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Seasonal changes in activity of Arctic foxes *Alopex lagopus* L. in Svalbard

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Daily and seasonal activity patterns of Arctic foxes *Alopex lagopus* were studied on the western coast of Svalbard from 1986 to 1989. The activity of radio collared foxes (n = 11, including two pups) was recorded on a chart recorder, and the activity of litters of pups (n = 6) was observed in denning areas. Only one collared fox, a female, was known to be breeding. The range in activity by month and individual was about 10—60%, and yearly means were 32% and 36% in adult males and females, respectively. Variation between months was not significant. A seasonal variation was found although no two seasons were different from each other. Average percentage of activity in the summer was 40%, and in the winter 15%. No influence on the rate of activity of temperature and wind speed was found. Foxes averaged 39% activity in nighttime hours (2000—0800) and 28% active in daytime hours (0800—2000) ($p = 0.06$). Three adults (two males, one female) and one pup that were monitored when living in the same bird cliffs influenced each others activity only to a small extent.

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INTRODUCTION

The Arctic fox *Alopex lagopus* L. is a common predator widely distributed in the arctic region (Garrott & Eberhardt 1987). Little information is available on the social organization and behaviour of Arctic foxes, but several authors suggest that they are territorial albeit with the potential for surplus adults in the denning area (Eberhardt et al. 1982, Hersteinsson 1984, Garrott et al. 1984). Arctic foxes mate in late March or early April, and the pups are born in an earthen den or in a rock ravine in May or June. Pups may leave they their natal den, following adults when they are at an early age (Frafjord 1986). They are nearly adult-sized when 3 months old. Little aggression among pups has been observed, and their contact with parents is mostly restricted to the transfer of food (Garrott et al. 1984, Frafjord 1986).

The activity patterns of most canids are likely to differ markedly between populations from different regions (Ferguson et al. 1988). Few studies on activity patterns of free-living Arctic foxes have been conducted, but Eberhardt et al. (1982) and Birks & Penford (1990) found that foxes were more nocturnal than diurnal. Free-living Red foxes *Vulpes vulpes* L. were likewise most active during the night, and their activity correlated with activity of prey species like small rodents (Ables 1969). Ables (1969) found climatic factors not very important for Red fox activity.

Arctic foxes in Svalbard are subject to large seasonal shifts in climate and prey availability. In summer, food is abundant in colonies of sea birds, and the sun is shining 24 hours a day. In winter, food is scarce, the sun in below horizon for nearly four months, and temperatures are low. Arctic foxes may maintain energy balance throughout the year by means of building up layers of body fat and by caching food during the summer. Such strategies would imply increased activity in summer, and because of the continuous daylight the foxes could use all 24 hours. A decreased activity in winter to reduce the demands of energy could be expected, as the costs of activity can be a major part of the energy expenditure (Green & Bear 1990). Foxes with less storage of fat or food may have to increase their activity in winter to

search for food. Growth of fur in Arctic foxes is highly correlated with season and temperature, and the winter pelage has a high insulation value (Underwood & Reynolds 1980). Thus, cold weather may have less influence on fox activity.

In this study I describe the activity of free-living Arctic foxes in Svalbard throughout the year, and attempt to identify some factors influencing their activity. Influences of season, weather (temperature and wind speed), time of day, and social interactions are examined. Unfortunately, the influence of reproduction, body condition (fat storage), and food availability could not be studied, but a few comments are made. Quantitative estimates of Arctic fox activity are needed to calculate the energy budgets for this medium-sized carnivore that lives under the most severe conditions.

STUDY AREA

I studied free-ranging Arctic foxes on the peninsula Brøggerhalvøya and in the regions of Kongsfjorden and Krossfjorden on the northwestern coast of Svalbard, at about 79° northern latitude. This region is characterized by a narrow level plain along the coast, while the inland consists of glaciers and steep mountains. Precipitation is low (average 385 mm per year, Steffensen 1982), but strong winds are common, notably during the autumn and winter.

During the summer, Arctic foxes prey mainly on sea birds. The first sea birds reach the region in April and most of them have left by the end of September. During the winter, the only terrestrial animals left in addition to foxes are ptarmigan *Lagopus mutus* and reindeer *Rangifer tarandus,* although fulmars *Fulmarus glacialis* may stray inland during most of the year. Reindeer mortality is low in this region (Øritsland & Alendal 1985), and carcasses are often collected for scientific purposes. The polar bear *Ursus maritimus* is not common in this region. Thus, opportunities for scavenging Arctic foxes are few. Ringed seals *Phoca hispida* are common in the fjords, and foxes prey upon their newborn pups in March and April (Lydersen & Gjertz 1986).

MATERIALS AND METHODS

Activity patterns of 11 radio collared foxes were recorded in the years 1987—1989, and some recordings were made of one fox in April 1990 (Table 1). Most foxes wandered extensively in periods (Frafjord & Prestrud 1992) and because of the difficult terrain activity data could only be gathered during shorter periods. If possible, activity was recorded continuously through 24 hours. Radio collared foxes were named, of which the two first letters are used as a short form throughout this text.

I separated adults older than one year from juveniles (3—12 months) according to the appearance and wear of their canines. Pups were aged according to their size and appearance relative to adults (cf. Frafjord 1992). Two pups fitted with radio collars were estimated to be 1 1/2 months old, and they became independent of their dens shortly afterwards. Two radio collared foxes (NJ, AR) were kept in captivity for 1 and 2 years respectively, before they were released.

Transmitters were Telonics Model 300 (Mesa, Arizona, USA). These transmitters have a very long range through open country (50 km was once recorded), but the range was very much shortened if signals were shielded by mountains. The two pups were fitted with a smaller transmitter, Televilt TXD-2S (Storå, Sweden), with a shorter range.

The radio receiver was connected with a two-channel chart recorder, placed either at the Research Station of the Norwegian Polar Research Institute in Ny-Ålesund or, during the summer of 1989, in a tent. A chart speed of 1 cm per minute was selected. Foxes could easily be determined as either active or passive on the continuous paper output. A varying signal strength showed them to be active (locomotor activity) and a continuously strong signal when they were passive. In addition, whenever foxes were located or observed, they were noted as active or passive. From simultaneous observations and signal recordings, I found minor bias toward the passive state because the fox moved at a constant angle toward the receiver antenna (of 35 cases 25 was biased toward passive). When observing foxes their behaviour had to be determined in a few seconds, but at minimum a half minute of paper output was needed to interpret the signals.

During the summers of 1986—1989 I observed the activity of a total of 6 Arctic fox litters to a varying extent (in the following denoted «litters», cf. Frafjord 1992). One observation was made every 5 minute, by scanning the area and noting the behaviour of each fox that was visible. During the snow melt in June (when pups first emerged), dens could not be reached either on snowmobile, by boat, or on foot. Furthermore, since the pups left their natal dens most often at a young age in early July, they were difficult to follow for any prolonged observations. Sample size for each litter was therefore small. Consequently, data for all litters were lumped for July and August, during the age of 1—3 months.

One recording of one fox was denoted a «fix», equivalent to one observation or one minute on the continuous paper output. Fox activity was calculated as percentages in each time period, weighed against the total number of fixes in the period. No data was collected during the months December and January. Winter was defined as November—March, spring as April—May, summer as June—August, and autumn as September—October.

Analysis of variance (ANOVA) was performed to test for significant differences ($p<0.05$) in seasonal and monthly activity patterns. In every ANOVA, the individual fox was the sampling unit. Only hours with 10 or more fixes were used in analysis of diel patterns. Influence on fox activity of two weather variables, temperature and wind speed, and one interaction term of these (the wind-chill index, WCI, Rosenberg et al. 1983), were examined by least squares regression analysis. Sampling units in this analysis were the daily mean of percent active or weather variable. Only days with more than 40 fixes were used. In linear regressions a scatterplot of residuals against predicted values was inspected for possible violations of linearity. Weather observations were from Ny-Ålesund (data from the Norwegian Meteorological Institute). Other statistical methods are indicated in the text.

RESULTS

Influence of season

The variation in fox activity by month (Fig. 1) was not significant ($F = 0.84$), and no significant sexual differences was found ($F = 0.35$). Yearly means were $31.5 \pm 16.2\%$ and $35.5 \pm 17.2\%$ for males and females, respectively. Litters had a 44% and 41% activity in July and August, respectively; slightly more than the two radio collared pups.

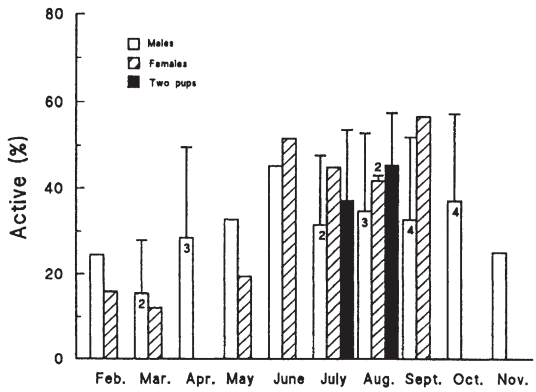

Fig. 1. Mean percentage of activity by month in adult male and female Arctic foxes, and in two male pups. When sample is from more than one fox, the number of foxes is given in the column. Bar length = 1 SD.

A seasonal shift in activity was found ($F = 3.27$, $p = 0.05$), but no two seasons were significantly different from each other (Scheffé multiple comparison test, $p>0.05$). Average summer activity was 40%, and winter activity 15% (Table 1). Variation between individuals was great, from 10% to 40—50% activity in the same season (Table 1). The only fox followed through all seasons (NJ), was most active in summer, least in winter, and intermediate in spring and autumn (Table 1). The difference between summer and winter was 15.5%.

Influence of weather

Influence of temperature and wind velocity on daily activity was examined for three «groups» of foxes; non-breeders (NJ, KI, IN, SV, KV, TE, AR, n = 118 days), one breeder (SY, n = 30), and two pups (MI, NU, n = 41). Daily mean temperature in this sample showed lower and higher values of -26.2 and 9.3°C, respectively. Daily mean wind velocity showed lower and higher values of 0 and 11 m/sec. No relationship between the percentage of activity and temperature (Fig. 2) or wind velocity was apparent from inspec-

Table 1. Mean percentage of Arctic fox activity during different seasons (average of months), and total numer of fixes for each fox. A = adult, J = juvenile, P = pup. MI was probably the son of SY.

Fox	Sex	Age	Spring	Summer	Autumn	Winter	No. fixes
KI	♂	A	10.7			6.8	2695
NJ	♂	A	39.0	40.1	34.0	24.6	23273
IN	♂	A	23.8		28.6		4612
KV	♂	A		37.3	16.6		1805
SV	♂	A		13.1			8290
QU	♀	J-A	19.4				1183
TE	♀	A				14.0	3782
AR	♀	A		46.2	53.7		4217
SY	♀	A		43.7			17207
MI	♂	P		51.1			15352
NU	♂	P-J		32.8	59.5		1625
Litters		P		56.7			3219
Mean all			23.2	40.1	38.5	15.1	
SD all			11.8	13.2	17.8	9.0	

ting the scatterplots (the plot for wind speed was similar to that for temperature).

No effect of temperature, wind velocity or WCI on fox activity was found, despite a variety of regression analysis (r^2-values varied from 0.00 to 0.09). Transformations (natural logarithms), non-linear regressions ($Y = a + bX + cX^2$), or multiple regressions only marginally improved the model compared to linear regressions. In non-breeders, linear regressions were also performed for autum + winter and spring + summer, and for temperatures below and above zero. Highest value of r^2 (0.05) was found when in (active) was regressed on ln (temperature) for temperatures below zero.

Diel activity

Non-breeding foxes were most active during the night at all seasons (Figs. 3 and 4). This pattern was least pronounced in winter, when foxes were least active. Foxes were on average 11% more active during nighttime hours than during daytime hours (Table 2). This differences was close to be significant (Wilcoxon $z = 1.88$, $p = 0.06$, using the whole year percentage for NJ). Day- and nighttime activity were split by season: summer + autumn and winter + spring (combined to increase sample size, using each season for NJ). Foxes averaged $15.8 \pm 11.8\%$ active during daytime hours in winter + spring and $34.3 \pm 12.2\%$ in summer + autumn ($z = 2.33$, $p<0.05$). The percentages for nighttime hours were $25.4 \pm 15.8\%$ and $49.5 \pm 17.7\%$ ($z = 2.21$, $p<0.05$). The two sexes did not differ in their diel activity ($F = 0.29$, $p<0.05$). Individual variation was, however, very great, as exemplified by the large standard deviations in Figs. 3—4.

The breeding female (SY) was somewhat more active during the night than during the day (Fig. 5). The two pups and litters seemed to have a more regular activity, with 3 or 4 activity maxima throughout the day (Fig. 5).

Social influence

The activity of the four foxes KV, SV, SY, and MI is of special interest, since they lived in the same bird cliffs during the summer. The pup MI was most active, his mother SY and the male KV intermediate, and the male SV least active (Table 2). Few interactions were observed between these three adults, but SY dominated SV in three of four encounters, while she was probably dominated by KV in

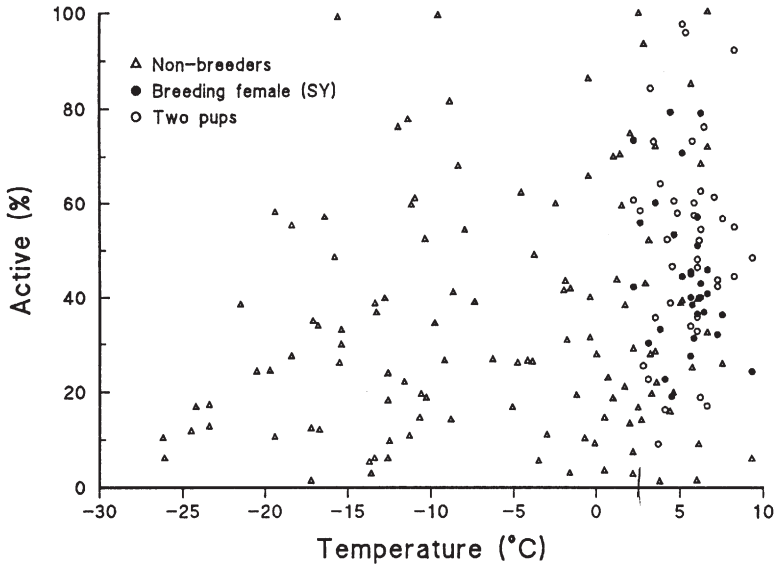

Fig. 2. Scatterplot of daily percent active against temperature for non-breeding foxes, one female breeder, and two pups.

one encounter. Daily activity patterns of these three foxes were not mutually exclusive, and all had a high proportion of activity during the evening. Comparisons of the per day percentages of these three adult foxes and the single pup were made by a sign test. The comparison was done to see whether one fox decreased his activity in response to increased activity in another fox. SV and MI showed a different pattern ($p = 0.04$, $n = 9$ days), but no other combinations of foxes yielded significant differences ($p > 0.05$, $n = 7$—24, SV-KV was not tested because of too few days).

DISCUSSION

I found a yearly change in activity, although no season was significantly different from any other. Foxes were most active in summer and autumn and least active in winter, which support the theory of reduced energy expenditure during the season when food is least available. Individual differences were large,

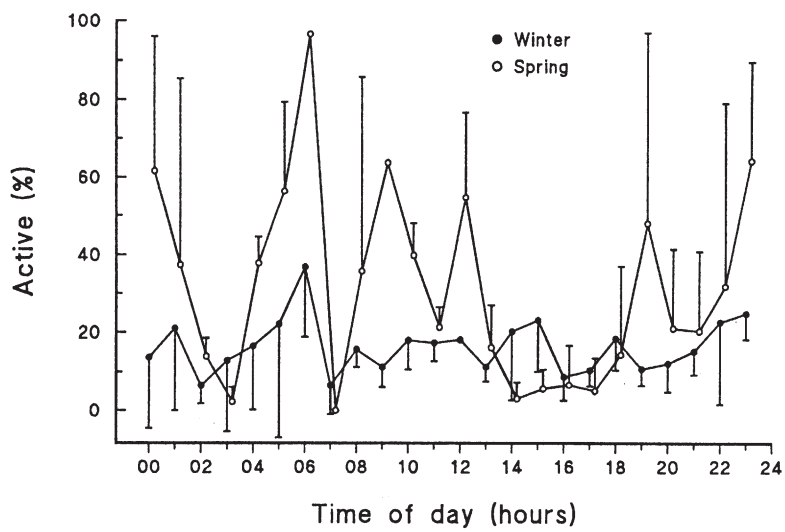

Fig. 3. Diel activity patterns during winter and spring of non-breeding Arctic foxes. Bar length = 1 SD (between individuals).

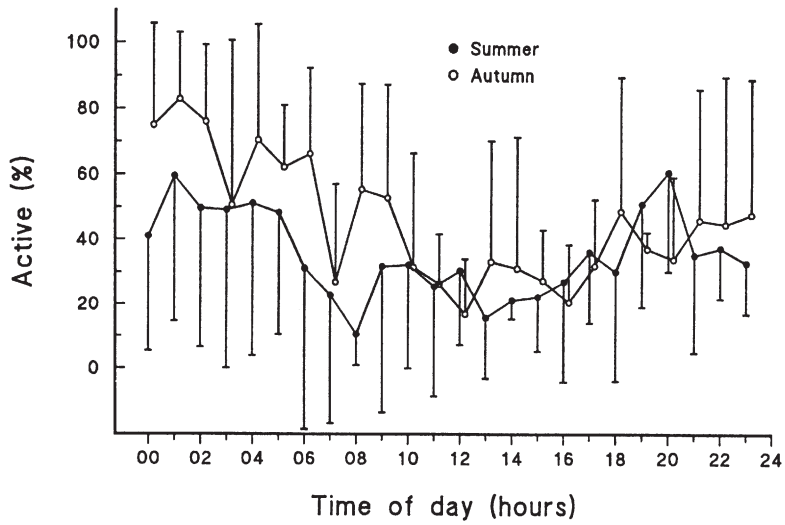

Fig. 4. Diel activity patterns during summer and autumn of non-breeding Arctic foxes. Bar length = 1 SD) (between individuals).

and one male showed low activity even in summer. The low rate of activity for one female and one male during winter time, may have resulted because their major feeding sites were nearby (an artificial feeding site and possibly a reindeer carcass, respectively). Food resources for other foxes tracked during the autumn and winter were largely unknown. Several foxes shifted their range between seasons (Frafjord & Prestrud 1992). Thus food cached during the summer may not have been important for winter survival.

A few studies on captive foxes indicate both a daily and seasonal shift in activity, with peaks during the night and early morning, and during the mating season (March and April) (Tembrock 1958, Folk 1964, Hilmer & Tembrock 1972, Korhonen 1989). Hilmer & Tembrock (1972) suggested that the activity of captive Arctic foxes showed an endogen, circadian rhythm in locomotor behaviour. Free-living animals have more flexible activity patterns than captive animals (Tester 1987), which may account for the somewhat more regular circadian rhythms found in captive Arctic foxes. Hilmer & Tembrock (1972) observed a high individual variation in Arctic foxes, but Korhonen (1988) concluded that individual and seasonal variation in activity were small. Daily

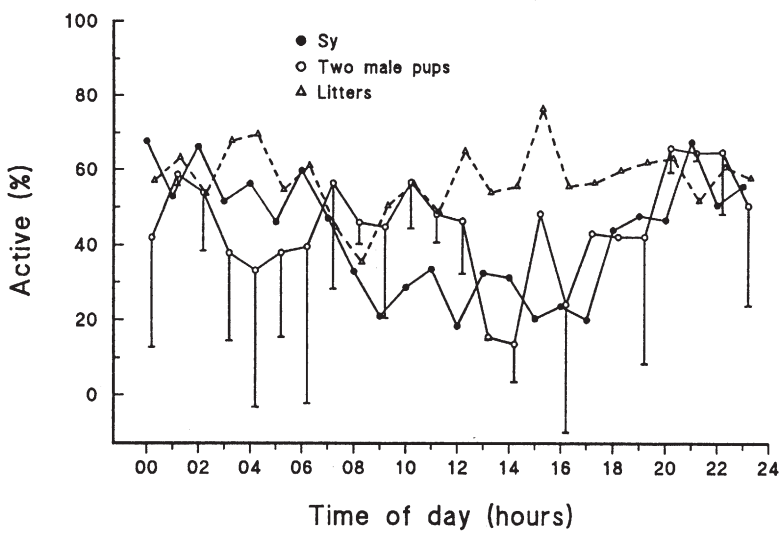

Fig. 5. Diel activity patterns of an adult female Arctic fox (SY) which cared for a litter of pups, two pups, and litters during summer. Bar length = 1 SD (between individuals).

Table 2. Mean percentage of Arctic fox activity during the day (0800—2000 hours) and during the night (2000—0800 hour).

Fox	Seasons[a]	Day	Night
KI ♂	Wi/Sp	13.6	8.7
NJ ♂	Whole year	27.6	50.5
	Sp	33.1	47.7
	Su	27.7	66.9
	Au	31.3	54.2
	Wi	18.2	33.4
IN ♂	Au/Sp	34.6	39.2
KV ♂	Su/Au	23.0	36.8
SV ♂	Su	14.4	11.0
TE ♀	Wi	14.0	13.1
QU ♀	Sp	0.3	24.1
AR ♀	Su/Au	36.7	65.6
SY ♀	Su	29.5	56.1
MI ♂	Su	41.3	66.1
NU ♂	Su/Au	48.3	40.4
Litters	Su	56.2	58.6
Mean all		28.3	39.2
SD all		16.2	21.0

[a] Wi = Winter, Sp = Spring, Su = Summer, Au = Autumn.

activity patterns of captive Red foxes were more regular than that of Arctic foxes, with three activity maxima during the night (Hilmer & Tembrock 1972).

Little is known on the daily activity of the prey species. The numbers of Brünnich's guillemot *Uria lomvia* sitting in the bird cliffs may vary as much as 20% during the day, but no clear pattern has been found (Bakken & Mehlum 1988). If this applies to all sea birds, time of day may be insignificant to the Arctic fox while hunting during the summer. The sun is above the horizon 24 hours a day in the summer time. The same argument can be used about the dark winter season when the sun is below horizon all day. As a consequence, activity of prey species or the probability of locating food should not have any profound effect on the daily activity patterns of Arctic foxes. Indeed, foxes were active both day and night in all seasons.

The summer climate is not very severe in Svalbard, and snow falls are infrequent during the three summer months June—August. Thus, it is not surprising that fox activity was not much affected by summer climate. More surprising was a lack of influence of temperature and wind at other seasons. However, Arctic foxes are so well insulated in winter — their lower critical temperature has been estimated to below -30°C (Underwood 1971) — that they probably are not much influenced by even the most severe weather. Strong winds may, however, reduce the likelihood of finding food, because they were always associated with drifting snow.

Influence from other foxes (social influence) did not seem to have any profound impact on daily activity patterns of four foxes that lived in the same bird cliffs during the study period. Some differences in activity between individuals were found, notably one adult male tended to avoid other foxes to some extent. His total activity during this period was very low, which supports this conclusion. He was probably subordinate to the adult female. He was observed to avoid pups although he was often located in about the same area as the pups and sometimes he did give them food. Most likely he was not the father of the litter.

The breeding female and the pups were the most active foxes during the summer, otherwise the influence of reproductive status could not be studied. No other radio collared fox was likely to breed during the study period. Experience, or age, could likewise not be studied, but increased activity of juveniles in the autumn relative to adults indicates that experience might influence activity patterns.

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SAMMENDRAG

Årlig aktivitetsmønster hos fjellrev på Svalbard

Fjellrevens døgn- og sesong-aktivitet ble studert på vestkysten av Svalbard i årene 1987—1989. Aktiviteten til rever merket med radiosender (n = 11, inkludert to valper) ble registrert på en skriver, og observasjoner av aktiviteten til valper i hiområdet ble også foretatt (6 kull). Kun en av de radiomerkede revene reproduserte (en tispe). Månedlig aktivitet varierte fra 10—60%, men variasjonen var ikke statistisk signifikant. En sesongmessig variasjon ble funnet selv om aktiviteten i en sesong ikke var signifikant forskjellig fra aktiviteten i en annen. Om sommeren var revene aktive gjennomsnittlig 40% av tiden og om vinteren 15% av tiden. Hanner var gjennomsnittlig 32% aktive i løpet av hele året, hunner 36%. Aktiviteten syntes ikke å være påvirket av været (temperatur og vind). Revene var gjennomsnittlig 39% aktive om natten og 28% om dagen (p = 0.06). Tre voksne rever og en valp som ble studert mens de levde i samme fuglefjell, syntes bare i mindre grad å påvirke hverandres aktivitetsmønster.

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