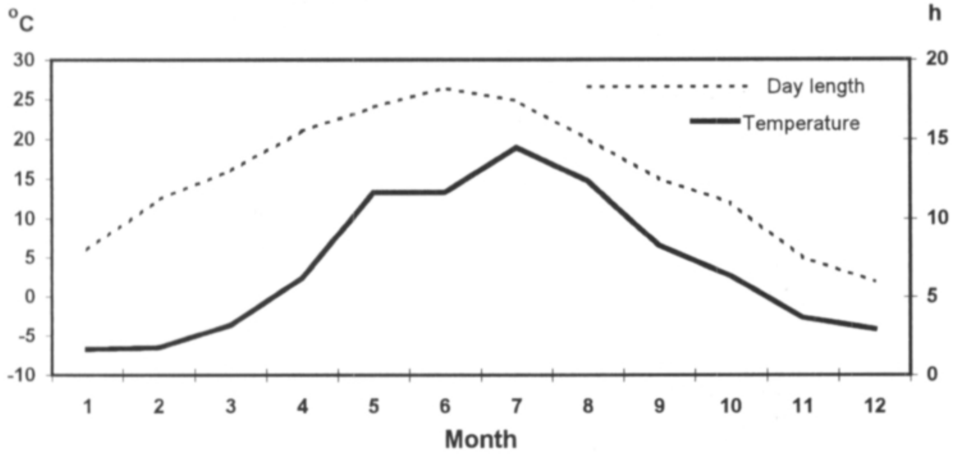

Fig. 1. Mean temperature and day length at the experimental farm.

ter was given once daily from the feed machine's water tank at temperatures below 0°C.

Activity recordings

Activity was measured using video camera equipment (CCD video camera 720, Bische UB-480 time-lapse tape recorder, Koyo monitor, Bische 12–300 infrared light: 500 W). Each animal was recorded continuously for a single 24-h period for each month between January and December. The only exception was 9 pregnant females whose video recordings were omitted during whelping and lactation (May to July). However, four additional non-mated females were introduced into the study in April and recordings of these continued until December. Activity recordings were performed during the working week, from Monday to Friday. Males and females were typically placed in neighbouring cages. The only exception was the four additional females which were kept in adjacent cages. Due to only one video camera being available in the present study, it was possible to record two cages during the same day. Thus, 12 working days were needed to record all experimental animals for one 24-h measurement.

Video tapes were analyzed by means of a continuous recording method (Martin and Bateson 1986) using a video tape recorder (JVC video casette recorder HR-D560E) and a TV monitor (Philips model). One crucial problem in the analyses was to determine when an active bout started and ended. Mainly this problem resulted from occasional bouts (<1 min) of standing or sitting behaviour between actual activity episodes. Therefore, activity in this study was determined to cover all activities, excluding restful lying, i.e. lying awake (1–10 min) or sleeping (>10 min): (a) curled on belly/side, with snout stuck in tail, (b) flat on side, legs more or less stretched out, (c) flat on belly, head and front legs stretched along the floor (Kronholm 1994, Korhonen and Niemelä 1996). Initial examination of the tapes revealed that the total activity consisted of two main activity patterns: (1) activity on the cage floor, and (2) jumping onto and off of the platform. Both patterns were initially analyzed separately. Since the amount of jumping activity proved to be very slight (from 1 min to 29 min/24 h; mean=10 min/24 h, median=9 min/24 h), it was finally summed with cage floor activity for statistical analysis. Consequently, the term 'daily active time' includes both cage floor and platform activity.

Statistical methods

As a result of performing repeated monthly measurements for individual foxes, statistical analysis was conducted using a mixed-model approach. A detailed description of statistical methods used is provided by Korhonen et al. (1995,1996). Briefly, data obtained from video recordings was analysed using the following model:

$$Y_{ijk} = \mu + S_j + P_k + SP_{jk} + e_{ijk}$$

where:

Y_{ijk}=activity of fox i of sex j during month k
μ=constant
S_j=effect of sex
P_k=effect of month
SP_{jk}=interaction of sex and month
e_{ijk}=residual, assumed to be independent and multivariate normal with the means 0 and arbitrary covariance matrices Σ.

Results

Seasonal changes in activity

Whole-year activity rate of males and females averaged 394 ± 116 min/24 h (mean ± SD) (median 393 min/24 h) and 349 ± 111 min/24 h (median 329 min/24 h), respectively. Monthly activity rates are presented in Figure 2. Statistically significant seasonal variation ($P<0.001$) was found in the amount of activity. Mean and median rates of monthly activities were typically close, indicating a normal distribution of data. Differences in seasonal activity rates between sexes were generally slight, however, some differences were found. Peak activity of females was in May (mean 539 ± 157 min/24 h; median 564 min/24 h) and that of males in June (mean 471 ± 128 min/24 h; median 469 min/24 h). Thereafter, a distinct decrease in activity rate was observed. Lowest values were found in September (males mean 290 ± 61 min/24 h; median 281 min/24 h, females mean 246 ± 63 min/24 h; median 255 min/24 h). A tendency for increased activity at the onset of the breeding season (March) was found, particularly in males.

Worktime activity

The duration of worktime activity in minutes, as well as its proportion of 24 h, varied ($P<0.01$) year-round (Fig. 2). In summer, the proportion of activity during worktime decreased, while the proportion of activity occuring outside worktime increased. During winter the situation was reversed. In this case, active time was concentrated around working hours. This phenomenon was more pronounced in females (Fig. 2). The proportion of active time during working hours was highest in October both in females (76% of total activity rate, or 229 ± 76 min/24 h) and males (73.6% total activity rate, or 240 ± 72 min/24 h).

Circadian activity

The present foxes displayed a clear circadian activity rhythm (Fig. 3). During each month, the highest activity typically occurred after the start of farm work. An intermediate phase of activity often occurred in the evening. In December, the activity was distinctly concentrated between sunrise and sunset in both sexes. A clear resting phase occurred in the early hours during December and September. In June, animals were active throughout the 24-h period, but during that time the dark period was also very short. During the breeding season in March, activity was widely distributed over the whole 24-h period. This pattern was more pronounced in males.

Discussion

Nocturnal animals often have two activity peaks which occur in the evening and early morning

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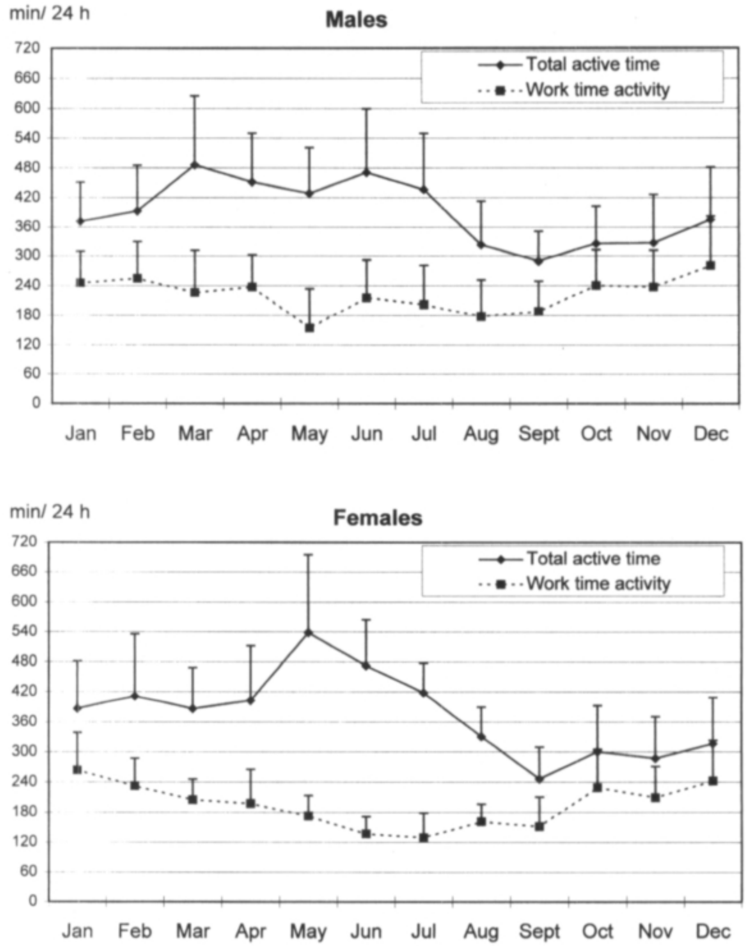

Fig. 2. Seasonal changes in total and worktime activity rates (mean ± SD). Worktime was between 0800 and 1600.

(Aschoff 1962). Wild red foxes have been considered to be mainly nocturnal since over 50% of their activity appears to occur between 1700 and 0900 (Ables 1969). Wild arctic foxes have been documented to have either clear (Eberhardt et al. 1982, 1983) or weak nocturnal patterns of activity (Frafjord 1992a). Nocturnal patterns in nature are adaptations to prey availability and predator avoidance. However, learned nocturnal patterns may be partly sustained when wild foxes are taken into captivity (Tembrock 1958, Österholm 1966). In contrast to wild foxes, farm-born blue and silver foxes seem to have activity patterns that are more concentrated on daytime hours (Kaleta and Brzozowski 1985, Korhonen 1988, Korhonen and Alasuutari 1994, Mononen et al. 1996, Rekilä et al. 1996). The present results also showed that activity of farmed blue foxes occurred mainly during light hours. In summer, when there was light almost throughout the 24 h, foxes were also more active day around than during winter. In winter, light hours as well as activity were concentrated on working times. Thus, it seems that the duration of light significantly affects the activity of farm blue foxes. Actually the same occurs in the wild, but the situation is reversed with wild foxes being most active outside light hours. The explanation

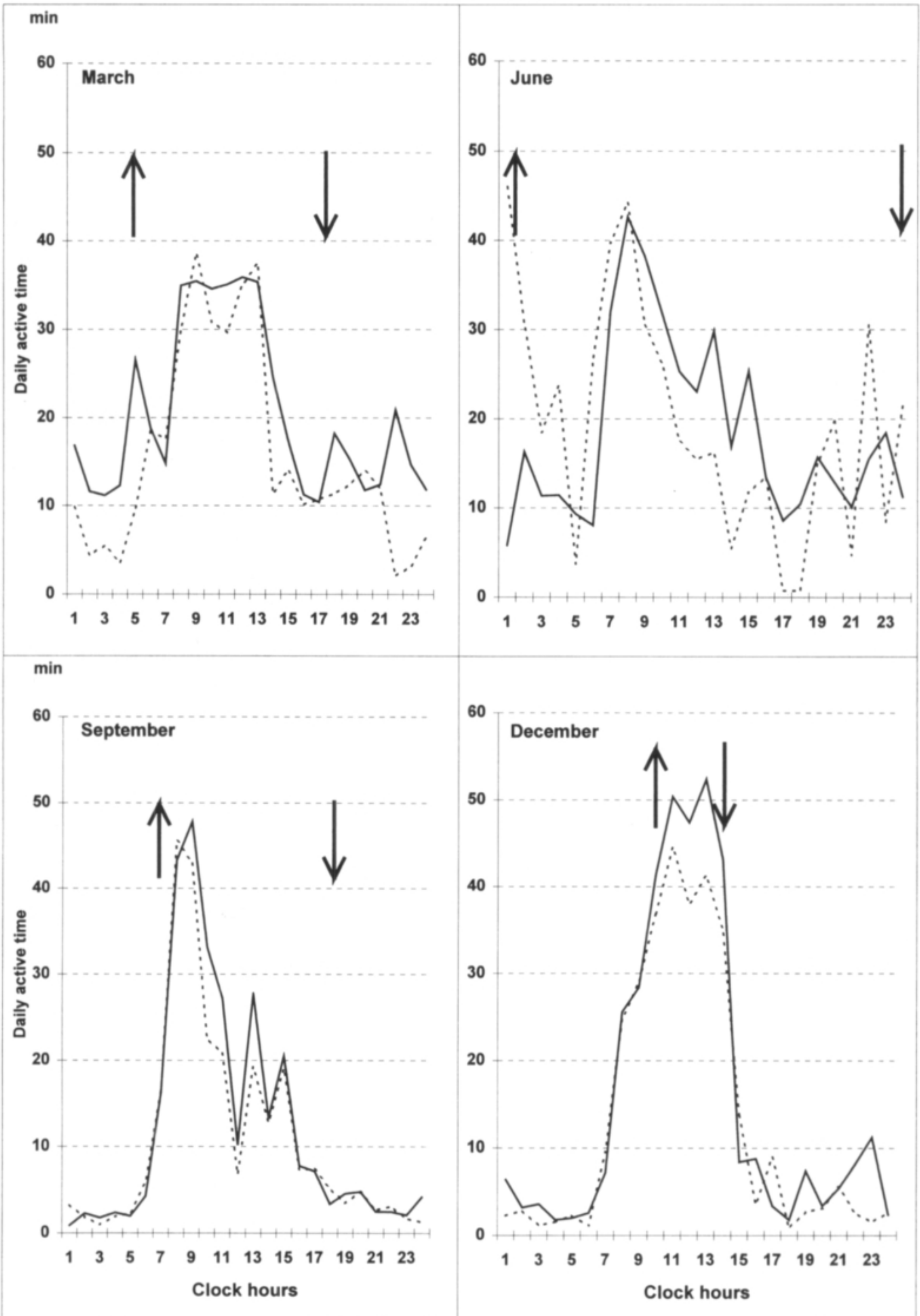

Fig. 3. Examples of circadian rhythm of activity in males and females during four different months. Sunrise and sunset are marked with arrows. Broken lines are female activity curves.

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to this difference between farm and wild conditions is due to farmed foxes not having enemies which need to be avoided. While food is also offered to them during daytime, there is no reason why they should be very active in the dark.

In the study of Tembrock (1958), captive arctic foxes were most active during the breeding season in March, but shortly before whelping they became rather inactive. Thereafter, they became active again but after mid-June their locomotorive activity decreased. The next activity peak was observed in autumn. Österholm (1966) presented rather similar results for captive red foxes. The results of the present study are in good agreement with these studies, confirming the conclusion that activity rates of captive foxes vary according to season. In the wild, activity rates of arctic foxes also show seasonal variations. Activity is highest in the summer and early autumn (Frafjord 1992a, b). This is obviously due to two reasons: (1) wild foxes must be very active in order to gain enough food and subcutaneous fat reserves for winter, and (2) dispersion of litters occurs in late summer or early autumn, which leads to animals migrating to new living and foraging areas (Eberhardt and Hanson 1978, Eberhardt et al. 1983). In contrast, on farms, feed is provided by farmers and therefore, foxes do not need to move in search of food. Nor is dispersion possible from cages. In late July, however, farm foxes are typically weaned from their mothers and put into their own cages. Despite these differences, a tendency for increased activity in farm foxes during late autumn was also found in the present study. The explanation for this phenomenon is unclear. However, farmers normally limit food availability at this time to avoid excessive obesity. This was also the case in the present study. Foxes are therefore slightly hungry and tend to be restless.

In the wild, arctic fox movements have been classified into four categories; (1) local movements, (2) general daily travels of individual foxes, (3) sporadic movements and (4) seasonal movements and migration (Chesemore 1975). For technical reasons, systematic information on arctic fox activity in nature is often based on the first category, and even then this information is typically limited to the denning season. During breeding season, adults have been documented to rest most of their time, i.e. 60–90% (Frafjord 1992b) or 79–80% of the total 24 h (Garrott et al. 1984). This data shows that in nature at the time when energy demand of a litter is at its highest, arctic foxes may be inactive for longer periods than their captive counterparts.

General observations from the wild obtained from several studies indicate that male arctic foxes tend to roam more than females, particularly during the winter period (Pulliainen 1965, Vibe 1967, Bannikov 1969). Also the results from group-housed blue foxes housed in semi-natural enclosures (Korhonen and Alasuutari 1994), and those from singly-caged blue foxes (Korhonen and Niemelä 1995), showed that males were more active than females in March. Parallel evidence also emerged from the present results with the difference in activity rates for males being highest in March and December. The tendency for higher winter activity in wild males is associated with the need to seek for breeding partners and new living territories. Although foxes often are considered rather solitary, they may also live in groups. Groups are typically comprised of several breeding and non-breeding females with a lesser number of males (Hersteinsson and Macdonald 1982, Eberhardt et al. 1982). Social tension with increased agressive interactions is pronounced, particularly in males prior to and during the breeding season (Korhonen and Alasuutari 1994, 1995). Thus, pressure for dispersal and roaming would be higher in males than females. The fact that winter activity of foxes on farms resembled that of wild foxes can be explained by the presence of social and sexual pressure on farms also. Although breeding males are kept singly in their cages, it has been found that a kind of social hierarchy also exists on farms (Korhonen and Niemelä 1993). Scent odours and vocal communication are the means by which farm foxes communicate social and sexual state.

A crucial problem when comparing activities of farm foxes to their wild relatives is that activity results gained from wild animals often concentrates on total active time,which does not discriminate behaviours such as standing, sitting, eating, self-grooming, defecation, and occasional short rest periods. Therefore, activity rates reported in wild animals can easily exceed those of farm animals. Another problem is that data from wild animals is not necessarily expressed as activity per 24 h. Urquhart (1973) and Eberhardt and Hanson (1978), for instance, reported the activity of arctic foxes as 27 km and 24 km/d, respectively. It is difficult to assertain from these figures the time taken to travel these distances. However, more comparable data is also available. In Svalbard, Frafjord (1992a) recorded that wild artic foxes were active for about 34% of the day (490 min/24 h) and captive ones for about 25.3% (364 min/24 h). In seminatural enclosures, mean activity of arctic blue foxes was 29.2%, i.e. 421 min/24 h (Korhonen et al. 1997). Activity of blue foxes in conventional farm cages was previously reported to vary from 127 min/ 24 h (Korhonen 1988) to 311 min/24 h (Korhonen and Niemelä 1995). However, when standing was also included, the activity in the study of Korhonen (1988), for instance, rose to 231 min/24 h. In the present study, the yearly mean activity was higher (372 min/24 h) than that in previous farm cage studies. The differences between results of various studies can be explained by differences between farms, individuals and/ or recording methodology.

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SELOSTUS

Tarhattujen sinikettujen vuodenaikainen ja vuorokautinen aktiivisuus

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Maatalouden tutkimuskeskus

Tässä työssä tutkittiin tarhattujen sinikettujen (9 urosta, 13 naarasta) vuodenaikaista ja vuorokautista aktiivisuutta. Kettujen käyttäytymistä videokuvattiin 24 tunnin jakso kerran kuukaudessa vuoden ympäri. Urosten keskimääräinen aktiivisuus oli hieman korkeampi (394 ± 116 min/vrk) kuin naaraiden (349 ± 111 min/vrk). Molempien sukupuolien aktiivisuus vaihteli vuodenajoittain. Naaraat olivat kaikkein aktiivisimpia toukokuussa (539 ± 157 min/vrk), kun taas urosten aktiivisuushuippu sattui kesäkuulle (471 ± 128 min/vrk). Pienimmät aktiivisuusarvot mitattiin syyskuussa. Talvella kettujen aktiivisuus keskittyi pääosin työaikaan (klo 8–16). Kesällä työajan ulkopuolinen aktiivisuus lisääntyi selvästi. Tulosten perusteella valon määrän lisääntyminen kesällä lisää aktiivisuutta. Talvella valoisaa on lähinnä työaikana, mikä selittää sen, että tarhakettujen aktiivisuus ajoittuu tällöin työaikaan.