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RESEARCH ARTICLE

Investigating the use of artificial nest boxes positioned at different heights on trees and in isolated positions by dormice (*Muscardinus avellanarius*): Implications for current survey guidelines

Debbie Bartlett[1] | **Sam Bower**[2] | **Peter Dear**[3]

[1]University of Greenwich, London, UK
[2]Balfour Beatty UK, London, UK
[3]National Trust, Sissinghurst Castle, UK

Correspondence
Debbie Bartlett
Email: d.bartlett@gre.ac.uk

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Abstract

1. This research, carried out in two phases, is a response to questions raised regarding the validity of surveys based on artificial nest boxes, positioned at around 1.4 m from ground level, to determine the presence of dormice (*Muscardinus avellanarius*). This species is generally considered to be an arboreal mammal that visits the ground infrequently other than for winter hibernation.
2. In Phase 1, artificial nest boxes were positioned high in the tree canopy and at standard height on the same tree. The presence of leaves and material from the woodland floor in nests informed the design of Phase 2 with the inclusion of a third box, on an isolated post with no arboreal connectivity, carried out on a different site.
3. Results demonstrate the presence of dormice and their nests in artificial nest boxes positioned in the tree canopy, at conventional height and on isolated posts with no arboreal connectivity. This suggests that the current method of surveying for dormice using boxes at around 1.4 m from ground level may not result in robust 'likely absence' conclusions for surveys aimed at determining the presence of dormice on a site.
4. Previous experience of long-term surveys has indicated that use of artificial next boxes declines with age of box. This was confirmed over the 6 years of the second project reported here. While often taken to indicate decline in population alternative explanations are proposed and this is highlighted as requiring further investigation.
5. The apparent decline of hazel dormice and the contraction of their range is evidenced by surveys carried out according to current 'good practice' guidance. The results of this research suggest that these should be reviewed and revised to ensure conservation objectives are being met.

KEYWORDS
arboreal survey, dormice (*Muscardinus avellanarius*), dormouse survey methods, ecological survey techniques

1 | INTRODUCTION

Hazel dormice (*Muscardinus avellanarius*), hereafter referred to as dormice, are predominantly arboreal nocturnal rodents widely distributed in northern Europe and are also found in parts of Asia Minor (Bright & Morris, 1992). In the United Kingdom, distribution is thought to be patchy, with most populations in the southern counties, and is particularly associated with ancient and previously coppiced woodlands. There are around 52,000 ancient woodland sites in England (Natural England, 2021) with the county of Kent, where this research was carried out, notable as particularly rich in this resource. Dormice are not restricted to these sites but are commonly associated with diverse, predominantly deciduous, woodlands with canopy connectivity and shrub understorey (Berg & Berg, 1998; Capizzi et al., 2002; Fedyń et al., 2021; Goodwin et al., 2018).

The National Dormouse Monitoring Programme (NDMP) is a citizen science scheme, overseen by the People's Trust for Endangered Species, that also receives records from professional ecologists and those working on conservation projects. It was established in 1988 due to concerns that the species was declining and was made possible by the discovery that dormice would use artificial nest boxes, enabling their presence to be recorded (White, 2012; Williams et al., 2013). The number of sites monitored by placing 50 nest boxes, usually in woodland, has increased over time with results suggesting rate of decline is increasing with a 72% drop in nest box occupancy recorded between 1993 and 2014 (Goodwin et al., 2017). This trend has been confirmed by Scopes et al. (2023) using the same NDMP data for the 27 years between 1994 and 2020 recording overall decline of 78%. However, the proportion of woodlands with potential for dormice that have been surveyed is unclear with sites selected on the basis of either threat from development or availability of volunteers.

This decline has also been observed in other European countries including the Netherlands, Sweden, Germany and Denmark with habitat loss and fragmentation frequently cited as the cause. A notable exception is Lithuania, where dormice remain common and widespread, thought to be due to the woodland management practice of creating small-scale clear cuts that provide favourable conditions (Juškaitis & Baltrūnaitė, 2013). It is highly likely that changing climate and extreme weather events are affecting dormice, particularly warmer winters that disrupt hibernation and can lead to early emergence when food is scarce.

Dormice are arboreal mammals, spending the active period mainly in the tree canopy but hibernating at ground level (Gubert et al., 2022; Juškaitis, 1999). This has resulted in particular concern regarding the impact of habitat fragmentation on dormice and isolation of populations where arboreal connectivity is absent. However, it has been established that dormice move across roads (Chanin & Gubert, 2012) so such features do not necessarily result in physical and genetic isolation of subpopulations (Friebe et al., 2018). Büchner (2008) explored this issue using marked dormice in isolated small woodlands in Germany and found individuals, particularly juveniles, crossed fields between woods for distances between 250 and 500 m. The material found in artificial nest boxes often contains senesced leaves, which must have been collected from the woodland floor, and other ground-level vegetation such as bluebell (*Hyacinthoides non-scripta*) and wood rush (*Luzula sylvatica*) stems (Hazel Ryan pers. comm) and this, combined with reports of dormice in other habitats such conifers (Juškaitis, 2007) and reedbeds, suggests that our understanding of dormouse behavioural ecology is incomplete.

1.1 | The requirement for dormouse surveys

Dormice are classified as of Least Concern by the International Union for the Conservation of Nature (IUCN) but considered as vulnerable in the United Kingdom[1] where individuals, their breeding sites and resting places are all protected by law under Schedule 5 of the Wildlife and Countryside Act 1981 (as amended) with additional significance as a European Protected Species under the Conservation of Habitats and Species Regulations 2010 (as amended).[2] Dormice are listed in Section 41 of the Natural Environment and Rural Communities Act 2006 (NERC) as one of the 'Species of Principal Importance for the Conservation of Biodiversity'.[3] This Act requires all public bodies to pay due regard to biodiversity conservation, restoration and enhancement. Local authorities are also required to conserve and enhance biodiversity by the National Planning Policy Framework (NPPF). This means any activity with potential to harm dormice requires a full risk assessment. There have been attempts to determine habitat suitability criteria, for example by Cartledge et al. (2021), but virtually all wooded areas, hedgerows or scrub are considered potentially suitable,[4] so the presence or likely absence of dormice must be determined. If found, then the nature or timing of works may need to be modified and/or appropriate mitigation put in place to ensure compliance with the legislation. A Natural England or Natural Resources Wales licence is required for carrying out any activity that may affect dormice, whether this is ecological surveys or siteworks.[5]

1.2 | Current 'good practice' survey methods

The National Dormouse Monitoring Programme (NDMP) survey method[6] has been widely adopted for surveys carried out by volunteers since the early 1990s (Morris et al., 1990). This method requires a minimum of 50 nest boxes to be placed at about 1.4 m from the ground, on trees, and checked by someone holding the

[1]See https://ptes.org/get-informed/facts-figures/hazel-common-dormouse-muscardinus-avellanarius/.

[2]See https://www.legislation.gov.uk/uksi/2017/1012/contents/made.

[3]See https://www.legislation.gov.uk/ukpga/2006/16/contents.

[4]Although, as had been previously noted, dormie are not restricted to these habitats.

[5]See https://www.gov.uk/guidance/hazel-dormice-protection-surveys-and-licences.

[6]See https://ptes.org/campaigns/dormice/surveying-and-monitoring-hazel-dormice/national-dormouse-monitoring-programme-ndmp/.

appropriate Natural England licence, multiple times, with either nests or dormice, recorded. However, 'good practice' for professional ecological surveys, undertaken as part of the risk assessment to ensure no harm comes to any protected species during development or management operations is based on the recommendations in the Dormouse Conservation Handbook (Bright et al., 2006). This also allows for tubes, first used for surveying edible dormice (*Glis glis*) (Morris & Temple, 1998), rather than boxes to be used and requires considerably more checks over the active season to achieve the minimum survey effort required by a development licence. The use of nest tubes has become popular as these are cheaper and easier to deploy than wooden boxes. A protocol for use in 'unusual' habitats such as heathland was given by Chanin and Woods (2003); however, a comparative study found boxes are used in preference to tubes when both were provided, and were more likely to be used for breeding, making tubes more appropriate for short duration surveys rather than long term monitoring (Chanin & Gubert, 2011). A 2-year comparative study suggested that tubes were more likely to be used when there was competition from wood or yellow-necked mice (*Apodemus sylvaticus* or *A. flavicollis*) which preferred boxes (Lang et al., 2022). Bullion et al. (2021) have researched the use of nest tubes and footprint tunnels in different conditions and provide recommendations as to how these techniques should be used to maximise the likelihood of detecting dormice. A recent development has been the collection of DNA from urine deposited in paper-lined nest tubes. Priestley et al. (2021) detected dormice in 3 out of 50 tubes within 8 days using this method, whereas a nest was only found in one tube on day 63 suggesting survey efficiency could be increased significantly. Research by Melcore et al. (2020) comparing nest boxes, nest tubes and footprint tunnels found the latter to be most effective and these are increasingly used, but, like the eDNA method, require regular checking and so best suited to short-term surveys. The results from the volunteer and professional surveys combined give a time series of data indicating the state of England's dormouse populations, revealing a decline of 70% since 2000 (Wembridge et al., 2023).

1.3 | Placement of survey/monitoring structures

Whatever the method used to record presence interaction between the target species and the box, tube or tunnel is essential and placement to maximises the chance of this occurring is important. Radio tracking and LiDAR studies have suggested dormice have home ranges of around 0.5 Ha and favour mid-height woodland habitat (5–10 m tall), with low proportions of high forest (over 10 m tall), for both ranging and resting sites (Goodwin et al., 2018). Nest preference research has demonstrated edible dormice (*Glis glis*) have marked preference for natural cavities even when nest boxes were provided (Iwińska et al., 2020). Dormice hibernate at ground level (Gubert et al., 2022) and have been established to travel across roads (Chanin & Gubert, 2012) but the regularity with which they move down tree trunks has not been established. This suggests that placement at 1.4 m above ground level, the standard practice, may lead to false negatives particularly in dense woodland with good canopy. Bullion and Looser (2022) have further questioned current survey methods and have presented evidence that dense woodland, often the favoured habitat for voluntary surveys contributing to the NDMP, may be a particularly difficult habitat in which to detect the species and using best practice survey methods has a high risk of false negatives. These authors recommend more research is needed to provide robust results for surveys in high canopy woodland.

Accurate determination of whether dormice are present on a site has ecological, legal and practical significance. Artificial nest boxes are a tool used for survey and monitoring but, despite some organisations suggesting that 'giving a dormouse a home' (https://ptes.org/house-a-dormouse-appeal-2018/) will help conserve them this would only be correct if lack of nest sites was a limiting factor. There is a tendency for boxes to be occupied for the first few years with use then tailing off. This tends to be interpreted as decline in the population but may equally reflect the boxes being explored initially as novel features and, particularly when these are also used by nesting birds, relocation due to parasites. The validity of the established survey method is widely discussed among surveyors and ecologists but remains the basis for determining the potential for risk of harm to dormice during development, which could result in a criminal offence, and as the basis for the call for raising the status of dormice to 'endangered' (Scopes et al., 2023).

This research, undertaken in two phases, aimed to explore the following research questions:

RQ1 to establish to extent to which dormice, considered to be mainly arboreal during the active season, will use artificial nest boxes at standard height, higher in the canopy or placed in isolation on a post so they can only be accessed from the ground (in Phase 2).

RQ2 to explore the anecdotally reported trend that artificial nest boxes are more frequently used when newly erected with occupancy tending to decline in subsequent years. If this is the case, then the apparent decline in dormice in the long-term monitoring scheme may be a function of survey method rather than population.

2 | MATERIALS AND METHODS

Dormice are protected and all activities in this research were carried out under licence from Natural England (2016-21604-CLS-CLS held by Debbie Bartlett; 2016-21844-CLS-CLS held by Sam Bower). This research, carried out over a 10-year period, comprises two different projects, on two separate sites in Kent, Southeast England. The first began as a student-led project investigating the use of artificial nest boxes placed in the tree canopy and comparing use with those at standard monitoring height. This indicated that not only were the high boxes being used by dormice confirming arboreal activity but also that dormice were traversing the woodland floor. Phase 2 was designed to explore this behaviour in more detail by including a third option in the research design.

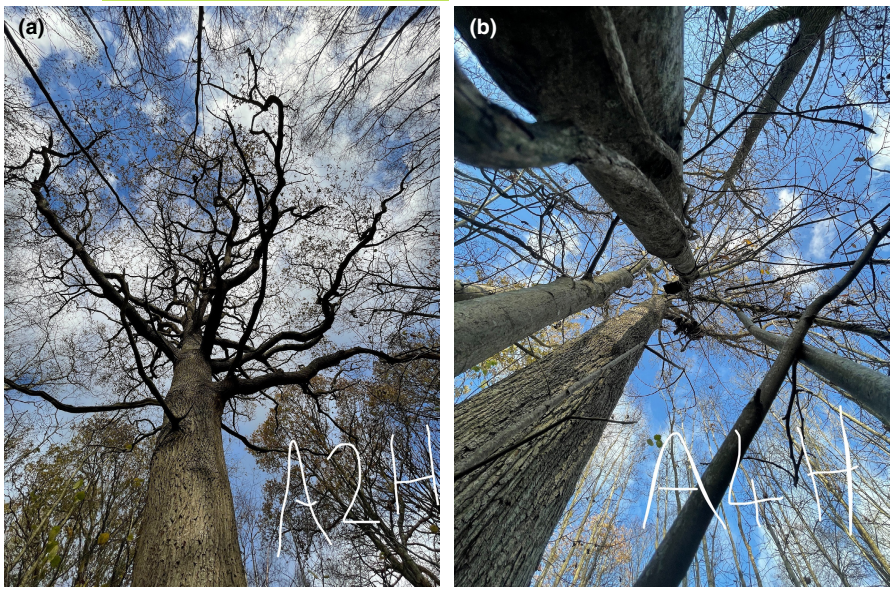


FIGURE 1 (a and b) Examples of visual assessment of canopy connectivity.

2.1 | Phase 1

This was carried out on a long-term monitoring site with a well-established population of dormice at Denge Woods, near Canterbury, Kent. Additional artificial dormouse nest boxes, were added to those that were part of the original monitoring project. The new boxes were erected on 23 trees distributed across the site with one box on each at the standard height of 1.4 m above ground, paired with a second box on the same trees installed by qualified climbers using roped access, at heights of between 3 and 14 m. Some trees had an additional mid-height box, giving a total of 49 boxes.

These boxes, identified by Roman numerals to distinguish them from the existing numbered ones, were checked monthly during the active season, between May and October, for three consecutive years. The ground layer, shrub layer, under- and overstorey were recorded; arboreal connectivity was classified as sparse moderate or dense.

2.2 | Phase 2

This was designed to develop our research into dormouse nest box use by reducing variables, considering arboreal connectivity networks, and to explore the use of the woodland floor by dormice in the active—as opposed to the hibernation—period. The study site was Round Hill Park Wood, an area of ancient deciduous woodland managed for recreational amenity and wildlife, part of the Sissinghurst Castle Estate owned by the National Trust. Artificial nest boxes were set out in five lines, labelled A–E, with five positions in each, the combination of the letter and number providing a unique identifier for each location.

Lines were kept as straight as possible while selecting trees safe for climbing and with good canopy connectivity. The importance of a complex vertical and horizontal structure of forest vegetation in providing arboreal movement corridors and safe nesting places for dormice has been confirmed in a recent review by Fedyń et al. (2021). Good arboreal connectivity was determined by eye and recorded using a fisheye lens attached to a smart phone (Arietta, 2022). The examples in Figure 1a,b demonstrate that dormice could, using tree branches, move between trees without the need to descend to ground level, a factor investigated by Mortelliti et al. (2010). At each position, three boxes were erected: Box H = high box, Box S = standard 1.4 m and Box P = box on isolated post. The high box height above ground and host tree species were recorded.

- *Box H*: attached to the tree stem at height; this varied between trees.
- *Box S*: was attached to a tree close to the one with box H and with good arboreal connectivity to it, at the standard height of 1.4 m.
- *Box P*: was placed on an isolated post at the standard 1–1.4 m height above the ground and within 5 m horizontally of the trees with the other boxes. This could only be reached by dormice coming down from the canopy and moving across woodland floor (Figure 2).

All 75 boxes were monitored in summer 2017, 2018 and 2019 as regularly as possible, and always in both June and October. Frequency was affected by the necessity to have at least two, and preferably three, qualified tree climbers competent to carry out aerial rescue, if necessary, present for each survey in addition to dormice licence holders. Surveys typically took two full days to complete due to the time required for climbing. COVID-19 regulations then restricted monitoring and boxes were checked for condition and repaired, as required, in autumn 2021.

The need to climb to monitor occupancy of the canopy boxes and the proximity of the three boxes at each position increased potential for disturbance which could lead to dormice vacating boxes. All operations were carried out as quietly as possible with the holes in the S and P boxes blocked before climbing commenced and processed

FIGURE 2 Isolated box on post.

when it was complete. Not all dormice in the canopy boxes were handled as the aim was to see whether the boxes were being used by dormice. The safety of the dormice and personnel was of paramount importance.

3 | RESULTS

3.1 | Phase 1

Over the 3 years of Phase 1, dormice were found in 20 of the high boxes and 21 of the low ones; in 11 instances just the high one was occupied. In eight cases, both the high and low boxes were used in the same year. There were two instances of a high or low box used 1 year and the alternative the following one (Table 1). There was no discernible difference in selection preference.

The frequency with which brown leaves were seen in nests prompted discussion of where these were sourced. This indicates the woodland floor was the source for nest material suggesting dormice travel down to ground level more regularly than previously thought. However, some species, for example, sweet chestnut (*Castanea sativa*), hold on to brown leaves and are late to leaf in spring so dormice may, in some cases, be using previous year leaves still retained on the tree. The results did not clarify whether height is a factor in box selection and led to questioning whether dormice are less strictly arboreal than generally thought. This informed the design of Phase 2 on a site with no existing boxes and including a box position that could only be accessed by crossing the woodland floor.

The aim of Phase 2 was firstly to establish the extent to which dormice, considered to be mainly arboreal during the active season, will use artificial nest boxes at standard height or higher in the canopy or placed to be only accessible from the ground and secondly to see if use declined over time. Actual numbers of dormice were therefore not important for this research, so occupancy rather than individual(s) was recorded. Some surveys were carried out in poor weather due to the difficulty of organising appropriately qualified volunteers for tree climbing, and handling dormice in wet weather is not advisable. Dormice unwilling to leave the box were left in peace as they could have been breeding.

3.2 | Phase 2

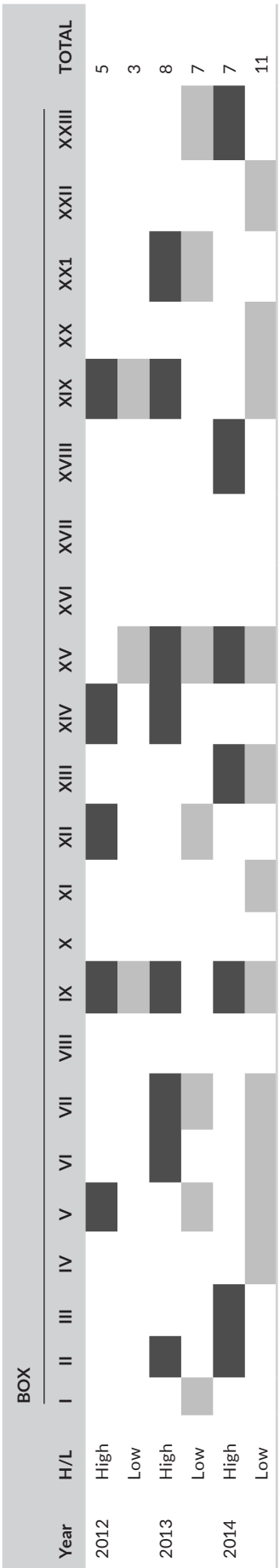
3.2.1 | 2017 survey results

While direct observation of one or more dormice in a nest box is clear evidence, it is not possible to determine whether a loose collection of leaves without a chamber has been assembled by a dormouse or another small mammal such as a wood mouse (*Apodemus sylvaticus*) or yellow-necked mouse (*Apodemus flavicollis*). For example, in 2017, four of the high boxes had nests occupied by dormice (A5;B1; D1;D5). Two had nests occupied by wood mice (C4; E4) and three had loose nests, all but one of which (A1) included green leaves (C1; D2). No dormice were observed in the standard boxes although two had nests with stripped bark (A2; A3), one had a nest with bluebell stems (B2) and one had a nest occupied by wood mice (A4). The only post occupied contained a nest with a dormouse in occupation (E3).

3.2.2 | 2018 survey results

Dormice were observed to be occupying eight of the high boxes (A3; B1; C1; C3; D1; D2; D4 and E4) and nests with green leaves and/or a central woven chamber were found in additional seven high boxes (A4; B3; B5; C2; C4; E3 and E5). Two contained loose leaves (A5 andE1). Dormice were observed occupying four of the standard boxes (A5; B2; C1 and D3) with loose nests in 12 (A4; B1; B3; B4; C2; C5; D1; D2; E2; E3; E4 and E5) and nests with bark/chamber in two (B5 and D5). Ten dormice were seen in the post boxes (A1; A2; A5; B2; B3; B4; B5; D3; E2 and E5) with loose nests in a further eight (A3; A4; B1; C4; D1; E1; E3 and E4) with an additional one (C3) containing a chamber.

TABLE 1 Box occupancy 2012–14 (hard cell outlines indicates use of both high and low boxes).



3.2.3 | 2019 survey results

Dormice were seen in four of the high boxes (A1; A5; B5 and C4) and three of the standard ones (B3; B5 and E4). None were seen in the post boxes and no wood mice or yellow-necked mice were seen. Loose leaves were present in A4 high box and E3, also in the canopy had a nest with green leaves. Four standard boxes had nests, one loose leaves (A2) the remainder with green leaves (A4; C2; D5). Eight of the boxes on the posts had nests, six loose leaves (A2; B3; C2; D5; E4 and E5) and two with shredded bark (A3 and A4).

No surveys were undertaken in 2020 or 2021 due to COVID-19 restrictions.

3.2.4 | 2022 survey results

Boxes were checked for condition in spring 2022, contents removed and lids replaced where necessary. A dormouse was observed using one high box (C2) with two having loose leaves (A3; C5) and leaves and shredded bark in one (A4). Wasp nests were found in two of the high boxes (D2; E5). A dormouse was found in one standard box (D1), loose leaves in A3 and a nest with a chamber in A4. Two active hornets nest was found in standard boxes, B3 and E1. A bumblebee nest in another (E3). There were loose leaves in one post box (A1). The decision was made not to undertake any more surveys at height due to the risk associated with hornets. The results are summarised in Table 2.

As the dormice observed were also in nests, the total nests in high boxes was 35 over all years, giving a total for all boxes of 96. Wood mice (*Apodemus sylvaticus*) were only observed in high boxes C4; E4 and standard A4 in 2017. C4 was 5.1 m above ground and on a hazel; E4 4.4 m and on a chestnut. In 2018, wood mice were found in standard box E4, and in post boxes E2 and E2, and both of the post boxes were occupied by dormouse on a later survey that year. No yellow-necked mice (*Apodemus flavicollis*) were encountered in either Phase of this research.

TABLE 2 Dormice and nests observed (note this does not equal number of individual dormice).

	2017	2018	2019	2022	Overall total
High box					
Dormice	4	8	4	1	17
Nests	3	9	2	4	18
Standard box					
Dormice	0	4	3	1	8
Nests	4	14	4	2	24
Post box					
Dormice	1	10	0	0	11
Nests	0	9	8	1	18
Annual totals					
Dormice	5	22	7	2	36
Nests	7	32	14	7	60

TABLE 3 Expected counts.

Expected count	2017	2018	2019	2020	2021	2022
High	1.85	8.45	3.7	1.14	1.14	2.72
Standard	2.91	13.28	5.81	1.74	1.74	3.93
Post	2.24	10.26	4.49	1.12	1.12	2.35

TABLE 4 Chi-square values.

Expected count	2017	2018	2019	2020	2021	2022
High	0.9	0.02	0.41	1.29	1.29	0.15
Standard	0.46	0.05	0.47	1.54	1.54	0.54
Post	4.95	0.46	3.44	1.25	1.25	0.45

TABLE 5 Chi-square results.

Overall chi-square	24.42
df	10
p-value (from the table)	0.0065
Significance level	0.05
	p-value <0.05

3.3 | Statistical analysis

From the data presented in the results, Table 2 showing the location of nests in the boxes in different positions the Null Hypothesis that there is no statistically significant difference in the occupancy (indicated by observation of nests) of boxes across the different years has been tested using the Chi-square test. The expected counts were calculated (Row Total * Column Total/Grand Total) assuming independence and are shown in Table 3.

Chi-Square = Σ [(Observed − Expected)^2/Expected] and the Degrees of Freedom determined df = (Number of Rows −1) * (Number of Columns − 1) = (3–1) * (6–1) = 10, shown in Table 4.

The aim of using the Chi-square test to analyse data was to statistically either reject or fail to reject the null hypothesis. If the calculated *p*-value is less than the significance level (0.05), it is rejected. As the *p*-value, shown above is 0.0065 (Table 5) we can conclude that there is a statistically significant difference in the occupancy of boxes across the different years. However, this conclusion is likely to have been affected by the missing data from 2020 and 2021.

4 | DISCUSSION

The results of both phases of this research depended on determining the use of artificial nest boxes by dormice evidenced either by direct observation of one or more dormice or the presence of a nest. It has long been considered that dormice collect green leaves directly from trees (e.g. Bracewell & Downs, 2017; Juškaitis, 2008) and it is assumed that the insulating properties improve as these dry out (Collins et al., 2023). However, in our experience dormice begin with assembling loose leaves, either green, brown or a mixture adding a woven breeding chamber, using stripped bark, grass or bluebell stems. Collins et al. (2023) have considered how transport costs affect nest construction material and have suggested that collection cannot be predicted by optimal foraging theory due to the apparent preferences for specific materials.

Phase 1 results clearly showed boxes in the canopy were used and that some dormice would not have been observed and recorded in boxes at the standard height. Occupancy may have been influenced by the presence of nest boxes on the site part of the original monitoring project; this was the rationale for conducting Phase 2 on a site that had not previously been monitored. It was not possible to tell whether the same dormice were using both high and low boxes as few can be individually identified (the exceptions we have seen are one with a short tail and another with a white tail tip) without fur clipping, which was not done in this project. Most of the nests observed in the boxes were composed of brown rather than green leaves. Freshly picked leaves do not go brown in the way that those shed in the autumn do, as a result of chlorophyll breakdown, but remain greenish grey. This suggested that the dormice were travelling to the woodland floor to collect nest material, the rationale for including isolated boxes in Phase 2.

Phase 2 results confirmed that dormice were regularly travelling to the woodland floor by finding of 18 nests with 11 dormice observed in the isolated boxes on posts.

Wood mice were also found to be using boxes and while these also collect leaves they are not known to make a chamber. When a loose collection of leaves is found, it is impossible to determine which species has assembled them; in one case, E5 post, on one visit a wood mouse was found in the loose nest but on a later visit the same year (2018) it was occupied by a dormouse. While only direct observation of a dormouse constitutes evidence of box use the presence of nest material in boxes, particularly when a chamber or stripped bark were present, this suggests dormice were using the box.

The largest number of boxes occupied by at least one dormouse (22) and nests (32) were observed in 2018 (Tables 3 and 4). In all 3 years (2017–19), more high boxes were occupied by dormice than standard ones, although in 2018 the largest number of dormice (10) was observed occupying isolated boxes on posts with nests in a further nine. With 19 of the 25 post boxes having evidence of use, this clearly indicates dormice are regularly coming down to the woodland floor and moving around despite there being good aerial connectivity above both the canopy and standard boxes.

4.1 | The influence of box height

In an ideal experiment, the boxes would have been placed more consistently so that influence of height and potentially of host tree species could have been included in the analysis; this would only be possible in woodland with uniform age structure and species distribution so highly unlikely in ancient woodland. In order to relocate boxes, a grid pattern was used as far as possible with the priorities being trees that could be climbed safely and with good arboreal connectivity. The highest occupied box was at 12 m in a mature oak, consistent with the findings of Williams et al. (2013) who stated natural nests may be found as high as 15 m. The estimation of available natural nest opportunities is difficult but this tree had many features that could have provided this. Wood mice were found in a box 5.1 m from the ground.

4.2 | Variation between years

It was unfortunate that restrictions prevented surveying in 2020 and 2021, limiting the data set to 4 years. Data for all 6 years would have provided more robust evidence regarding the anecdotally reported fall off in box occupancy over time. Surveys in 2022 (Year 6) found low numbers of dormice and few nests. There was just one dormouse and three nests in the canopy boxes and a single nest in a standard height nest box and a post box. Five of the boxes, two high, two standard height and one on a post had wasp, bumblebee or hornets in occupation. The age of the boxes may influence their attractiveness to dormice and other species. Although old bird's nests were removed at the start of each season, parasites are known to build up in wooden nest boxes with increased loads found in 2-year-old boxes despite thorough cleaning between breeding seasons (Blunsden & Goodenough, 2023); research is required to determine the effect on dormice. In an earlier project the research team had tried to exclude birds by using corks to seal boxes in January to prevent use by birds, removing these in early May. A similar approach has been taken in Treswell Woods, a re-introduction site, managed by Nottinghamshire Wildlife Trust when birds are excluded by squaring the box entrances. Here no decline in dormouse numbers has been observed in long term monitoring (Lorna Griffiths pers. comm). More detailed investigation of this issue, which could account for decline in nest box use over time where natural alternatives are present, is required. Evidence of use of boxes in different positions at the same location suggests that dormice are exploring alternatives, perhaps before selecting the most appropriate for breeding, and this may suggest there is a 'novelty value', so artificial nest sites are used when newly positioned before reversion to natural ones. Statistical analysis suggests there is a significant difference in the occupancy of boxes over the years of the research carried out at Park Wood, Sissinghurst; however, this conclusion is likely to have been affected by the missing data from 2020 and 2021. More time series research is required to explore this issue in more depth.

4.3 | Limitations of this research

- COVID-19 restrictions and volunteer illness affected surveying during 2020/21
- The research design focused on the use of boxes rather than breeding or population estimation.
- Some volunteers—with dormouse licences—felt they could distinguish between nests made by dormice and those made by wood mice and so removed several potential nests, loose collections of leaves, from boxes. This may have had a negative influence with dormice not completing nests with a woven chamber, as well as reducing the overall number of nests.
- Dormouse numbers recorded are not indicative of the population size. In the research design, it was decided not to count individuals but to focus on box occupancy (use) by dormice, on the basis of welfare concerns. Despite great care being taken to approach quietly dormice were sometimes observed exiting the canopy box before the climber arrived. If a box was closed and a dormouse seen when the lid was moved the lid was replaced, the cloth removed, and the climber retreated to minimise disturbance and potential danger to dormice.

5 | CONCLUSIONS

The first research question aimed to establish the extent to which dormice, considered to be mainly arboreal during the active season, will use artificial nest boxes at standard height, higher in the canopy or placed to be only accessible from the ground. The results clearly demonstrate that dormice use artificial nest boxes placed at height as well as isolated boxes on posts. This is a clear indication that the use of the standard protocol, relying solely on boxes, tubes or footprint tunnels placed at 1.4 m on trees may not result in robust 'likely absence' conclusions for surveys aimed at determining presence of dormice on a site. This provides additional weight to the research of others, such as Bullion and Looser (2022) who have suggested that current survey methods based on placing monitoring structures in woodland at a height of around 1.4 m may not be providing accurate information about the presence or likely absence of dormice.

The second research question aimed to explore the anecdotally reported trend that artificial nest boxes are more frequently used when newly erected with occupancy tending to decline in subsequent years. This was found to be the case over the 6 years of the Sissinghurst project with the highest evidence of use seen in the second summer, 22 dormice and 32 nests observed, with 7 dormice and 14 nests the following year.

These results, although limited, lead to the questioning of the reported increase in the rate of decline, concluded from a 72% drop in nest box occupancy between 1993 and 2014 (Goodwin et al., 2017) a trend confirmed by Scopes et al. (2023) using the same NDMP data for the 27 years between 1994 and 2020 recording overall decline of 78%. The significance of this cannot be underestimated. Dormice are highly protected and, as a result, significant effort in both time and money is expended on determining presence or likely absence when areas of potentially suitable habitat are subject to planning proposals, management or any activity that could have an adverse impact on these animals.

If, as the results of the two phases of this research indicate, the current 'best practice' methods for surveying dormice are less than ideal, then more research is required to ensure that survey and monitoring techniques are robust enough to accurately reveal population trends and inform appropriate conservation action for this species.

5.1 | Recommendations for further research

- The evidence base for current 'good practice' guidelines for surveys to determine dormouse presence should be revisited and revised to reflect current understanding that dormice are less strictly arboreal than previously thought to ensure that they are achieving the desired conservation outcome for this important protected species.
- The NDMP data should be analysed to see whether there is a pattern of occupancy falling over time as this could indicate artificial boxes are explored as novel features in the environment when first erected, but become less attractive over time.
- Nests used by dormice should be examined after removal at the end of the season to determine whether parasites are present and whether this is related to box use by birds in early spring.
- Training for dormouse surveyors should ensure that collections of leaves in boxes are left in place rather than removed. Bird nests should only be removed once they are no longer in use.

AUTHOR CONTRIBUTIONS

Debbie Bartlett and Sam Bower: project design, data analysis and fieldwork. Sam Bower: Health and Safety protocols and risk assessment for arboreal survey. Peter Dear: fieldwork and logistics. All took part in fieldwork.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/2688-8319.12330.

DATA AVAILABILITY STATEMENT

All data used for this study are provided in Tables 1 and 2.

ORCID

Debbie Bartlett https://orcid.org/0000-0002-5125-6466

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