

# Bat box occupancy by noctule and brown long-eared bat

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**Abstract:** Bats occupying 44 bat boxes in Park Randenbroek, Amersfoort, the Netherlands, were studied during a twelve-year period. The main aim was to determine how much time is needed before bats are using the boxes regularly and if exposition, mounting height and box type influence occupancy. During 16 autumn inspections, noctules (*Nyctalus noctula*) and brown long-eared bats (*Plecotus auritus*) were encountered in bat boxes 45 times ( $n=212$ ) and 11 times ( $n=54$ ) respectively. Large cylinder-shaped boxes were used more often by noctules and contained more individuals than small cylinder and flat boxes. Noctules preferred bat boxes with a southern exposition but no effect of mounting height was detected within our range of 3.7-7 m. Brown long-eared bats preferred small cylinder-shaped boxes over flat boxes. It took five years until noctules started to use the bat boxes regularly and occupancy increased to 25% after ten years. Noctules seem hesitant to accept new roost sites and /or need a lot of time to discover that bat boxes are suitable roost sites. Guidelines suggest that placing bat boxes one year before logging commences would give bats sufficient time to habituate to the new roost sites. Our study shows that a lot more time may be needed. Occupying new roost sites may be a group decision; this provides a possible further explanation for the long habituation period needed.

*Keywords:* bat box occupancy, noctule, *Nyctalus noctula*, brown long-eared bat, *Plecotus auritus*, exposition, mounting height, habituation.

## Introduction

Bat boxes are often used to compensate for the loss of bat roost sites due to logging or forest maintenance. The underlying assumption is that bat boxes provide a suitable alternative for natural tree cavities that bats select for roosting. This is not always the case. Maternity roosts are rarely encountered in bat boxes and there is a general agreement that boxes cannot fully compensate for the loss of natural tree roost sites (Chambers et al. 2002, Zahn & Hammer 2016, Griffiths et al. 2017). But because bat boxes are commonly used by

many bat species, it should be considered as a valuable tool to reduce at least some negative effects of logging.

There are dozens of different types of bat boxes commercially available, while at the same time bats have specific demands for their roost sites (Mering & Chambers 2014). Not every bat box has the temperature, size and shape that bats prefer. The way bat boxes are installed can also influence occupancy. A large number of bat boxes is more effective than a small (<10) number of boxes (Ruegger 2016). More exposure to sunlight will increase the temperature of the bat box and close to the ground bats may not have sufficient ground clearance. Bat boxes installed at low (<2.5 m) height are also vulnerable to

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Table 1. Characteristics of 44 bat boxes that were monitored. Exposition = compass direction from the centre of the bat box towards the space directly in front of the box.

Box type	Number	Height Average (min-max)	Exposition			
			N	E	S	W
Schwegler 1FF	19	5.3 (3.8-6.9)	6	7	3	3
Schwegler 2FN	18	4.9 (3.6-7.0)	7	5	5	1
Schwegler 1FS	5	5.4 (3.7-6.6)	2		1	2
Schwegler 1FW	2	6.1 (6.0-6.1)	1		1	

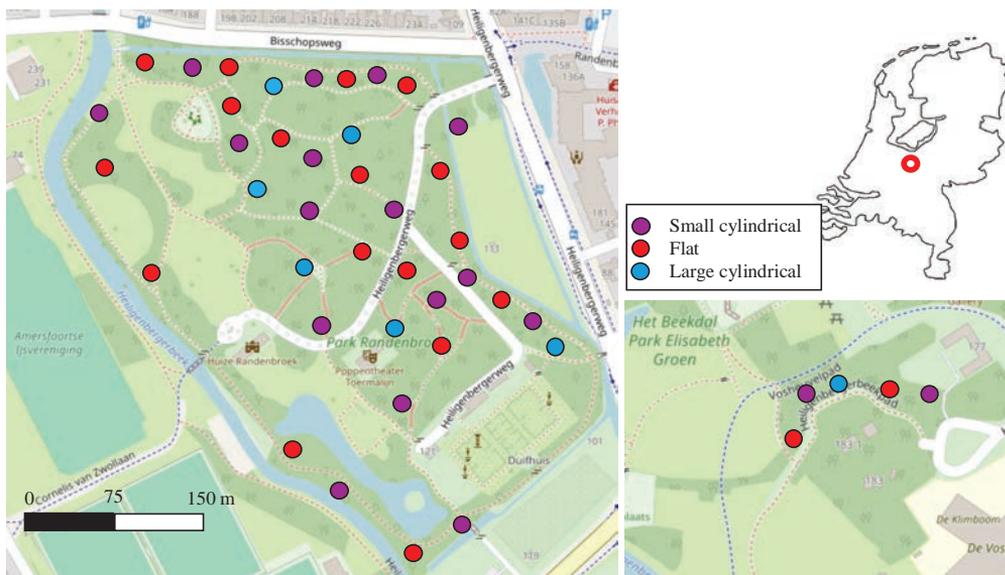


Figure 1. Location of the different bat box types within the study area Park Randenbroek.

vandalism. Although some guidelines for bat boxes exist (Korsten 2012, Rueegger 2016, BIJ-12 2017), a lot of expert judgement is still needed, as guidelines often simply state that the bat boxes should have the same quality as the original natural roost sites that they compensate for. This is unfortunate because much information about bat box occupancy has already been gathered by monitoring. By analysing monitoring data from 44 bat boxes during a twelve-year period, we aim to contribute to the knowledge of bat box occupancy by two forest dwelling bat species that can be used for more detailed guidelines. Our study focused on the following questions:

- How much time does it take before bat boxes are used by bats?

- Is there an effect of box type, mounting height and exposition on bat box occupancy?

## Method

### Study location

Monitoring of bat boxes took place in Park Randenbroek, a former estate situated in the city of Amersfoort, the Netherlands (Figure 1). The city park consists mainly of beech (*Fagus sylvatica*) forest in the last stage of succession. During maintenance of the park in 2013, dozens of mature trees were logged. One large (>20 animals) and 2-3 smaller (<10 animals) noctule (*Nyctalus noctula*) roosts were

present in the park in the years prior to 2013 (Boonman & Brekelmans 2012).

## Bat boxes

In March 2012 47 bat boxes were put up on mature trees in the park. Three bat boxes disappeared over the years and were removed from the analysis. Four different bat boxes were used: Schwegler 1FF (flat box with wide opening), 2FN (small cylinder), 1FS (large cylinder), FW (large cylinder with thick wall). We reduced the width of the entrance of the 2FN boxes to 15 mm to prevent frequent use of the boxes by birds. All four bat box types are composed of a mixture of cement and wood. Except for Schwegler 1FW, all bat box types were installed at a range of mounting heights and exposition (Table 1).

1FF and 2FN boxes were alternately placed in the tree lanes to ensure that in every section of the park all bat box type were present in equal quantity (Figure 1).

## Monitoring

Between 2012 and 2024 all bat boxes were checked 16 times in total. 1FF boxes can be checked without opening them. All other bat box types were opened and the number of bats present was counted. Identification was done according to Dietz & von Helversen (2004). Bats were not handled unless this was necessary for safely closing the lid after the inspection. Unused bird nests and large amounts of guano were removed if this was feasible without disturbing the bats. During the first five years the bat boxes were checked 2-3 times a year in spring, summer and autumn. From 2015 checks were no longer part of a funded monitoring programme and were continued by volunteers of the Bat Group Amersfoort. Due to the very low bat box occupancy in spring and summer, checks were done once a year during autumn from 2017 onwards. Dur-

ing the covid years bat boxes were not checked. During every visit, all bat boxes were checked.

## Statistical analysis

Before 2016 and during spring, the number of bats occupying the boxes was too low for quantitative analysis. Therefore, we only used data collected after 2016 during autumn inspections. Data from both Schwegler 1FS and 1FW boxes were combined as box type 'large cylinder', since both boxes have approximately the same size and shape. To determine the influence of bat box type, height and exposition on occupancy by bats we used a binomial GLMM from the lme4 package of R (R development core team). The observations (presence or absence of bats in a box) are not fully independent because the same bat boxes were checked during every inspection. When bats use a bat box, their scent and droppings are left behind. This may influence the chance of future occupancy. We incorporated this dependency in the model by using bat box ID as random effect. We tested an effect of exposition by looking at the deviation from north. Differences between north and south in occupancy can be detected by using this method.

## Results

During the first four years of monitoring, the boxes were used only incidentally by bats. Only during a few inspections bats were encountered and only a few bat droppings were found. After four years, occupancy started to increase for both noctule and brown long-eared bat (*Plecotus auritus*) (Figure 2). Occupancy increased to 25% during 2022 and 2023 for noctules. Noctules were encountered in bat boxes 45 times ( $n=212$ ). Brown long-eared bats were seen in boxes 11 times ( $n=54$ ). A Nathusius' pipistrelle (*Pipistrellus nathusii*) was seen once. Never were two species seen in the same box at the same time.

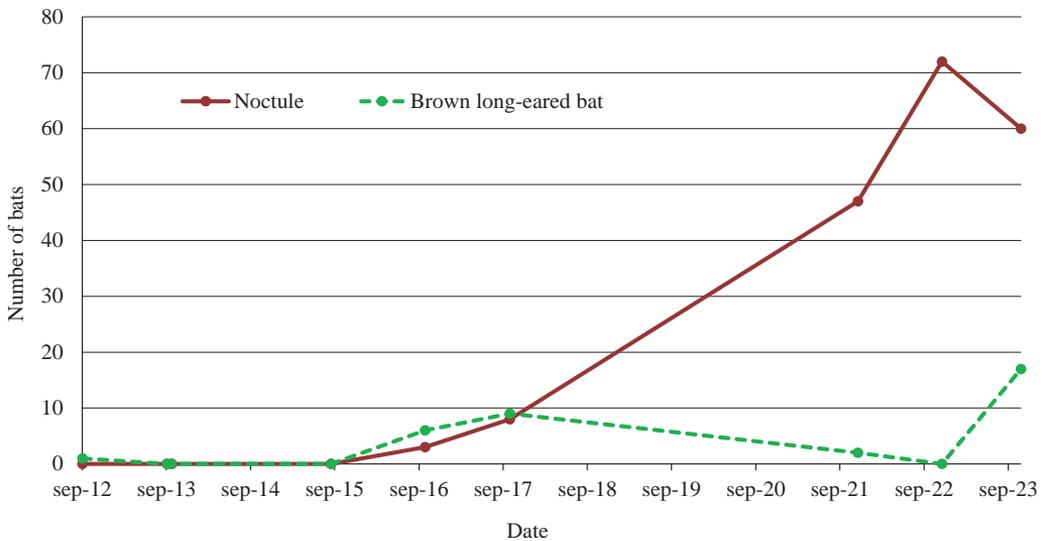


Figure 2. Total number of noctules and brown long-eared bats encountered in 44 bat boxes in autumn between 2012 and 2023. During covid-years no inspections were carried out.

### Influence of box type, height and exposition

Box type and exposition had a significant effect on bat box occupancy by noctules (Table 2). Approximately one third of the larger cylindrical bat boxes were used by noctules, compared to one fifth and one sixth for flat boxes and small cylindrical boxes respectively. The larger cylindrical bat boxes contained on average 3.4 noctules per inspection compared to 0.4 and 0.6 for flat boxes and small cylindrical boxes (Figures 3 and 4). The largest number of noctules encountered in a bat box (Schwegler FS) was 19. Occupancy of the bat boxes by noctules decreased when boxes were more exposed to the north, hence showing a preference for a southern exposition. Bat box height did not affect occupancy.

Brown long-eared bats were encountered in bat boxes 11 times ( $n=54$ ). This number is too low for an extended statistical analysis. Brown long-eared bats were found more often in small cylindrical boxes ( $n=8$ ) than in flat boxes ( $n=2$ ). This difference is significantly different from a distribution over both box

Table 2. Results of the binomial GLMM, comparing the occupancy of the large cylindrical (LC) boxes by noctules with the occupancy of small cylindrical (SC) and flat boxes (F). The influence of height above ground and exposition (deviation from north) on occupancy is also shown. \* significant

Covariate	Z-value	Probability ( <i>P</i> )
Box type LC: SC	-2.0	0.047 *
Box type LC: F	-1.3	0.19
Deviation from north	2.3	0.023 *
Height above ground	0.5	0.64

types that would occur if there was no preference for box type (Chi-squared test  $\chi^2=3.9$ ,  $df=1$ ,  $P<0.05$ ). Only once were brown long-eared bats found in large cylindrical boxes. The highest number of brown long-eared bats found in a single bat box was 17 (Figure 5).

### Discussion

Bats often use distinctly different roost sites during each part of their yearly life cycle. In winter bats select roost sites that are suitable for hibernation, such as caves with a high



Figure 3. Two noctules in large cylinder-shaped bat box (Schwegler 1FS). Photo: Erik Broer.

humidity and a constant temperature. In summer the same bat species may be found in warm and dry roost sites that are more suitable for raising young. Although noctules use trees as roost sites all year round, a shift in roost preference throughout the year is also likely in this species. In winter, larger roost sites may be preferred as larger group sizes are generally recorded in this time of the year. It is assumed that increasing group size facilitates enduring low ambient temperatures (Gaisler et al. 1979). More subtle changes can also be expected during the year as reproductive females spend less time in torpor compared to post-lactating females (Dzal & Brigham 2013). Our study focused on bat box occupancy in autumn. The results of this study may not be applicable for occupancy in spring and summer when bats may have different preferences. Although the number of bat boxes and checks is relatively low, our wide range in mounting height and exposition that is evenly spread over the study area is rarely shown in other studies. Merging the results from different

studies that each have limited variation in covariates is helpful to obtain a bigger sample size, but will certainly result in unbalanced data. In many areas for example, only a single bat box model is used. Bats can also be more common in a specific area, leading to a high bat box occupancy. In this case it will be impossible to tell whether high occupancy is the result of a preference for this box type or a preference for this area.

In our study, noctules showed a preference for large boxes with a cylindrical shape. These boxes are three times more expensive than small cylindrical boxes. Occupancy in larger boxes is twice as good and the average number of noctules encountered in these boxes is six times larger. Therefore, buying larger boxes seems to be the best choice for this species, and well worth the extra costs. Brown long-eared bats preferred the smaller cylindrical boxes over flat boxes in our study. Flat boxes have a wide opening at the bottom and may not provide the best microclimate in autumn. It should be noted that the cylindri-





Figure 5. Seventeen brown long-eared bats occupying a small cylinder-shaped bat box (Schwegler 2FN). Photo: Erik Broer.

ties constructed by woodpeckers (Boonman 2000) while *Nathusius'* pipistrelles often use the space behind tree bark as roost site (Dietz et al. 2009).

The mounting height of the boxes did not affect occupancy within our range of 3.6 to 7 m. Other studies showed a weak positive effect of mounting height on occupancy in common pipistrelle and Natterer's bat (*Myotis nattereri*) (Pschonny et al. 2022). The mounting height of their boxes was substantially lower (2-4 m) than the boxes in our study. We expect, therefore, that below 3.6 m there may indeed be an effect of mounting height on occupancy in noctules, which need sufficient ground clearance during emergence. Our study showed a preference for boxes with a southern exposition in noctules. Although the boxes are located under the forest canopy, the boxes facing south may still receive a bit more sunlight, making them slightly warmer than boxes with a northern exposition. Kerth et al. (2001) also found a preference

for warmer boxes in Bechstein's bats (*Myotis bechsteinii*) in autumn. Printz et al. (2021) on the other hand found a preference for NW exposed boxes (that only receive sunlight at the end of the day) in noctules in spring. Bats may prefer to spend more time in torpor in spring compared to autumn.

One year after the bat boxes were mounted, dozens of mature trees were logged. This was done under surveillance of ecologists. Each tree was carefully inspected from a cherry picker and cavities were inspected with an endoscope camera before felling to make sure no bat was killed. The logging reduced the availability of potential and known roost sites for noctules (Boonman & Brekelmans 2012) and led to disturbance during the autumn of 2013, but not to high mortality in the local population. Printz et al. (2021) suggested that a lower density of roosting opportunities may lead to an increase in bat box occupancy. We could, however, not detect an increase in bat box occupancy during the

first four years after the trees had been logged. The logging led to a gradual increase in forest undergrowth over the twelve-year period (personal observation), which may have led to an increased food availability for brown long-eared bats. Contrary to long-eared bats, noctules are aerial hawkers, adapted to forage in open areas (Norberg & Rayner 1987, Mackie & Racey 2007), and do not forage in dense forest undergrowth. It took five years before noctules began to use the boxes in our study regularly. It is unlikely that this reflects changes in local population size. Noctules populations may have increased, such as observed in the western part of the Netherlands (Mostert & Bekker 2024), but due to the noctule's low reproduction rate such an increase is taking place relatively slow (Zukalova et al. 2022), i.e. has been occurring over several decades and not just over the last ten years. We think that it is more likely that noctules need a lot of time to discover that bat boxes are suitable roost sites and / or that they are hesitant to accept new roost sites. Guidelines (BIJ12 2017) suggest that placing bat boxes one year before logging commences would give bats sufficient time to habituate to the new roost sites. Our study shows that much more time may be needed. Griffiths et al. (2017) and Pschonny et al. (2022) also showed that occupancy of bat boxes depends on the age of the boxes, an effect that may last for up to ten years. This even exceeds the life expectancy of most individuals. A possible explanation for the extensive amount of time needed to accept new roost sites is that bats are social animals that prefer to roost in a colony or in close vicinity of conspecifics. Fleischmann & Kerth (2014) showed that in brown long-eared bats group decision making about communal roost were made unanimously. Pre-dawn swarming behaviour in tree-dwelling bats is believed to drive the collective selection of new roosts (Zelenka et al. 2020). Accepting new roost sites as a group will take more time because more animals need to agree with the decision. As a consequence of this exten-

sive habituation time, monitoring bat boxes may not be suitable for detecting population trends in noctules. Other bat species can be less selective. There are examples of flat bat boxes that are frequently used by Nathusius' pipistrelles within one year after installation (personal communication J. Boshamer, own observation). Additionally, bats that are already familiar with bat boxes may accept new bat boxes more quickly (Bergmann et al. 2025).

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## Samenvatting

### Het gebruik van vleermuiskasten door de rosse vleermuis en de gewone grootoorvleermuis

Vleermuiskasten worden veel gebruikt om de effecten van het kappen van bomen op boom-bewonende vleermuizen te verminderen. Het type kast en de wijze waarop ze worden opge-

hangen kan gevolgen hebben voor de kans dat ze door vleermuizen gebruikt worden. De richtlijnen die hiervoor zijn opgesteld, zijn niet altijd concreet, wat veel ruimte overlaat voor een eigen interpretatie. Dit is jammer, omdat inmiddels veel gegevens beschikbaar zijn over het gebruik van vleermuiskasten. We hebben in deze studie het najaarsgebruik geanalyseerd van 44 houtbetonnen vleermuiskasten in Park Randenbroek in Amersfoort over een periode van twaalf jaar. Daartoe hebben we bepaald hoelang het duurde voordat de kasten in gebruik genomen werden en of er een effect op het gebruik is van het type kast, de hoogte waarop deze was opgehangen en de expositie. De vleermuiskasten werden opgehangen één jaar voordat de kap van tientallen volwassen bomen plaatsvond. De eerste vier jaar werden vleermuizen en vleermuiskeutels slechts incidenteel aangetroffen. Het gebruik van de kasten door rosse vleermuizen (*Nyctalus noctula*) in de herfst begon na vijf jaar toe te nemen en bedroeg een kwart na tien jaar. Het lijkt erop

dat het erg lang duurde voordat rosse vleermuizen ontdekten dat de vleermuiskasten als verblijfplaats gebruikt kunnen worden en /of dat de soort erg terughoudend is in het accepteren van nieuwe verblijfplaatsen. Mogelijk speelt hierbij een rol dat het in gebruik nemen van een nieuwe verblijfplaats een groepsbeslissing is in plaats van een individuele keuze. Grote cilindervormige kasten werden het meest gebruikt door rosse vleermuizen en bevatte ook het hoogste aantal dieren. Rosse vleermuizen bleken een voorkeur te hebben voor kasten met een zuidelijke expositie. Binnen de range van 3,6-7 m was er geen significant effect van hoogte boven de grond op het gebruik. Gewone grootoorvleermuizen (*Plecotus auritus*) gebruikten kleine cilindervormige kasten vaker dan platte kasten. We hopen dat vleermuiskasten effectiever ingezet kunnen worden met behulp van deze informatie.

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