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Research Article

Diel Activity Patterns of Garden Dormice *Eliomys quercinus* (Linnaeus, 1766) (Rodentia: Gliridae) Assessed by Camera Trap Data

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Abstract: Garden dormouse *Eliomys quercinus* populations have been declining in range and number throughout Europe. Understanding and, therefore, preventing this decline is urgently needed. To devise effective conservation strategies, it is essential to gain knowledge on activity patterns of the target species. Diel activity patterns of garden dormice were investigated at 25 different sites in Germany. In an intensive camera-trap survey from March to October 2020, a total of 192,136 pictures were recorded in 3,682 camera-trap days. The relation between activity and environmental parameters such as habitat (urban vs. natural) and sunrise vs. sunset was investigated. In 2021, the cameras continued to monitor the forest sites and collected a further 41,659 images. The study revealed the effectiveness of camera trapping to gather information on activity of an elusive small rodent with minimum disturbance to the animals. Garden dormice were found to be predominantly nocturnal but were occasionally active during the day in the summer months. The peak of activity at all sites was shortly before midnight. Daytime activities could be related to the presence of young garden dormice or the supply of food. The fact that garden dormice maintain their nocturnal activity, even in urban areas, can be interpreted as an effect of predation pressure in the city.

Key words: In search for the garden dormouse, wildlife research, photographic sampling, phenology, non-invasive monitoring

Introduction

Diurnal and seasonal cycles affect the reproduction, physiology and behaviour of many species. Analysing the daily activities of a species and their dependencies is an important part of understanding the biology of an organism. Knowledge of a species' habitat requirements and environmental conditions facilitates appropriate conservation action. The population of the garden dormouse *Eliomys quercinus* (Linnaeus, 1966) has declined by about 50% within the last three decades (as of 2009) (Temple & Terry 2009). So far, the reasons for this remain unclear (Bertolino 2007) and the species has not been of great interest to researchers (Lang et al. 2022). The lack of reliable data is in contrast with the urgent need of information on the actual numbers and population trends of the species. Therefore, a project called "In search for the garden dormouse" was launched in Germany. It aims to investigate what is causing the decline and subsequently, using the findings, a conservation strategy will be developed and implemented (Büchner et al. 2024). Part of the research focuses on the biology on the species, as even some basic data are not available (Büchner et al. 2024). The garden dormouse is mostly found in structurally diverse forests in the highlands of low mountain ranges. It prefers to live on rocky ground but also occurs around cities (Meinig & Büchner 2012). It is already known that garden dormice are predominantly nocturnal and arrange their activity according to sunrise and sunset (Vaterlaus-Schlegel 1997). Their night-activity is interpreted as avoidance of predation (Mori et al. 2020).

In the present paper, we aim to investigate changes in daily activity during the active season from spring to autumn. We studied activity patterns using camera traps, observing the animals over a long period to gain an understanding of their behaviour. The aim of this study is to gain a better understanding of garden dormouse activity by examining its diurnal rhythm. Our goal is to learn the possible reasons for fluctuations in both daily and seasonal activity. However, the question arises as to what extent this manifests itself reliably, and what differences are seen in the various habitats where the garden dormouse lives.

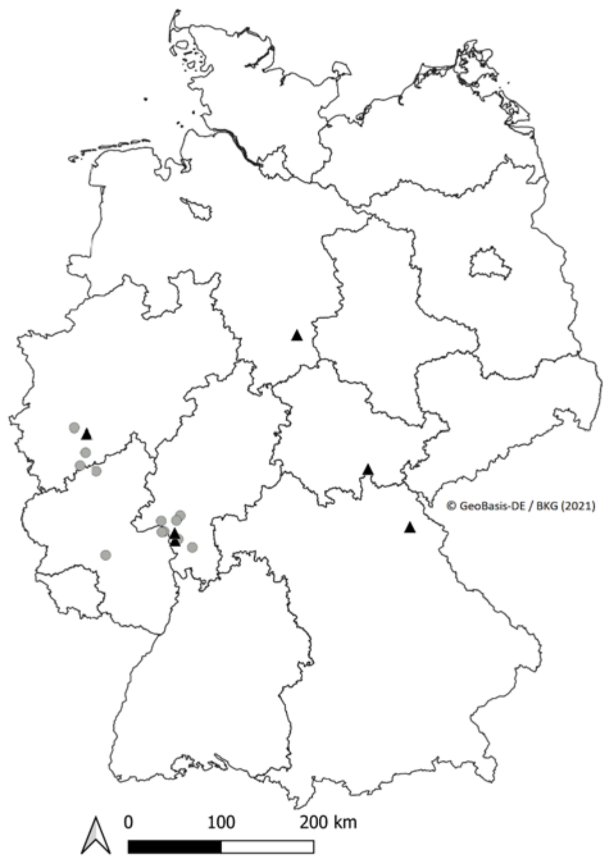

Fig. 1. Overview map of the study areas. Urban areas marked with a circle and forest areas marked with a triangle; the symbols represent study sites and not single camera traps. In these study areas, a total of 25 camera traps were deployed in 2020 and 2021.

Materials and Methods

The survey took place at 25 different locations in Germany (Fig. 1). The study areas were classified as either urban or forest areas. Urban sites were defined as those that are within human settlements and under human influence. Forest sites were defined as those outside human settlement and influence, and at least close to their natural state. The Groß-Gerau forest site, for example, is a small patch of woodland at 1 km from the nearest settlement. Although it is not surrounded by a large contiguous area of forest, it can be clearly distinguished from the urban sites, which are in the middle of a town.

A digital wildlife camera (Minox DTC 550, Minox GmbH, Isny, Germany) was deployed at each of the 25 study sites. These cameras have a shutter release speed of 0.4 seconds, and the motion sensor has a range of up to 15 metres. This model has a 40° angle of view. No special changes to the lens were necessary to improve the capture of images of small animals. However, the maximum rate of nine frames per shutter release was set to capture fast moving individuals.

The study period started in June 2020 and ended in late October 2020. To collect more data from the forest sites, these cameras were deployed there again between March and October 2021.

Household sponges sprinkled with walnut oil or fruit juice (e.g. apple juice) were used as bait to increase the yield of photos. The cameras were deployed and maintained by selected volunteers who followed a protocol with instructions for mounting, baiting, checking cameras, and reading of the memory cards. Settings for the camera (exact time) and guidelines for the documentation (including coordinates of camera locations) were pre-defined and protected accordingly, enabling the recording of standardized and comparable data. The memory cards were collected once a month. Incorrect deployment can lead to false negatives. However, with bait placement, a fast shutter speed and a wide angle of coverage, this risk can be minimised.

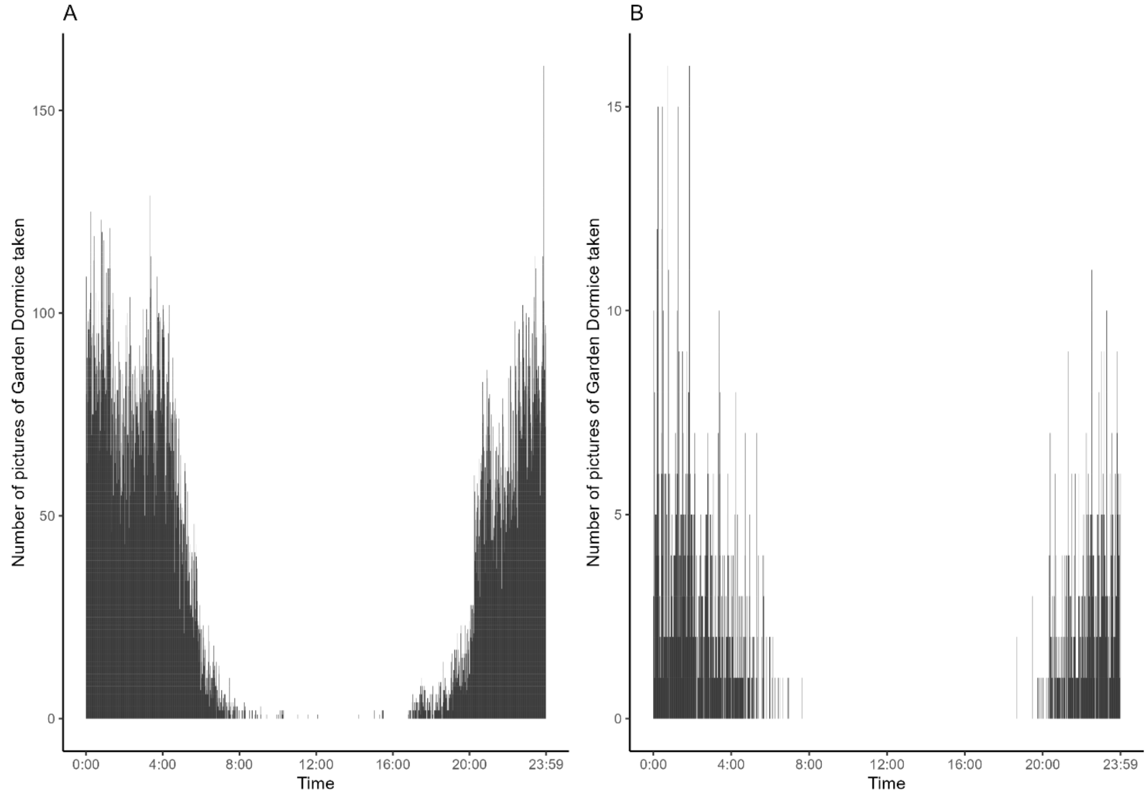

Fig. 2. Garden dormice activity in a 24-hour period based on the number of pictures taken on camera traps in urban areas (A) from June – October in 2020 with n = 43,752 (data from 7 camera traps) and in forest areas (B) from June – October in 2020 and 2021 with n = 2,331 (data from 12 camera traps combined) in Germany.

In 2020, we monitored 12 urban study sites with 12 active cameras. The maximum photo yield of a single camera, at an urban site was 85,057 and the minimum was 22 with a mean of 13,808 photos per site. There were 13 cameras active at 13 forest sites in 2020. The maximum yield of a camera at the forest sites was 2,562 and the minimum zero, with a mean of 817 pictures per site. In 2021, 11 cameras were active at ten forest sites with the maximum yield of a camera being 12,141 and the minimum 2 with a mean of 3,119 pictures per site. However, out of 25 sites with active cameras, only 19 contributed to this study with data for analysis, as the others had no recordings of garden dormice or suffered technical failures.

In total, 192,136 photos were taken in 2020. Out of those, 44,904 photos showed garden dormice and were included in the analyses. In 2021, there were 2,405 photos showing garden dormice (out of 41,659). First, the raw images were sorted. All animals were identified at least to the genus but mostly to species level. Photos with animals were fed into the programme Wild.ID (Version 1.0.1, Wildlife Insights). The data was then transferred to an Excel spreadsheet (Version 2101, Microsoft Corporation, USA) where the tables were formatted and saved in CSV file format.

The times and triggers were taken from the EXIF data of the camera recordings.

For the display of activity in relation to sunrises and sunsets, it was necessary to determine them for each camera location. The calculations were made with R Studio (R Studio Team 2022). The mean values of these times were used for the graphical representation. Calculation of the sun times was done with maptools (Bivand 2021). The R package ggplot2 (Wickham 2016) was used for the graphical representation. Based on these calculations, the classification into day and night was made. The period between the calculated times for sunset and sunrise is referred to as 'night'.

Results

Garden dormice were active during the night with a few exceptions. Activity occurred primarily in the evening or morning hours and during the dark night hours (Fig. 2 A and B). Phases of higher and lower activity occurred. A phase of particularly high activity was generally followed by a period of low-

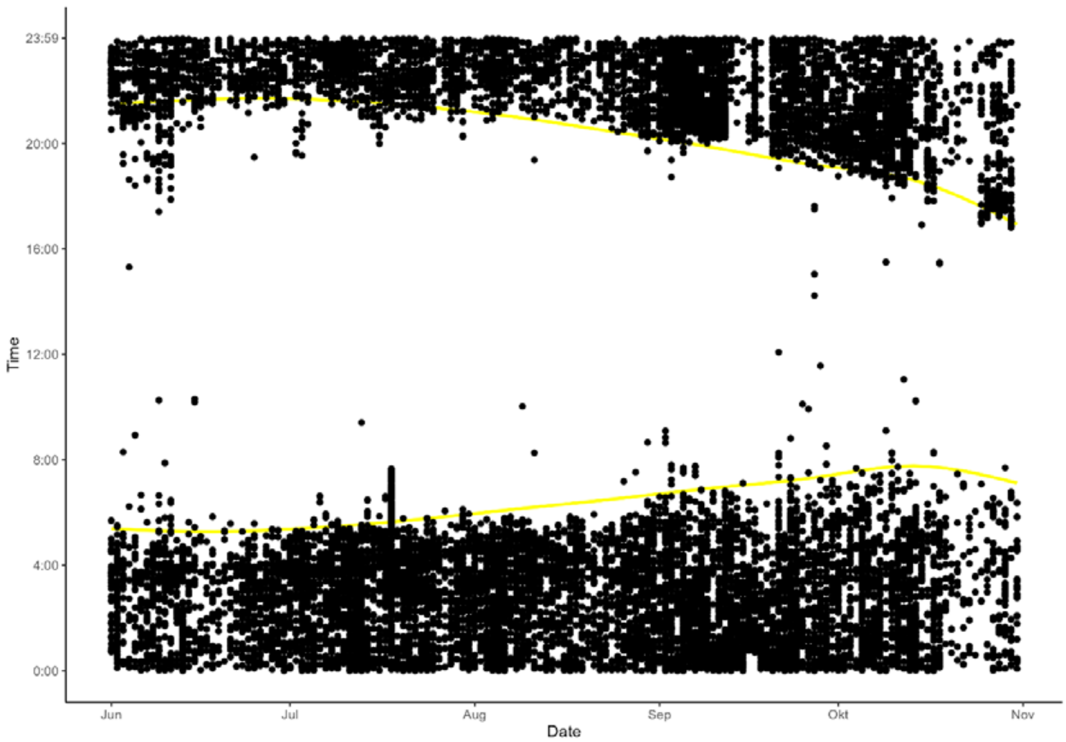

Fig. 3. Seasonal activity of garden dormice in relation to sunrise and sunset (yellow lines) based on the number of pictures taken on camera traps in urban areas from June – October with n = 43,752 (data from seven camera traps) in Germany.

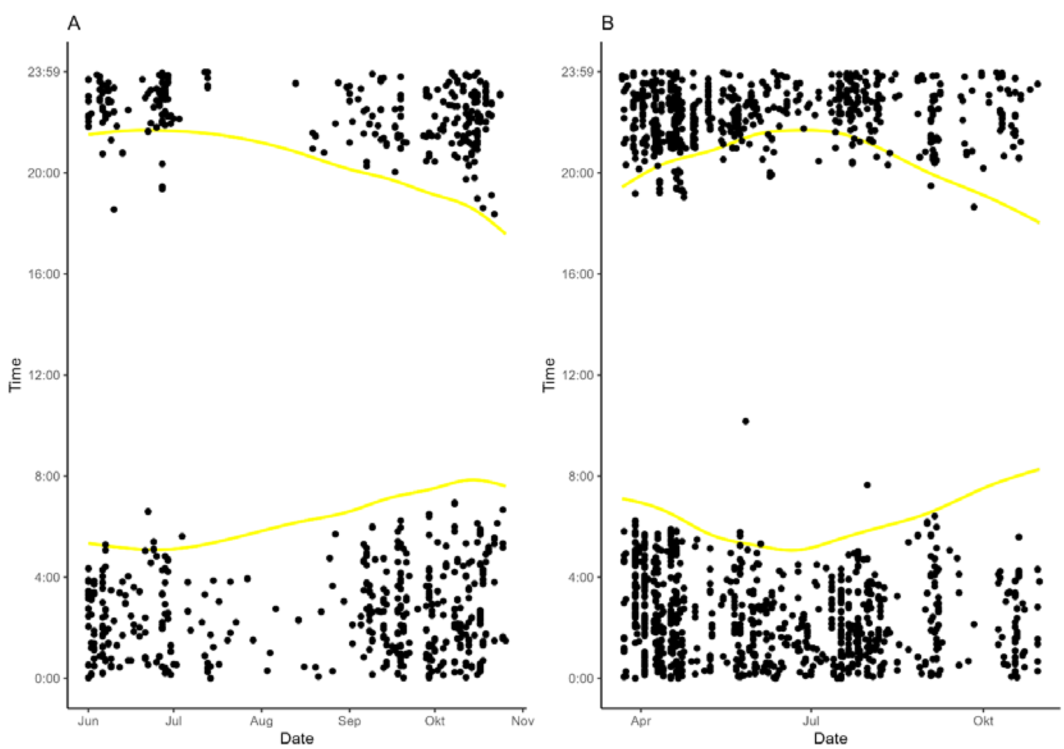

Fig. 4. Seasonal activity of garden dormice in relation to sunrise and sunset (yellow lines) based on the number of pictures taken on camera traps in forest areas from June – October in 2020 (A) with n = 1,152 (data from eight camera traps) and in forest areas from March – October in 2021 (B) with n = 2,405 (data from four camera traps) in Germany.

er activity. Activity steadily increased in the early evening and gradually decreased towards morning. Occasionally, activity during the day was recorded. Juveniles were photographed at some sites.

In urban areas, the highest activity occurred just before and just after midnight, also shortly before 4 a.m. in the early morning hours.

There were two peaks in nocturnal activity of the garden dormice at the forest sites. The first occurred shortly after midnight and a second peak occurred around 2 a.m. Shortly before and shortly after 4 a.m. further peaks of activity occurred. Compared to the early morning and evening hours, activity around midnight was consistently high. After 7 a.m., activity ceased at forest sites, with no further daytime activity until after 6 p.m. (Fig. 2 B).

The analysis of seasonal activity also shows that garden dormice are predominantly nocturnal. However, there were occasional recordings of daytime activity (cf. Figs. 3 and 4 A, B).

In general, daytime activity did not seem to depend on the habitat of the animals. At the forest sites (Fig. 4 A and B), the animals were active in daylight as well as in the urban areas (Fig. 3).

In the urban areas, daytime activities occurred throughout the study period, with more in June and in the autumn. Animals were active for several hours after sunrise and before sunset. During these periods, any influence of twilight could be ruled out. Daytime activities appear to be reasonably balanced between the morning and evening hours with a slightly higher proportion in the hours before sunset.

The forest sites showed a similar picture in both years. Most daytime activity occurred just before sunset. At the forest sites in 2020 (Fig. 4 A), no daytime activity occurred before sunset or after sunrise after early July. At the same sites in 2021 (Fig. 4 B), daytime activity was recorded almost until October. Altogether, at the forest sites, daytime activity tended to be more closely tied to solar times than in the urban areas.

All sites are similar in one aspect: camera triggering occurred repeatedly during the day, but predominantly in the evening hours. Garden dormice were not exclusively tied to the dark hours of the night. Nevertheless, the main activity phases occurred during these hours. The animals were least active in the morning hours. In the forest sites, they were only sporadically active in the summer months after sunrise.

Discussion

Our results confirm that garden dormice are predominantly active at night. This is in line with camera trap data from the Italian Alps where nocturnal activity was mainly interpreted as avoidance of predation pressure (Mori et al. 2020, Vaterlaus-Schlegel 1997). However, individual recordings show that at least some individuals can also be active during the day. These daytime activities are not habitat dependent. They occurred in forest sites as well as in urban areas. One possible reason for daytime activity could be the need to care for juveniles. Mammals expose themselves to a fundamental risk when it comes to obtaining food for their young (Castillo et al. 2012). Garden dormice have their offspring from the beginning of June (Storch 1978, Weis-Dootz 2007). Pregnant and later lactating females have a higher energy demand and need more food (Rogowitz & McClure 1995). It is conceivable that diurnal activity increased because of this.

Small mammals in urban areas can be active around the clock, whereas the same species is strictly nocturnal in rural areas (Łopucki & Kiersztyn 2020). This could be the response to less intense predation pressure in built-up areas (Łopucki & Kiersztyn 2020). Another reason for daytime activity may be disturbance. The extent to which this is the case cannot be accurately determined as the animals were usually recorded when foraging and feeding on bait. However, garden dormice in urban areas are still mainly nocturnal as in forest habitats, even if slightly more activity was observed during the day in cities. Garden dormice may be under pressure from urban predators, which is also indicated by data from carcasses (Famira-Parcsetich et. al. submitted). Garden dormice are oriented to night-time as well as to sunrises and sunsets (Vaterlaus-Schlegel 1997). This behaviour alleviates predation pressure (Smith & Smith 2009).

Temperature is also a factor that could affect animal activity (Buffo et al. 2007). According to Bertolino (2007), garden dormice rely on stored radiant heat from the day. This may be mainly due to increased activity of arthropods, the potential prey of garden dormice, at higher temperatures. Summer torpor occurs regularly in garden dormice (Gabe et al. 1964, Daan 1973). Torpor is the possible response to unfavourable temperatures, extreme drought or food shortage, which all suggests that activity can be affected by temperature (Heinrich & Müller-Stiess 2004). However, the effect of night-time temperature may be less pronounced in urban areas than in forests or open spaces, because buildings emit and trap heat, helping to sustain higher ambient temperatures (Parlow et al. 2011). There was higher activity before sunset than after sunrise at dawn at all sites. Again, the influence of temperature could be responsible for this (Buffo et al. 2007).

Garden dormice showed peaks of activity around midnight at both urban and forest sites. After 4 a.m. there was a clear increase in activity at the forest sites. The reason for this could be that fewer woodland predators are active in the morning hours (Vilella et al. 2020, Posillico et al. 1995, Kämmerle et al. 2020). In contrast, disturbance in urban areas can be higher due to human activity. Garden dormice in forests in the Italian alpine region increased the activity significantly around 10:48 p.m. (Mori et al. 2020). A similar pattern is known for several nocturnal species, like the brown hare (*Lepus europaeus*), with a peak of activity in the evening (Schai-Braun et al. 2012). Around midnight, the brown hare's activity decreased again with an increase in the morning hours. It was thought that these periods of low activity served to conserve energy reserves (Schai-Braun et al. 2012). A similar behaviour can be assumed for garden dormice with less activity after phases of higher activity.

In citizen science projects, professional scientists collaborate with volunteer citizen scientists, both sharing a common research interest. While scientists are often sceptical of the ability of unpaid volunteers with variable (and often unknown) expertise to produce accurate datasets, a growing body of publications clearly shows that diverse types of citizen-science projects can produce data with accuracy equal to or surpassing that of professionals (e.g. Crall et al. 2011, Gadsden et al. 2021, Leocadio et al. 2021). A key to success is the project's ability to build an engaged community of volunteers who generate high-quality data to support robust scientific conclusions (Jäckel et al. 2023). In our case, this was achieved though:

(a) The selection of a small group of highly motivated volunteers who had already shown their dedication to the project in the past ("elite", sensu Randler 2022).

(b) Using wildlife cameras as sensors that allowed for consistent and verifiable quality (Lasky et al. 2021).

(c) Precise instructions on how to manage cameras and bait.

Despite this, in some cases the camera was pointed directly at the midday sun or too close to a bright object, resulting in unusable images. Consistency of data collection was a challenge, too. Most data were received on time on a monthly basis. However, in some cases, data were received months late. Despite these occasional problems, citizen science not only helped to save money and personnel in our project but it also promotes public awareness of science and conservation. As a result, large quantities of reliable data on the activity ecology of the garden dormouse were obtained that would otherwise have been too costly to generate.

Our results confirm the nocturnal activity of the garden dormouse and we suspect predation risk is the main reason for the animals remaining nocturnal in cities. This understanding is important to develop conservation measures for garden dormice in urban areas.

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