



Circadian activity of the fat dormouse *Glis glis* measured with camera traps at bait stations

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Abstract

Monitoring of small nocturnal and arboreal rodents is difficult and often conducted using indirect techniques. Here, we measured the circadian activity of the fat dormouse (*Glis glis*) directly using camera traps. The study took place at the Spitzberg in SW Germany. Data were collected using six Bushnell Natureview cameras with a macro lens at baited feeding stations. At 14 out of 41 active camera locations, edible dormice occurred. We collected 301 events between 8th July and 5th October 2018. There were 21.5 events per camera trap (SD 30.4), ranging from 1 to 82. The edible dormouse showed a nocturnal pattern, with a mean activity around midnight at 24:15 h. The pattern shows a slightly bimodal activity. Feeding activity started around or even slightly before sunset and stopped right before sunrise. The study shows that circadian activity, in this respect feeding activity, can be captured by camera trapping, which is a non-invasive method, and can be applied easily in the field.

Keywords Camera trapping · Circadian activity · Diel activity · Fat dormouse · *Glis glis*

Introduction

Monitoring of small nocturnal and arboreal rodent species is difficult and has been conducted mostly with indirect techniques (Melcore et al. 2020; Mills et al. 2016; but see Adamík et al. 2019). Concerning indirect techniques, camera-trapping can be superior to the detection of footprints or hair collection for arboreal species because it enables researchers to collect data about the circadian or diel activity with non-invasive methods (Suzuki and Ando 2019).

The edible or fat dormouse (*Glis glis*) is a small, arboreal, and nocturnal mammal (Mrosovsky et al. 1980) with an average body length between 147.4 ± 10.2 mm (mean \pm SD, males) and 152.4 ± 10.2 mm (females), and a mean body weight of 91.1 ± 18.8 g (males) to 113.2 ± 35.2 g (females) (Čanády et al. 2016). The main distribution of *G. glis* ranges from northern Spain, Italy, Greece, and northern Turkey in the south to central and eastern Europe with Lithuania in the north, and Ukraine in the east with some isolated

populations in Latvia, Russia, the Caucasus, Turkmenistan, and Iran (Amori et al. 2021). *G. glis* inhabits deciduous and mixed woodland with a high proportion of mast seeders (Kryštufek 2010), and denser forest stands with well-connected tree canopies (Juskaitis and Siozinyte 2008). Its main predators are different owl species, foxes (*Vulpes vulpes*), and martens (*Martes martes*, *Martes foina*; Kryštufek 2010). The activity of the edible dormouse occurs from early June to early November (Rodolfi 1994). Just recently, studies started using camera trapping techniques for dormice (Mori et al. 2020a, b; Randler and Kalb 2020). The dormouse is a mostly nocturnal species and has been reported to show a monophasic activity (Braun and Dieterlen 2005), but also a bimodal activity has been reported for the month of August (Laufens 1975) and October (Rodolfi 1994). Laufens (1975) used infrared light barriers to measure the beginning and end of the activity at nest boxes and found some individuals returning to the nest boxes at night (between 23:30 and 24:00; Laufens 1975). Vietinghoff-Riesch (1960) observed fat dormice in an outdoor enclosure and reported that dormice occur sometimes before sunset, occasionally stopped feeding before 3:00 (on June 21st and July 4th) and showed their highest activity between 24:00 and 1:00. These findings suggest that edible dormice might indeed not have a monophasic but bimodal activity pattern. Hence, the aim of this study was to assess the circadian activity rhythm of

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the edible dormouse with camera traps and compare the results with data from published literature concerning the activity rhythm of *Glis glis*. According to previous findings by Vietinghoff-Riesch (1960), Laufens (1975), and Rodolfi (1994), we expect edible dormice to show a bimodal activity pattern during our study period.

Materials and methods

Study area

The study took place at the Spitzberg in Baden-Württemberg (SW Germany). The area is located between Tübingen in the east and Rottenburg-Wurmlingen in the west, about 623 ha in size. The largest part is covered by wood, including the heights and the northerly slopes. The forest is characterized mainly by Scots pine (*Pinus sylvestris*), oak (*Quercus spec.*), and beech (*Fagus sylvatica*). A total of 32 mammal species (excluding bats, Chiroptera) have been reported for the Spitzberg (Randler et al. 2019). The main predators of fat dormice, pine marten (*M. martes*), beech marten (*M. foina*), fox, and tawny owl (*Strix aluco*) are abundant species in the study area (Randler et al. 2019).

Camera trapping

We collected data between 29th June and 5th October 2018, using six Bushnell Natureview cameras (model 119740). Due to a limited number of camera traps, we swapped observation locations approximately every two to 3 weeks to collect activity data from various habitats and individuals across the study site, resulting in a total number of 41 locations at the end of the study period. Initially, the study area was separated into grids ($N=37$; Randler et al. 2019), but some were not suitable for the bait stations (e.g., because they were in the open field or in vineyards). Then, in every grid, a camera trap was installed. Based on habitat characteristics, sometimes a second camera trap was installed, e.g., when habitat heterogeneity was high (this was based on a convenience decision). At seven of the 41 camera locations, no mammals were photographed (but some bird species instead; Randler 2021). However, there were only 14 camera locations where *G. glis* could be detected. These sites were on average 344 m (SD 214 m) apart from each other; minimum distance was 77 m, and maximum distance was 827 m.

All cameras had a macro lens, which allows taking sharp images at 60 cm distance. Own observations in the lab with house mice (*Mus musculus*) showed that such small mammals are reliably captured at distances of 50 to 75 cm. Camera traps operated 24 h/day and collected a series of three photos when triggered by motion, whereby the trigger sensor level was set to the highest level. Furthermore, we

activated the night vision shutter and set the LED control to “low” to enhance photo quality during nighttime. Cameras were mounted on trees approximately on a mean height of 1.20–1.30 m above the ground (between 0.5 and 1.9 m) close to baits in open, unsheltered feeding places to allow approaches from all sides. The bait stations were placed in a way that they could be reached from above to avoid that dormice had to touch the ground to reach the bait stations. Baits consisted of a standardized self-mixed food of apples, apple juice, honey, peanut mousse, raisins, prunes, and mixed bird food, including different seeds, e.g., sunflower seeds. Food was replenished every other or third day to provide a continuous food supply. During these occasions, we also checked cameras for malfunction and switched memory cards or batteries if necessary.

Image analysis

We used the clock time of a triggered camera photo as activity record of *G. glis*. If an individual triggered a camera repeatedly without leaving the field of view for 5 min (Meek et al. 2016), we only used the time stamp of the first photo as activity record to reduce pseudo-replication. We tried to distinguish juveniles from adults, but the quality of most images was not good enough. In high-quality images, the structure of tail, ears, and overall body size could be assessed. However, when images were not sharp enough, it was not possible to identify whether, e.g., the tail was “fluffy” as in adults or if juveniles only produced the impression of a “fluffy” tail by showing fast tail movements in front of the camera. Since we could not reliably identify the age of most individuals, we decided to neglect any further comparison of activity patterns between adults and juveniles.

Statistical analysis

All statistics was performed with the “activity” package (Rowcliffe 2019) in R (R Core Team 2020). As the activity of animals is known to be related to daily oscillation in illumination (Halle and Stenseth 2012), we used the solartime function to anchor event times to sunrise and sunset at the given location. Afterwards, we used the “fitact” function to fit circular kernel models to our data, while estimating error by bootstrapping with sampling from our data. Additionally, we compared the activity patterns of the months July, September, and October with the “overlap” package (Ridout and Linkie 2009). This method calculates a coefficient of overlapping, ranging from zero (no overlap) to 1 (total overlap; Meredith and Ridout 2014). This is widely used to identify the overlapping activities between species and seasons (e.g., see Viviano et al. 2020; Fan et al. 2020; Mori et al. 2020a, b). To account for different day length across the 3 months, we converted clock times to “sun times” by mapping the time

to sunrise ($2/\pi$) and sunset ($3\pi/2$) prior to analysis with the “mapprools” package (Bivand and Nicholas 2020). The data are available in the Harvard Dataverse (<https://doi.org/10.7910/DVN/GTZRNI>).

Results

During the whole study period (29th June to 5th October 2018), we applied camera traps at 41 different locations at the Spitzberg. However, at seven locations, no animal activity was observed, and edible dormice were only captured by camera traps at 14 of these locations between 8th July 2018 and 5th October 2018. The 14 camera locations, which successfully caught dormice, operated on average about 12 days (range 7–21; Fig. 1). The mean distance between the sites that captured edible dormice was $344.38 \text{ m} \pm 214.51$. We collected 301 independent of dormouse activity with an average of 21.5 capture activity events per camera trap (SD 30.4), ranging from 1 to 82 activity captures per camera.

The edible dormouse showed a strong nocturnal pattern, with a mean activity around midnight 24:15 h (standard deviation; 2:34 h) (Fig. 2). The pattern showed a slightly bimodal activity. Feeding activity started around or even slightly before sunset and ended before sunrise (Fig. 2).

We further analyzed the activity patterns for the months of July ($N=60$), September ($N=205$), and October ($N=31$) separately. Edible dormice showed a strong bimodal activity pattern in September and October, whereas the activity pattern in July had only a unimodal pattern peaking around midnight (Fig. 3). The analysis of the activity patterns showed a high degree of overlap between all months (July–September 0.86, 95% CI 0.78–0.95; July–October 0.88, 0.83–1.06; September–October 0.95, 0.95–1.13). The



Fig. 1 Edible dormouse (*G. glis*) at a baited camera trap

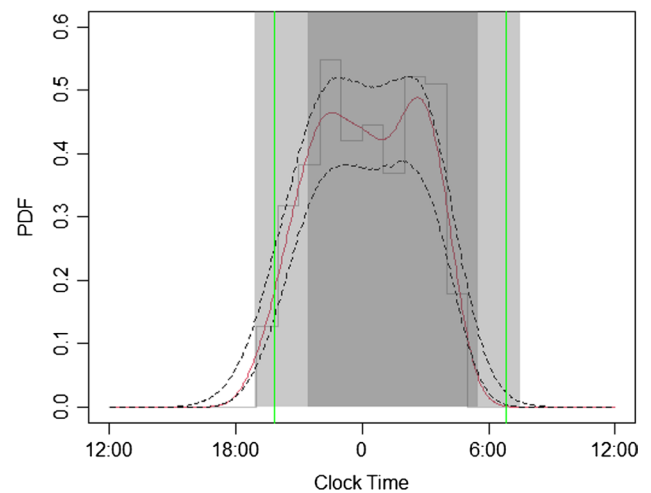


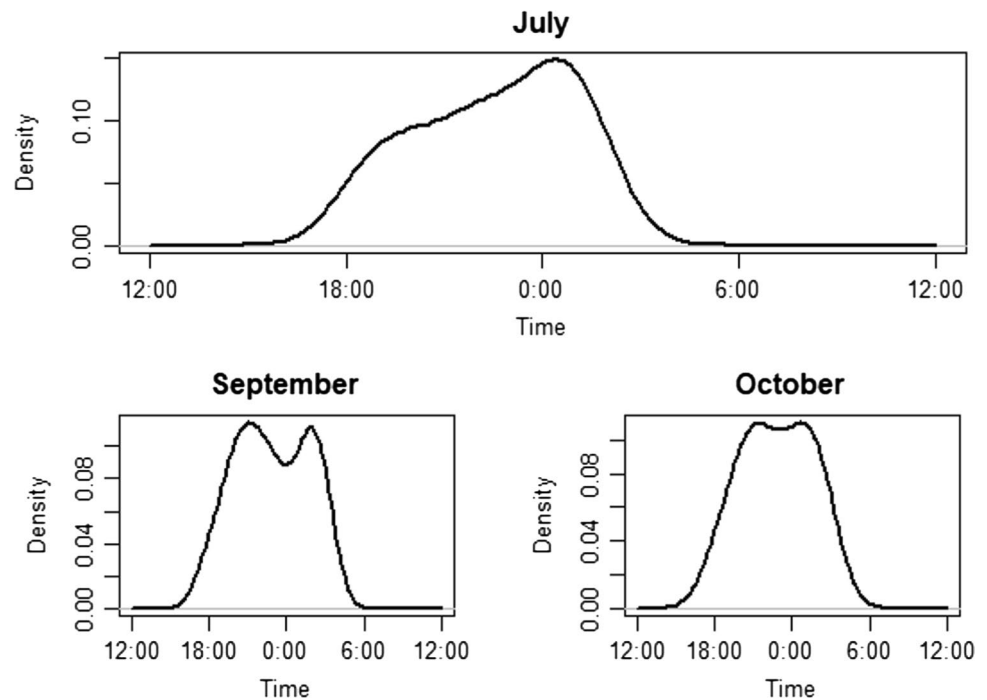
Fig. 2 Feeding activity pattern of the fat dormouse (*G. glis*) at baited stations. Activity patterns are shown as probability density functions (PDF) dependent on average anchored clock times, i.e., observation times mapped to sunrise and sunset. Diel activity is illustrated by observation frequencies (grey step functions) and fitted Von Mises kernel distributions (red lines, including 95% confidence intervals (dashed lines)). Green lines indicate the mean sunrise and sunset. Dark grey regions indicate night hours, light grey regions the range of sunrise, and sunset times during the study period

month of August was not analyzed as only five individuals were photographed during this period.

Discussion

Although usual textbooks about mammals report a monophasic activity period of the edible dormouse, we here found a bimodal pattern both across the study period as well as for the months September and October. Concerning July, data suggest a unimodal pattern. However, this does not seem untypical, because Laufens (1975) reported dormice returning to their nest boxes at night, and Rodolfi (1994) similarly reported a bimodal pattern in October. Taken together with our results, the statement about monophasic activity should be reconsidered. However, future studies are needed to support our results. Also, we found that feeding activity started around or even before sunset but ended before sunrise, even though *G. glis* seemed to stop feeding activity earlier in July than in September and October (Fig. 3). Moreover, when comparing the activity pattern of the three months, in July, dormice did not show such a bimodal pattern as in September and October. This is in accordance with Vietinghoff-Riesch (1960), who reported that during summer (June/July), feeding activity stopped sometimes at 3:00 and dormice occurred outside their nest boxes before sunset. The difference between the activity pattern of July and other months might be due to more time being allocated

Fig. 3 Activity pattern of edible dormice for the months of July, September, and October. Activity for August is not depicted due to low sample size ($N=5$). The graphs depict fitted kernel densities depending on daytime



to mating activity which usually takes place during June and July (Vietinghoff-Riesch 1960). Also, duration of the night is shorter compared to autumn which may shift two activity phases into one.

Furthermore, our study showed that circadian activity, in this respect feeding activity, can be captured by camera trapping, which is a non-invasive method, that can be easily applied. Baited camera traps are known to have an influence on species detection compared with non-baited traps (Randler et al. 2020), and probably as well on the circadian activity (Di Cerbo and Biancardi 2013). In particular, studies using baited traps mainly portray feeding activity (and not, e.g., activity in relation to sexual behavior). Dormice are known to move only short distances away from their shelters. For example, Hürner and Michaux (2009) showed that edible dormice sometimes move (mean \pm SE) $252 \text{ m} \pm 19$ (range 60–479 m) per night but usually do not move that far away from their nesting site (72 ± 6 , 16–140 m). Cornils et al. (2017) showed that traveling distance seems to depend on food availability as edible dormice traveled about 87.7 ± 73.02 m in full mast years of beech and oak, but 125.4 ± 91.6 m in non-mast years. Hence, feeding stations might cause edible dormice to not travel that far away from their shelter and hence enhance the capture rate of (feeding) activity with baited camera traps. The year 2018 was a year with a high mast of beech and oak in the area (pers. observation).

The animals in our study could not be identified individually which makes it difficult to disentangle individual activity patterns from patterns on the population level. For example, Bosch et al. (2015) showed an influence

of body weight on diel activity in Eurasian red squirrels (*Sciurus vulgaris*), suggesting some hierarchies concerning feeder visitations. As there are personality differences in red squirrels (Uchida et al. 2020), these individual differences may also influence daily activity in dormice (Thomas et al. 2018). Moreover, we were not able to reliably distinguish between adults and juveniles, and therefore did not compare the activity pattern between age groups. However, the activity pattern between juvenile and adult rodents is known to differ as, for example, juvenile Siberian flying squirrels (*Pteromys volans*) are active during daytime while adults have an exclusively nocturnal activity pattern (Suzuki et al. 2016). Hence, future studies might focus on comparing the activity pattern of juvenile edible dormice and adults. The strength of our study is that we collected direct measurements of dormouse activity for 24/7 at baited camera stations. However, we did not place any camera traps higher in trees (e.g., > 2 m high), which could have further enhanced the capture rate of dormice activity. Future studies might therefore combine baited and unbaited traps as well as camera traps near the ground and in trees to compare capture rates and further identify the diel activity rhythm of edible dormice in the field. Ideally, it could be combined with radio-tagged individuals.

Author contribution CreDIT statemet: CR did the fieldwork, NK made the analyses, and both authors contributed to the writing of the paper.

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