Activity patterns of male Tengmalm's owls, *Aegolius funereus* under varying food conditions

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A b s t r a c t . This study investigated whether the males of the Tengmalm's owl change their activity patterns, evaluated based on delivering prey to nestlings in respect of different food supply. During two breeding seasons 12 owl nests were continuously monitored by a camera system to obtain data on the time of male prey delivery and identification of prey items brought to nestlings. Even though the abundance of food supply differed in both years, there was no difference in the number of prey items delivered by males to their nests. Nevertheless, the species composition of food supply as well as the species composition of prey delivered by males to the nests differed between 2004 and 2006. Yet male activity patterns were the same in both years; they showed a monophasic cycle with one peak at the beginning of the night, around 22:00 and 23:00. Moreover, the males delivered prey to their chicks strictly at night time in both years and they started (the first evening arrival at the nest) and ended (the last morning arrival at the nest) their nest visiting in the same time in 2004 and 2006. The results of this study suggest that activity patterns of Tengmalm's owl males in Central Europe do not depend on varying food conditions.

Key words: food supply, prey delivery, nesting, Czech Republic, Ore Mountains

Introduction

Activity patterns of each individual consist of active and resting phases, while timing and length of these phases strongly vary depending on changes of environment (V e s e l o v s k ý 2001). There are several studies that focus on the effects of environmental factors on activity patterns of raptors. These studies show that the activity of raptors may be influenced by food conditions (M i k k o l a 1970, S n y d e r et al. 1975, K o r p i m ä k i 1981, R i j n s d o r p et al. 1981, F e r n a n d e z - D u q u e 2003), light conditions (A c s h o f f & W e v e r 1962, M i k k o l a 1970, K l a u s et al. 1975, K o r p i m ä k i 1981, D e l a n e y et al. 1999, F e r n a n d e z - D u q u e 2003, Z á r y b n i c k á unpubl.), ambient temperature (F e r n a n d e z - D u q u e 2003), nesting phase (D e l a n e y et al. 1999, R u t z 2006) or the demands of starving nestlings (B e r g m a n n & G a n s o 1965). The monitoring of activity patterns of raptors is most often based on prey delivery to nestlings (M i k k o l a 1970, K l a u s et al. 1975, K o r p i m ä k i 1981, D e l a n e y et al. 1999), which reflects hunting effort (S n y d e r et al. 1975, R i j n s d o r p et al. 1981, R u t z 2006) or foraging and moving activity (F e r n a n d e z - D u q u e 2003).

The Tengmalm's owl is primarily a nocturnal species. Nevertheless, in the breeding season, birds can also be active in early mornings (K l a u s et al. 1975, K o r p i m ä k i 1981). The circadian rhythm of the Tengmalm's Owl, evaluated based on the frequency of prey delivery to the nest in Central Europe is biphasic with peaks at late dusk (20:00–22:00) and early dawn (2:00–5:00), and a period of low activity before midnight (22:00–2:00) and during the day (K l a u s et al. 1975). Regardless of the latitude, the beginning and end of activity usually follows the sunset and sunrise, while the first visit to the nest is usually more strictly dependent on the sunset than the last one on the sunrise (K l a u s et al. 1975, K o r p i m ä k i 1981).

Based on prey delivery to nestlings, this study focuses on male activity patterns of the Tengmalm's owl during the two years differing in food supply. A relatively recently developed methodological approach (see review in R e i f & T o r n b e r g 2006) of continuous nest recording by a camera system enabled to obtain detailed data on the time of male prey delivery and identification of prey items brought to nestlings. It was possible to ask whether 1) male activity patterns depend on different species composition of food supply; and 2) males become active during the day as a result of low food abundance.

Study Area

The study area was situated in forests damaged by industrial air pollution in the Ore Moutains (50° N, 13°E), Czech Republic, at altitudes ranging between 735 to 956 meters a. s. l. This area is covered by spruce forest fragments (in different stages of the damage), open areas and forest clearings (dominated by wood reed *Calamagrostis villosa*), solitary trees (mostly European beech *Fagus sylvatica*) and secondary growth of young trees, mainly prickly spruce *Picea pungens*, birch *Betula* spp., European mountain ash *Sorbus aucuparia* and European larch *Larix decidua*. Within these habitats, 120 nest boxes for the Tengmalm's owl were placed in an area of 70 km^2.

Material and Methods

The data were collected between May and July in 2004 and 2006. In total, the activity of birds was monitored at six nests in 2004 (40% of the nest-box breeding population in 2004) and at six nests in 2006 (25% of the nest-box breeding population in 2006). All nests in both study areas were successful, i.e. at least one young fledged at each nest. The nests were continuously monitored by a camera system for 24 hours per day from hatching to fledging phase. Each nest was recorded over a mean period of 27.5 ± 6.6 days in 2004 and 25.0 ± 7.0 days in 2006. In 2004 in the period of nest monitoring, the average time of sunrise was 4:13 (SD = 11 min) and the average time of sunset was 20:00 (SD = 15 min). In 2006 in the period of nest monitoring, the average time of sunrise was 4:01 (SD = 8 min) and the average time of sunset was 20:11 (SD = 11 min).

The activity of males was evaluated based on time records of their arrivals in the nest-box openings (delivering prey). The equipment I used to monitor the circadian activity and composition of prey delivered to the nest consisted of a camera (DECAM), a chip reader device, a movement data-logger, a movement infrared detector (KS96) and infrared lightning (IR diodes, SFH 485–2 880 nm; B e z o u š k a et al. 2005). The camera was installed inside the nest-box opposite the opening. It was initialized by the infrared detector sensitive to movements in the nest-box opening. The time of detection was recorded by the movement data-logger and one to three photos were taken for each event. During the night, the opening was illuminated by infrared diodes at the moment of making photos by the camera. All adult owls and nestlings were marked by chip rings. A chip reader device fixed by the nest-box opening detected and archived all movements of chips in the nest opening. Using this equipment, I was able to record arrival and departure of parents to the nest box, feeding frequency and species composition of prey delivered to the nests. I recorded 1028 prey deliveries at six nests in 2004 and 779 prey deliveries at six nests in 2006.

The abundance of small mammals was assessed using snap-trap captures. The captures were carried out in both years at the beginning of June. The traps were laid out in a 500 m long line in a 5 m spacing (2 x 250 m, a total of 100 traps). Four lines were laid in each year. The traps were deposited for three days and they were checked once a day. All captured mammals (74 items in 2004 and 13 items in 2006) were determined to the species level. The diet composition of the Tengmalm's owl was assessed by pictures taken by the nest-box camera system, which enabled to determine the prey items down to the family or genus level. Pictures taken by the nest-box camera system enabled to determine 84.1% (n = 865) of the delivered prey in 2004 and 82.3% (n = 641) in 2006 at least to the family or genus level.

I used conventional statistic methods with parametric tests where the data fit normal distribution. T-tests were used to compare the differences between the two years in food abundance, number of prey items delivered by male at the nest, time of the first male arrival after sunset and the last male arrival before sunrise. I used χ^2-test to compare the differences between the two years in the distribution of prey delivery by males to the nests during 24-hour time period. Multiple Linear Regression was used to test the effect of the changing time of sunset and sunrise on the first and the last male arrival at the nest. To correct the analysis for the age of nestlings, I recorded all nests during the same age period; in 2004 the nestlings were monitored at the average age of 17.4 ± 3.0 days of the oldest nestling, in 2006 at the average age of 17.3 ± 5.4 days of the oldest nestling (t test: t = 0.04, P = 1.0). All data analyses were processed in Statistica 6.0 software package (StatSoft 2003). Values are reported as means ± SD per nest or trapping site.

Results

In both years, 2004 and 2006, the males arrived at the nest box opening in most cases with prey (99.8% ± 0.6 vs. 99.1% ± 1.0 prey visits/nest) but they entered the nest box only rarely (12.8% ± 6.1 vs. 10.8% ± 5.9 visits/nest). Their longer visits took place only when the females were not present in the nest boxes; the longest stay of a male in the nest box took 49 seconds in 2004 and 38 seconds in 2006.

Differences in food supply of small mammals were found between the two study years both in the abundance and the species composition as revealed by snap-trapping. The abundance of small mammals was significantly higher in 2004 than in 2006 (5.5 vs. 1.1 ind./100 traps/night; *t*-test: t = 4.96, $P < 0.001$, $n_1 = 4$, $n_2 = 4$). The taxonomic composition of food supply also differed significantly between the two study years ($\chi^2 = 50.0$, df = 5, $P < 0.001$). In 2004, the yellow-necked mouse *Apodemus flavicollis* was the dominant prey species and accounted for 85.0% of all trapped small mammals, while the field vole *Microtus agrestis* (9.5%), common vole *Microtus arvalis* (2.7%), bank vole *Clethrionomys glareolus* (1.4%) and common shrew *Sorex araneus* (1.4%) were caught less frequently. In 2006, the field vole *Microtus agrestis* (85.8%) was the most common species. The common vole *Microtus arvalis* (7.1%) and yellow-necked mouse *Apodemus flavicollis* (7.1%) were trapped only rarely.

There were also significant differences between the two study years in the taxonomic composition of prey delivered to the nests of Tengmalm's owls ($\chi^2 = 454.7$, df = 4, $P < 0.001$). In 2004, the males brought to the nestlings mostly the *Apodemus* mice (58.6%) and *Microtus* and *Clethrionomys* voles (32.6%), while in 2006, the males fed their nestlings

Table 1. Diet composition of prey items of Tengmalm's owls delivered to the nests in the Ore Mountains in 2004 and 2006 ($\chi^2 = 454.7$, df = 4, $P < 0.001$, $n_{2004} = 6$, $n_{2006} = 6$).

	2004		2006	
Taxa	Number of prey items	%	Number of prey items	%
Muridae (*Apodemus*)	507	58.6	15	2.3
Microtidae (*Microtus,Clethrionomys*)	282	32.6	488	76.1
Gliridae (*Muscardinus*)	10	1.2	4	0.6
Soricidae (*Sorex*)	36	4.2	92	14.4
Aves	30	3.4	42	6.6
Total	865	100	641	100

mostly by *Microtus* and *Clethrionomys* voles (76.1%) and *Sorex* shrews (14.4%) – Table 1. Nevertheless, I found no significant differences between 2004 and 2006 in the number of prey items delivered to the nests by males (6.3±0.8 vs. 5.2±1.5 prey items/night; *t*-test: t = 1.4, $P = 0.2$, $n_1 = 6$, $n_2 = 6$).

Even though the species of the delivered prey differed, there was no difference in male activity between 2004 and 2006 ($\chi^2 = 12.6$, df = 9, $P = 0.2$). In both years male activity showed a monophasic cycle with one peak at the beginning of the night, around 22:00 and 23:00 – Figs 1, 2. Also, in both years, the males were active strictly at night time. Only 5.7% ± 1.2 of their arrivals took place during the daylight (between sunrise and sunset) in 2004 and 4.3% ± 2.3 arrivals were recorded in the same period in 2006 (*t*-test: t = 1.2, $P = 0.3$, $n_1 = 6$, $n_2 = 6$), while most of these daylight arrivals took place within one hour after sunrise (96.7% ± 4.7 vs. 100% ± 0 arrivals/nest) .

The beginning of male activity (the first evening arrival at the nest) positively correlated with the changing time of sunset in 2004 (r =0.7, $P = 0.03$, n = 6) as well as in 2006 (r =

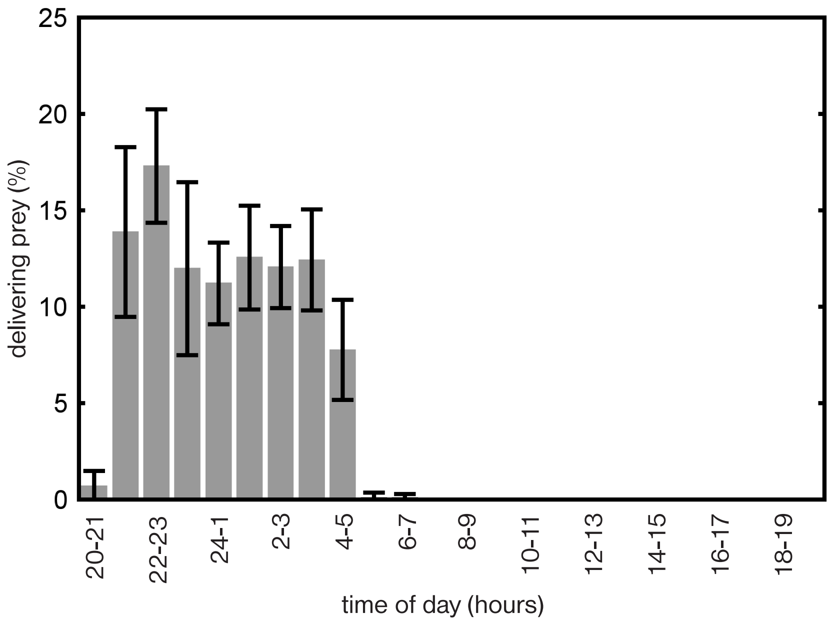

Fig. 1. Activity patterns of Tengmalm's owl males (n = 6) in 2004 evaluated based on prey delivery to nestlings. Values are reported as means ± SD per nest.

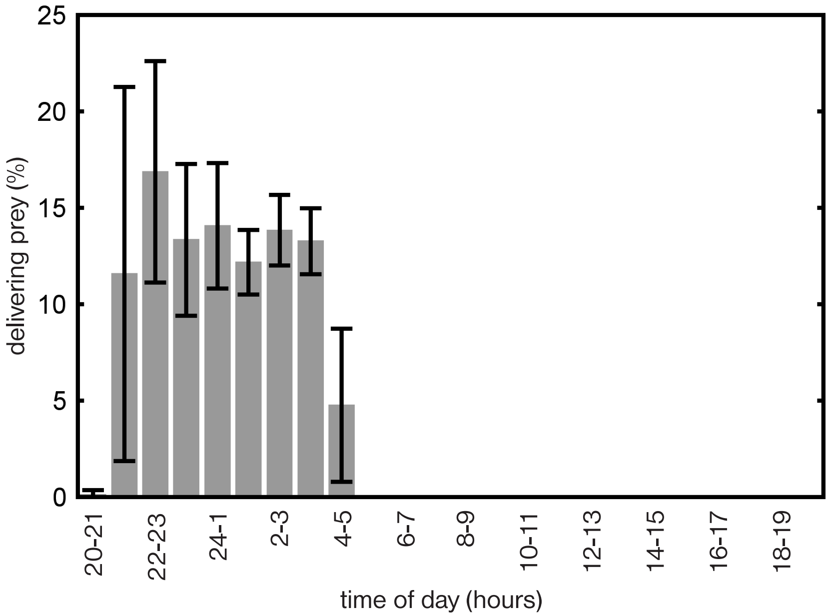

Fig. 2. Activity patterns of Tengmalm's owl males (n = 6) in 2006 evaluated based on prey delivery to nestlings. Values are reported as means ± SD per nest.

0.7, P = 0.04, n = 6) – Fig. 3. However, the end of male activity (the last morning arrival at the nest) was not significantly influenced by the sunrise in 2004 (r =0.5, P = 0.1, n = 6) as well as in 2006 (r =0.2, P = 0.1, n = 6) – Fig. 4. At the same time, no difference was found

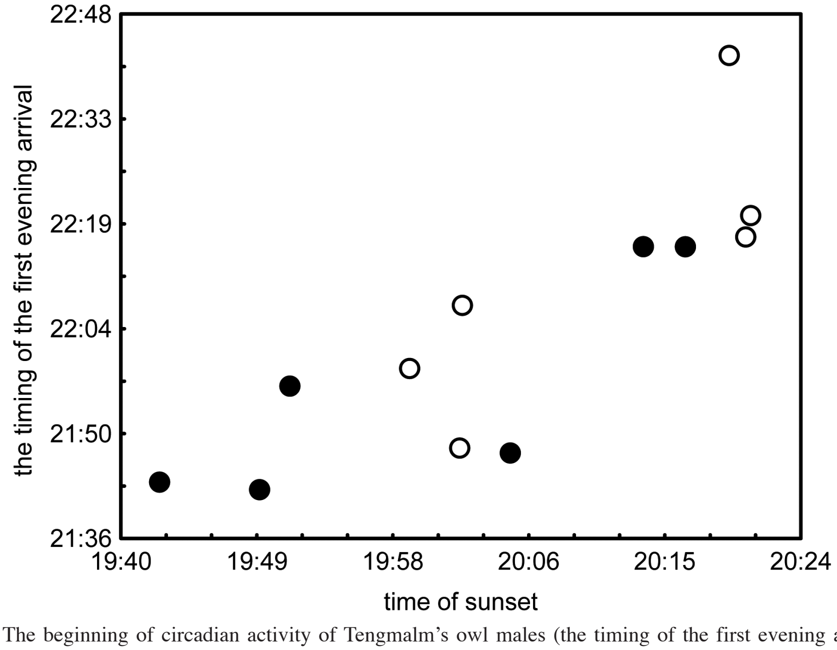

Fig. 3. The beginning of circadian activity of Tengmalm's owl males (the timing of the first evening arrival at the nest) in relation to sunset in 2004 (marked by ●, r =0.7, P = 0.03, n = 6) and in 2006 (marked by ○, r =0.7, P = 0.04, n = 6). Values are reported as means per nest.

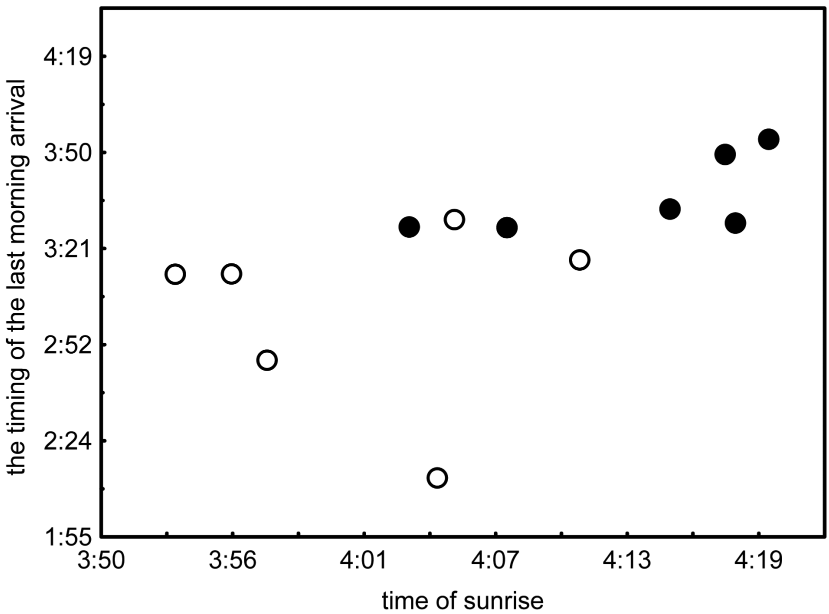

Fig. 4. The beginning of circadian activity of Tengmalm's owl males (the timing of the last morning arrival at the nest) in relation to sunrise in 2004 (marked by ●, r =0.5, *P* = 0.1, n = 6) and in 2006 (marked by ○, r =0.2, *P* = 0.1, n = 6). Values are reported as means per nest.

between the timing of the first male arrival after sunset between 2004 and 2006 (*t*-test: t = 0.8, *P* = 0.4, n_1 = 6, n_2 = 6); in 2004 the males arrived at the nest with prey for the first time 117 ± 7 minutes after sunset, while in 2006 it was 121 ± 11 minutes after sunset. No difference was found between the last morning arrival of a male with prey at the nest before sunrise between 2004 and 2006 either (*t*-test: t = 1.8, *P* = 0.1, n_1 = 6, n_2 = 6); in 2004 males brought the last prey item on average 36 ± 8 minutes before sunrise, while in 2006 it was 58 ± 26 minutes before sunrise.

Discussion

I found significant differences in the abundance and the species composition of small mammals between 2004 and 2006. Simultaneously, I recorded significant differences between the two years in the taxonomic composition of prey delivered by male Tengmalm's owls to their nests. Small mammals were the dominant prey of these owls in both years, whereas birds were rarely taken. Mice (*Apodemus*) and voles (*Microtus* and *Clethrionomys*) were the staple food of Tengmalm's owls in 2004. On the other hand, males in 2006 fed their nestlings mainly by voles (*Microtus* and *Clethrionomys*) and shrews (*Sorex*).

Even though mice and voles show predominantly nocturnal activity during summer (Erkinaro 1969, Wolten 1983), their circadian rhythms differ in relation to their specific metabolic demands. Voles show ultradian activity patterns with range of 2–6 hours for the length of one activity cycle (Erkinaro 1969, Bäumler 1975, Halle & Stenseth 2000), while mice in late spring and in summer show predominantly monophasic activity patterns without distinctive peaks (Gurnell 1975, Wolton 1983, Halle & Stenseth 2000). Since the males fed their nestlings with different prey in

2004 and in 2006, it was possible to expect difference in their activity (S t a r c k & D a v i s 1966, M i k k o l a 1970, S c h u h et al. 1971, Z i e l i n s k i et al. 1983, E n g e l & Y o u n g 1992). Yet their activity patterns in the two years did not differ significantly and no short-term cycles typical for activity patterns of voles or monophasic activity throughout the whole night typical for mice were recorded. In both years, the males brought prey to their nestlings during the whole night uniformly with a single distinctive peak of activity at the beginning of the night. It can be suggested that this activity peak might have been induced by the loud requests of the nestlings in the nest, hungry after a long day of rest, similarly as it is known from the pygmy owl (B e r g m a n n & G a n s o 1965). It is thus possible to presume that the male purposefully increases his activity in this period, or perhaps brings to the nest, at a higher frequency, the prey that was caught earlier at dusk and cached (N o r b e r g 1970, C a t l i n g 1972, K l a u s et al. 1975, K o r p i m ä k i 1981).

Although the taxonomic composition of prey delivered to a nest has been identified only to the family or genus level, it is obvious from small mammals snap-trap captures that the yellow-necked mouse was the most common prey in 2004, whereas the field vole was most frequent in 2004. These two species of small rodents form, together with the common shrew, the most common prey of Tengmalm's owls in the Ore Mountains (H o l ý 2002). Field vole is the dominant herbivore at forest clearings with tall undergrowth of the wood reed (*Calamagrostis villosa*) and in areas covered by prickly spruce (*Picea pungens*) – B e j č e k et al. (1999). On the other hand, yellow-necked mouse dominates in wooded areas, i. e. in mature beech or spruce forests, but also in areas with the absence of dead wood biomass and with removed upper soil layer (B e j č e k et al. 1999). Because of the different habitat preferences of these small mammals, it is probable that their availability for owls is also different (e. g. number and distances of foraging habitats, foraging time and hunting tactics) and their hunting is more or less energetically demanding (see K o r p i m ä k i 1986, 1988, V i l l a g e 1987, K o r p i m ä k i & N o r r d a h l 1989, 1991). Despite the apparent differences in prey abundance between 2004 and 2006, I found no significant differences in the number of prey items delivered to the nests by males between years. It is therefore possible that the two main food types differed in their availability for the Tengmalm's owl. However, the number of prey delivered by males to their nests could be influenced by other factors, mainly by quality (weight) of available prey (J ö n s s o n et al. 1999, D u r a n t et al. 2004, Z á r y b n i c k á et al. 2009).

Even as the abundance of food supply differed in the two years of the study, the circadian activity of males was limited by light conditions in the same way in 2004 and in 2006. The beginning of male activity correlated significantly with the timing of sunset in both years and the males started their activity with the same delay after sunset. The last arrival at the nest was not influenced by the timing of sunrise in either of the years and the males ended their activity at the same time before sunrise in both years. Moreover, the males delivered prey to the nest strictly at night time in both years although the food abundance was significantly lower in 2006 than 2004. During the daylight (between sunrise and sunset) only 5.7% of prey was delivered to the nest in 2004 and only 4.3% in 2006, while most these arrivals took place within an hour of sunrise when the light conditions were still limited. According to N o r b e r g (1964) and K l a u s et al. (1975) the activity of Tengmalm´s owls is not exceptional during the day, and K o r p i m ä k i (1981) notes that low level of activity during the day may be recorded in pairs with older and larger offspring. Observations of activity during the day, and, above all, records of vocal manifestations, are also mentioned by V a c í k (1991), M r l í k (1994), K l o u b e c & P a č e n o v s k ý (1996). However, the results of this study show that circadian activity of male Tengmalm's owls in Central Europe evaluated based on prey delivery to the nests is linked strictly to the period without light and is not significantly influenced by varying food conditions.

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