



The Garden Dormouse as a Research and Conservation Priority in a German Large-Scale Citizen Science Project

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Abstract: The garden dormouse is a European mammal whose range has shrunk rapidly within the last 40–50 years, disappearing from large parts of Central and Eastern Europe. This ongoing decline is worrying, especially because the underlying reasons are poorly understood. Since 2018, the German-wide project ‘In Search of the Garden Dormouse’ aims to reveal and investigate causes for this drastic decline. The current garden dormouse distribution has been assessed using a large-scale citizen science approach. Dormouse records were gathered via an online reporting tool and systematically by biologists and citizen science volunteers with different methods. The current garden dormouse distribution in Germany is divided into several isolated areas. The species is currently common in central and southwestern parts of Germany but has declined or is even locally extinct in several regions. A range loss of ca. 35 % since

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1970 could be calculated. The observations in some urban areas are so numerous that vital populations can be assumed for this part of the range, in contrast to a decline in several low mountainous areas. The project provides insights into the biology and ecology of an endangered and understudied species; it has shown that a small mammal can become a flagship species. It successfully raised awareness of dormouse conservation needs with the public.

Key words: In Search of the Garden Dormouse, geographic range, ecology, conservation, *Eliomys quercinus*

Introduction

As the earth is losing species at an alarming rate (BARNOSKY et al. 2011), adequate data on geographic distribution and species' conservation status become essential for a conservation strategy. Data on species distribution are generally collected by continuous and effective monitoring (MARTIN et al. 2007, ROBINSON et al. 2018, SCHMIDT & VAN DER SLUIS 2021). Key principles include an appropriate monitoring design and its integration into management actions, involvement of people and organizations, sound data management and public outreach (ROBINSON et al. 2018). At the same time, attributes such as rarity, low detectability, a cryptic lifestyle, and narrow habitat niches present particular challenges associated with monitoring of threatened taxa (MARTIN et al. 2007). This is why data collected on threatened species often focus on geographic distribution and trends (SCHMIDT & VAN DER SLUIS 2021). Distribution maps based on reliable observations represent the first step in status assessments and for developing conservation strategies.

The garden dormouse is a European mammal whose range has shrunk rapidly within the last 40–50 years, disappearing from large parts of Central and Eastern Europe (BERTOLINO 2017). This ongoing decline is worrying, especially because the underlying reasons are poorly understood (BERTOLINO 2017). Although various hypotheses were discussed among dormice experts – such as during some of the previous International Dormouse Conferences (MORRIS 2003) – no conspicuous drivers for the decline could be identified, also owing to the contrasting habitats occupied by garden dormice. In Germany, for example, habitats range from vineyards, gardens and settlements in the warmest regions, to predominantly cold and damp areas such as spruce forests and boulders in low mountain ranges (MEINIG & BÜCHNER 2012). Based on this diversity, garden dormice appear adaptable in terms of habitat. So why should they decline? How should the effective conservation strategy look like?

Despite the urgent need for accurate data on the species' distribution and its ecology for developing conservation measures, the garden dormouse has

rarely been in the focus of current research until recently (LANG et al. 2022). Since 2018, the German-wide project 'In Search of the Garden Dormouse' aims to investigate causes for this drastic decline. Based on the findings of this project, a conservation strategy is being developed and will be implemented. In particular, the project encompasses research on the current versus previous garden dormouse distribution in Germany; genetic diversity; phenology, such as daily activity, timing of hibernation and reproduction; habitat use and regional differences; feeding ecology and spatial variation in diet composition; as well as causes of mortality, diseases and parasite load. This broad research approach is realised as a joint project, involving the Friends of the Earth Germany (BUND), the Conservation Genetics Group at Senckenberg Research Institute, the Justus-Liebig-University Giessen and several partners as well as hundreds of citizen scientists. The project is funded within the Federal Programme for Biological Diversity by the German Federal Agency for Nature Conservation. Here, we describe the results of the current garden dormouse distribution in Germany, representing the basis for all subsequent conservation measures.

Materials and Methods

The project is the joint work of biologists, students and citizen science volunteers (CSV) with different levels of involvement. A crowd science approach was chosen to map the distribution of the garden dormouse in Germany. A reporting tool on the project website was installed (<https://www.gartenschlaefer.de/en/reporting-tool/>). One challenge to this approach is the time-consuming verification of data quality. In some other projects, the ratio of data sets submitted by volunteers to usable data sets was criticised as low (Hunter et al. 2012). Limited training, background knowledge and expertise of CSV can potentially lead to poor quality or misleading data being submitted (Hunter et al. 2012). Considering this, a great effort was invested to train volunteers in this project. The reporting tool collects data on the observed dormouse species: all four species occurring in Germany could be reported: garden dormouse (*Eliomys quercinus*),

Table 1. Small Mammal Evaluation Criteria (SMEC) used for evaluating garden dormouse reports (from ZISTL 2021, with modifications).

Category	Definition
C1	<i>Absolutely unambiguous:</i> The report represents positive evidence. The evidence is substantiated by photos, videos, recorded calls, footprints, carcass, DNA-sample. It passes repeatable verification (by experts).
C2	<i>Very likely:</i> The report comes from an expert. The report cannot be re-checked; it cannot be re-determined. This observation is also counted as evidence.
C3	<i>Uncertain:</i> The report cannot be counted as evidence.
C3a	<i>Promising:</i> The report is coherent and fits the characteristics of the target species. Details and characteristics of the species are described (e.g., eye mask for the garden dormouse). A longer observation time, e.g., over several minutes, or repeated encounters can also be classified as promising. The species has most likely been encountered but cannot be unambiguously identified. The description is conclusive of behaviour / location.
C3b	<i>Possible:</i> The report is not typical, cannot be clearly assigned to the target species, or there is not enough information to assign the report to a higher category.
C4	<i>False report:</i> The report is demonstrably not the target species or the report is obviously incorrectly located (conflict between description and photo).
C5	<i>Translocated:</i> This level is particularly important. Strictly speaking, the level translocated is also a sub-level of “absolutely unambiguous”. However, it is a non-natural occurrence. The report is confirmed as a target species (positive detection, categories C1 or C2), but the animal did not arrive at the site by natural dispersal but was passively moved to the site for other reasons. One of the following statements applies to this: The site of discovery is outside the species area. The site of discovery does not represent a suitable habitat for a population capable of reproducing, or the animal genetically belongs to a different group. The classification is based on an expert assessment or genetic verification. In case of doubt, the animal is considered for displacement. Released animals in original or suitable habitats are not considered as category C5.
C6	<i>No assessment possible:</i> No classification in one of the other categories is possible (e.g., the data is too poor for a verification).
C0	<i>Active search without result</i> (so called zero counts, used additionally for the project work, not used in the online reporting tool)

edible dormouse (*Glis glis*), hazel dormouse (*Muscardinus avellanarius*) and forest dormouse (*Dryomys nitedula*). Respective observation date and location (a map application was developed to allow to mark the point and get geographic coordinates) and the type of observation are to be added. The reporting tool also allows adding remarks. Observers are further requested to upload images, videos or recorded calls for a subsequent verification. All observation reports were carefully verified using Small Mammal Evaluation Criteria (SMEC) (Table 1), which were defined within the framework of this project (ZISTL 2021, MEINIG et al. 2023).

The online reporting tool is available online since April 2019. It was promoted and supported by ongoing public relations work within the project, consisting of approx. 12,500 media articles (TV, radio, newspapers and journals until the end of 2021 resulting in 2 billion reads) and social media (about 250,000 post shares p.a.). The project’s actions were accompanied by a film team for a TV documentary about the project, a cooperation with Museum Wiesbaden for a new exhibition entitled *Germany’s Panda – The Garden Dormouse* ([\[schlaefer-pm\]\(https://www.buergerschaftenwissen.de/projekt/spurensuche-gartenschlaefer\)\). Talks on different events such as *Citizen Science Forum* \(<https://www.buergerschaftenwissen.de/projekt/spurensuche-gartenschlaefer>\) or *Environmental Week* \(hosted by the Federal President of Germany, <https://www.woche-der-umwelt.de/ausstellerKonkret/1587>\) as well as national and regional garden dormouse conferences.](https://museum-wiesbaden.de/deutschlands-panda-der-garten-</p>
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Until 15th of December 2022, approx. 5,000 persons reported their observations at the online reporting tool. The accompanying verification was done by some of the authors (SB, HM, JL, KZ, TN, AA) and, since 2022, also supported by special trained volunteers.

A more labour-intensive involvement for volunteers (more than 450 persons) was taking part in an active search for the garden dormouse. Methods used for an active search were footprint tunnels (HAAG & TESTER 2016, BULLION et al. 2018, MELCORE et al. 2020), camera traps (MILLS et al. 2016, ROVERO & ZIMMERMANN 2016) and checking of nest-boxes (MELCORE et al. 2020). Active searches were coordinated by the regional chapters of the BUND in consultation with the whole project team. The main focus of the active search were 10 km raster cells of the European Environment Agency (EEA)-

grid without records so far, and with either (i) old records, or (ii) close by known populations, or (iii) several C3a reports from the online reporting tool.

Detailed information was provided to volunteers on where and how to use the methods. For each plot, a consecutive protocol with date, place, observer and remarks was kept.

Footprint tunnels (7,542 in total) were placed in transects of 25 tunnels, reduced to 12 tunnels at some places in 2021. Distances between the tunnels were 20–25 m. During the active garden dormouse season, the tunnels were checked every fortnight, the tracking cards were replaced and the ink refreshed. Volunteers were also provided with an identification key for the footprints. Cards with prints were stored, scanned and footprints were verified by experts. As soon as a garden dormouse could be reported, the tunnels were moved to the next transect.

In total, 567 camera traps were used (Minox DTC 550, Minox GmbH, Isny, Germany). The camera traps were put up at 50–70 cm height from the ground on a tree trunk. Bait was placed (a sponge with nut oil or apple juice) at a distance of approximately 1.5 m. The cameras were checked at least monthly when batteries and memory cards were exchanged. Data on memory cards were uploaded to a database for verification. If a garden dormouse was found, the camera was transferred to a new site.

Nestboxes, deployed in 24 transects, played only a minor role for the search of garden dormouse presence. A total of 500 wooden boxes measuring 20x20x21 cm were used, sited with the entrance hole (diameter 32 mm) facing the tree trunk. Volunteers also collected garden dormouse carcasses (FAMIRA-PARCSETICH et al. 2023) and DNA samples and provided them for research.

In addition, we conducted surveys for garden dormice using the specific calls of the species (NAVA et al., in press), checked samples in museums in Germany and the monitoring databases of the German Federal States.

All collected data were combined in a central project database that will be maintained long-term and available beyond the end of the project. The total surface area (in km²) of the current range was calculated according to the guidelines for reporting the range of a species under the European Habitats Directive and the specifications for Germany (DG ENVIRONMENT 2017, SACHTELEBEN & BEHRENS 2010). A ‘gap distance’ of 20 km was used as the distance between two distribution grids that will not be joined together to form a single range polygon but will be shown as discontinuities in a range (DG ENVIRONMENT 2017).

The project has been supported and still is supported by accompanying social research. The focus is on the experiences of the CSV in the collaborative research project and therefore several surveys are carried out (MOCZEK & KÖHLER 2020).

Results

In total, 16,557 data are included in the database by December 15th 2022. The majority consists of records on the garden dormouse (not exclusively from Germany), followed by C3 reports, records of edible and hazel dormice, reports of the categories C4-6 and zero counts (C0). Most of the collected evidence comes from observations registered on the online reporting tool (Table 2). Reports of dormice via this tool were sent in almost daily, with peaks during the summer months of more than 10 new reports per day.

Garden dormice are currently common in the central part of Rhineland-Palatinate (RP), southern Hesse (HE) and North Rhine-Westphalia (NW) along river Rhine. The species also occurs in clusters in the mountains of Harz, Thuringian Schiefergebirge and Bavarian Frankenwald and Fichtelgebirge as well as the Black Forest (Fig. 1). Some isolated populations could be documented, which are leftovers of a formerly larger range. The recent distribution covers an area of approx. 36,917 km².

Comparing old and recent records (Fig. 1), a decline or even local extinction can be document-

Table 2. Numbers of records of garden dormice and origin in the data base of the project “In the search for the Garden Dormouse”.

Method	Number of C1 and C2 evidences
Opportunistic	
Online reporting tool	4,681
Reports directly to the team	1,508
Collected carcasses	501
Active search	
Footprint tunnels	77
Camera traps*	251
Nest boxes	117
Genetic samples	1,751
Existing data	
Data bases of federal states	498
Museum samples	1,523
Total:	10,907

* Excluding images of long-term observations from special sites

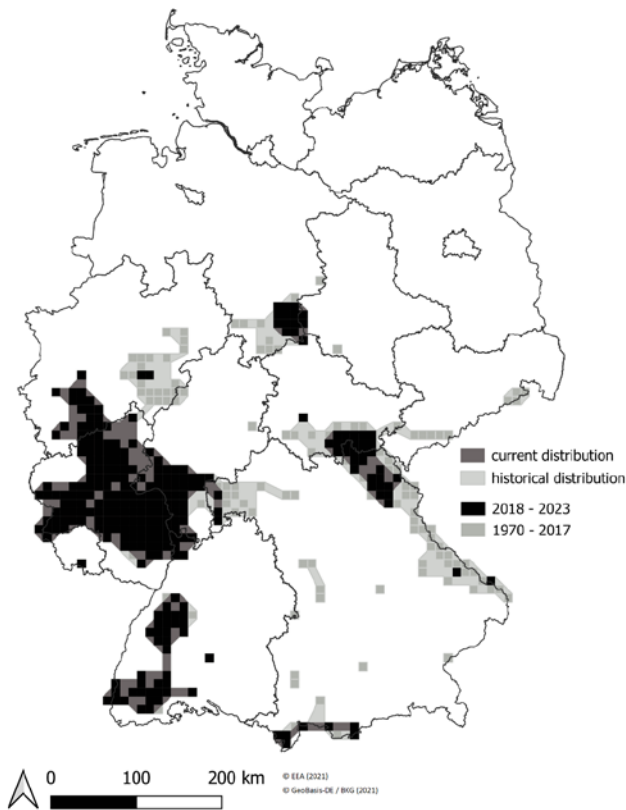


Fig. 1. Records of Garden dormice in Germany and neighbouring countries between 1970 and 2022 provided as part of the project “In search for the Garden Dormouse”. Grey squares = 10x10 km raster cell with Garden dormouse presence between 1970 and 2017; Black squares = 10x10 km raster cell with Garden dormouse presence between 2018 and 2022; white circle = translocated individual.

ed for Saxony (SN), parts of Thuringia (TH) and Hesse, the eastern part of Bavaria (BY) (along the border to Czech Republic) and the eastern part of North Rhine-Westphalia. The habitat loss amounts to approx. 223,022 km² (35.2 %) since 1970.

Concerning the translocated garden dormice, 67 cases of have been documented. These include individuals trapped at a military air base, at a container terminal or found in cars or flats far away from known garden dormouse populations. In some of these cases, it was possible to collect hair or faeces and the region of origin (partly several 100 km away) could be determined via genetic analysis.

Discussion

Through a multidisciplinary approach including research institutions, NGOs and a professional involvement of hundreds of citizen scientists, it was possible to generate comprehensive large-scale sci-

entific data sets in the first three years of the project. This data now provides a much clearer picture of the current garden dormouse distribution in Germany. They also allow deep insights into the biology and ecology of an endangered species, which will be the basis for effective conservation programmes and further studies.

A first range map of the garden dormouse for Germany by MEINIG & BÜCHNER (2012) was based mainly on expert assessment. Now, with more than 10,000 records, it is possible to describe the distribution of garden dormice in Germany in much more detail. This is a solid basis for the identification of future distribution trends.

The data quality of the online reports was very high. We attribute this to the intensive professional public relations work, which, among other things, consistently communicated the identification features of the garden dormouse and the (preliminary) findings of the project. Due to its fur coloration, the garden dormouse can be clearly identified even by laypersons. The newly developed evaluation criteria SMEC proved themselves very useful in practice for the database and were helpful in the feedback to reporting persons.

In total, 66.8 % of the online reports contained evidence of dormice such as photos (Fig. 2), videos or recorded calls. The availability of smartphones with the ability to take high quality photos/videos even in low light conditions or sound recordings was very helpful for the project. In addition, many people use camera traps in their gardens or on the balcony and were willing to share their observations. Numerous messages accompanying the reports asked for information about the observed wildlife in the immediate vicinity. This shows the interest in animals in general, the lack of knowledge about small mammals, and at the same time the potential for citizen science projects. It is particularly gratifying that even carcasses were collected and made available for further investigations. We therefore conclude that citizen science can be an extremely powerful and robust method for mapping small mammal distributions. We suggest that cautious combination of citizen science data with long-term expert surveying could be a highly reliable method for monitoring biodiversity. In order to learn systematically from this experience, a large-scale survey with 4138 CSVs was conducted in September 2022 (MOCZEK & THEIS, in preparation).

Even if it is still ongoing, the project has already yielded the largest data set on Garden dormice known to us to date. Particularly helpful in the evaluation of the data were the targeted active searches



Fig. 2. Garden dormouse photo as proof for an online report of observation. Photo Jochen Pulch.

with different methods without detection. Of course, citizen scientists were keen and happy to detect garden dormice. Fortunately, it was possible to convey that zero counts were just as important as detections of garden dormice. The active searches contributed significantly to confirming the lack of occurrences. We are therefore confident that we have largely captured the general distribution pattern of the garden dormouse in Germany and that only individual small and isolated populations may have been overlooked.

The garden dormouse range in Germany is divided into several isolated parts. The observations in the urban areas along river Rhine are so numerous that a vital population (or vital populations) can be assumed for this part of the range, even taking into account the bias in the number of records due to more contact between humans and garden dormice in settlements. Occurrences in cities and villages were known for decades (e.g., HEROLD 1916, JANSEN 1922, KAHMANN & STAUDENMAYER 1969). Urban areas can provide good habitats for the garden dormouse and the species has adapted to this environment like other species, e.g., the Blackbird (*Turdus merula*) or the Black Redstart (*Phoenicurus ochruros*). It remains unclear so far why garden dormice do not occur in cities along the river Rhine south and north of the known range or in the eastern

parts of Germany. However, in comparison to older records, there is no distribution decline in this habitat type, but even a slight spreading of the species southwards into the city of Mannheim during the last 30 years. Nevertheless, it must be emphasised this does not mean there are no threats to the species in urban areas (see FAMIRA-PARCSETICH et al. 2023).

Frequent reports of active garden dormice during the winter months or individuals found in torpor in nestboxes during frost periods instead of hibernating in the ground indicate an adaption of the animals to the urban habitats where food is available nearly all the year round. Garden dormice in the cities used bird feeders or directly fed with seeds and fruits. KAHMANN & STAUDENMAYER (1969) previously stated that the species could benefit from mild conditions in urban areas with prolonged active season and consequently having a second litter because of a better food supply.

In contrast to urban areas, there is a clear and, in some cases, rapid decline in the low mountain ranges. For some parts, this is well documented, such as in the Bavarian Forest where garden dormice have been frequently reported until the 1990s (FALTIN 1988, MÜLLER-STIESS 1996) but could not be recently confirmed at almost all sites; or for Saxony where the decline already started in the 1920s

and extinction is very likely (BÜCHNER 2009). There are fewer old data for other parts of Germany, which makes comparison difficult for several regions. In general, it can be stated that the decline was greater in the eastern and central parts of Germany where the garden dormouse mainly inhabited forests dominated by spruce (*Picea abies*). However, there are still populations in such habitats, which is why the garden dormouse must also be considered a typical forest species. Consequently, conservation measures should also be focused on this type of habitat. Bark beetle (*Ips typographus*) calamities or the associated forest treatments with clearing of large areas using big machinery in response to the calamity are currently putting these habitats under particular pressure. Therefore, conservation strategies must be developed and implemented together with the forestry sector urgently. Climate change is thought to impact garden dormouse populations in the south of its range (SANTORO et al. 2017). However, milder winters and poorer hibernation conditions could also pose a threat to the species in the low mountain regions in Germany.

Comparing the distribution of the species over the time should also take into account that the garden dormouse is vulnerable to translocations. Its ability to enter torpor and its adaptability to urban areas may result in (unintended) transportation in association with food or other goods. We can assume that at least some single old observations or museum specimens do not represent a former permanent occurrence. However, it is difficult to review such cases in retrospect. The estimate of a distribution loss of approximately 35 % since 1970 is therefore very conservative, as all isolated individual specimens were excluded from the calculation of the former range. Consequently, a considerable range loss has to be assumed also for Germany, as is described for the whole species' range (BERTOLINO 2017). On the other hand, the stable occurrences along river Rhine invalidate the assumption of low habitat suitability for garden dormice in Germany by BENNET & RICHARD (2021).

Large mammals seem to have a higher extinction risk compared to small ones (PURVIS et al. 2003, CARDILLO et al. 2015). However, the recent extinction rates of all mammals are higher than expected from the fossil records (BARNOSKY et al. 2011), and small mammals are as threatened as large mammals (TEMPLE & TERRY 2007). In contrast to the charismatic, large flagship species there is little positive publicity for small mammals and only little attention has been directed to their conservation. Our garden dormouse project has shown that a small mammal can become a flagship species and it has success-

fully raised awareness on dormouse conservation needs among the public.

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