Date: October 2023

New Zealand Bat Recovery Group Advice Note – The Use of Artificial Bat Roosts

Context

Artificial roosts (also known as bat boxes) have increasingly been used in New Zealand with the aim of providing bats with alternative roosting options in response to tree felling and vegetation removal. However, there has been minimal research into the effectiveness of artificial roosts for New Zealand bat species at replacing natural roosts. This is not unusual, and, world-wide, recommendations on construction and installation are often based on anecdotes, rather than rigorous research (Mering and Chambers 2014). One of the exceptions is the long-running Melbourne-based bat box research programme[1]. This Australian research suggests “bat boxes are not a silver bullet conservation tool” and that “bat boxes are unlikely to compensate adequately for the broad-scale loss of tree hollows caused by various forms of human disturbance” (Griffiths, Bender et al. 2017). This is because bat boxes have typically catered to common, abundant bat species of minimal conservation concern (Mering and Chambers 2014; Griffiths et al. 2017). Thereby, reducing their effectiveness for conservation purposes (Rueegger, 2016; Rueegger et al. 2019). In addition, bat box programmes rarely consider species-specific roost preferences which should be understood and targeted prior to installation (Robinson et al. 2023).

The purpose of this advice note is to provide the current view of New Zealand’s Department of Conservation’s Bat Recovery Group on the use of artificial roosts for bats. It is based on a knowledge of New Zealand long-tailed bat ecology, the limited research made to date, and research on artificial bat roosts in Australia on different species.

Artificial Bat Roosts are untested for effectiveness in mitigating loss of roosts.

- The use of artificial roosts should be a last resort rather than a first port of call. Focus should instead be on retaining vegetation, particularly old trees and natural roosts (Chambers, Aim et al. 2002), and predator control for bats.
- This is because bats use roosts that are chosen specifically for their thermal properties (Sedgeley 2001), and these are used over many years by generations of bats (O'Donnell and Sedgeley 1999). Reductions in the numbers of trees that are suitable as roosts may affect population viability, and populations in areas where roosts are few or rare are likely to be limited by roost numbers (O'Donnell and Sedgeley 1999, Sedgeley and O'Donnell 1999).
- When bats use roosts that have poorer thermal qualities, populations are likely to have lower reproductive fitness (productivity i.e., fewer weaned young/female) and survival rates (Sedgeley and O'Donnell 2004).
- Most research into roosting ecology for New Zealand bats has taken place in summer months. This means that we know even less about what types of roosts bats require over winter.
- We know very little about how to design artificial roosts to replicate the properties of natural roosts that best suit New Zealand bats, or where to place them that is (a) attractive to, or (b) suitable for bats.

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[1] https://batboxes.wordpress.com/

- Microclimates provided by artificial roosts are likely to be different from those provided by natural roosts (Chambers, Aim et al. 2002). Without robust research into how to design artificial roosts so that they replicate conditions found in natural roosts, where bats have high reproductive fitness and survival, it is likely that these will provide roosts that are inferior.

- If artificial bat roosts are used to replace natural high-quality roosts, then it is likely that populations using them will have reduced reproductive fitness and survival, especially if they are poorly designed. This is because poorly designed artificial roosts are likely to have inferior thermal qualities than natural roosts. Roosts with inferior thermal qualities are associated with lower survival and productivity (Sedgeley and O'Donnell 2004).

- Artificial roosts can be too hot or too cold for bats because of their design or placement. Research in Melbourne found that some artificial roosts were hotter than ambient temperatures on hot days, putting bats at risk of heat stress and even death (Griffiths 2021). Whilst this is concerning for adult bats, this is even riskier for young pups, which cannot readily thermoregulate so are likely to be more susceptible to overheating (Crawford and O'Keefe 2021), and cannot fly so cannot leave a roost independently if they get too hot. Climate change is likely to increase these risks even higher (Flaquer, Puig et al. 2014).

- It may take some time for bats to begin using artificial roosts, if they ever do. A short-term DOC-led trial of artificial roost boxes in South Canterbury, found that long-tailed bats began to use some of the boxes within two years, and these were still in use five years after installation (Jones, Borkin et al. 2019). However, few of the boxes were ever used, and checks after five years no longer found evidence of bats using boxes (Jones, Borkin et al. 2019). If long-tailed bats use roost boxes, it is likely that their use may take some years to be observed (Moira Pryde, pers. comm., DOC, 12 October 2015 in Jones, Borkin et al. (2019)).

- Several artificial roosts were installed in Hamilton City’s southern parks from 2011, five years after their installation long-tailed bats were first observed roosting in some of the artificial bat boxes. But it is unknown how soon after installation use began (K. Borkin, pers. obs. in Jones, Borkin et al. (2019)) or the proportion of boxes used by bats.

- From 2019, a further 80 artificial roosts were installed throughout Hamilton City. Long-tailed bats were first observed roosting in a number of these bat boxes 1-2 years after installation (O’Sullivan 2021, Robinson 2022). Previous exposure to bat boxes has corresponded with quicker uptake elsewhere (Rueegger 2016). Therefore, it is likely that the previous use of artificial roosts in Hamilton City facilitated the relatively quick uptake of some boxes (Robinson et al. 2023).

General Advice on installation, placement, and maintenance

- We don’t know which artificial roost box type is best at replicating conditions New Zealand bats require, or even whether these are an effective way of mitigating roost loss. This is untested.

- Therefore, anyone considering using artificial roosts as a mitigation approach should undertake/support robust research into the thermal qualities of artificial roosts and their placement and compare these to the preferences of bats and temperatures at which overheating may occur (Flaquer, Puig et al. 2014). This is crucial for ensuring better outcomes for bats when bat boxes are used as mitigation tools (Crawford and O'Keefe 2021).

Artificial bat roosts should be considered a short-term tool (Chambers, Aim et al. 2002). Focussing on retaining vegetation and planting to provide for roosts should be long-term goals (Chambers, Aim et al. 2002). Note that new plants will not have suitable roosting opportunities for many years. The youngest trees known to be used as roosts were 16 year old *Eucalyptus fastigata* (Borkin and Parsons 2011); native vegetation is likely to take much longer to mature and become suitable as bat roosts. Some botanists have suggested that it may take 80 years or more for natural roosts to form within native vegetation (Borkin and Martin 2018).

- If you intend to mitigate for potential roost loss by providing artificial roosts, then you should provide multiple artificial roosts for each potential roost that is lost. This is because:
    - of the lack of knowledge, as outlined throughout this advice note.
    - most artificial roosts that are deployed won't meet the criteria that bats are looking for; and,
    - the high likelihood that bats will not find the artificial roosts, even if suitable.
- Placement, and other advice below, is based on general understanding of bat ecology, generally learned through research that has taken place over summer. This is untested. We don't know a lot about roost selection for long-tailed bats in winter, so the advice provided below is focussed on knowledge of summer roosting ecology.
- Female and male bats use different roosts because they have different metabolic requirements, so a variety of roosts are required to maintain a population (Borkin and Parsons 2011).
- To meet these different needs, boxes should be placed in locations and on trees so that they are exposed to variable amounts of sunlight, particularly on the north-eastern and south-western sides of trees.
- Female long-tailed bats: in summer, often choose roosts that warm in the morning (most exposed to the sun in the North-East) and stay warm all day (Borkin and Parsons 2011).
- Male long-tailed bats: in summer, often choose roosts that warm in the afternoon (most exposed to the sun in the South-West)(Borkin and Parsons 2011).
- Other placements/orientations are likely to be required to maintain a population, particularly given we know so little about roosts chosen by bats outside of summer.
- Research in Hamilton City indicates that bat boxes should be installed in the interior of tree stands rather than stand fringes or exposed ridge sites (Robinson et al. 2023). Sheltered artificial roosts likely have more stable microclimates compared to those on marginal features, which allows bats to conserve energy during winter and avoid over heating in summer (Hamilton and Barclay 1994; Borkin and Parsons 2011; Hoeh et al. 2018).

There are overheating risks with artificial roosts

- Bats are considered to be at risk of heat stress, dehydration, or death when temperatures inside bat boxes reach 40 ^{0}C or greater (Flaquer, Puig et al. 2014). Even in high altitude mountainous regions in Europe (990 m a.s.l.), bat box interiors reached these high temperatures on 60% of days in late summer (Flaquer, Puig et al. 2014). When ambient temperatures approach or exceed 30 ^{0}C, bat box interiors may approach 40 ^{0}C, putting bats at risk (Griffiths 2021).

- Providing boxes that are shaded may be one method to ensure boxes are cooler and reduce the risks of overheating (Crawford and O'Keefe 2021).

Don't paint or put out dark-coloured roost boxes. This is because temperatures get very hot inside when painted dark colours; this puts bats (and other animals) at risk of heat stress during high temperatures (Griffiths, Rowland et al. 2017). Because of this risk, a recent review suggested that a "dark, ventless bat house" was inappropriate for deployment in most temperate climates (Crawford and O'Keefe 2021).

- Consider/trial other ways to reduce overheating risks, such as these recommended by Crawford and O'Keefe (2021) and (Griffiths 2021):
    - provide multi-chambered boxes with transfer holes between chambers so that bats can move between chambers – altering the temperatures that they are exposed to – without exiting the box
    - vary shading and the exposure of boxes to the sun
    - choose boxes that are light-coloured or have high surface reflectance to reduce radiation absorption
    - constructing boxes using thicker timber walls, and,
    - using materials with greater insulative capacity (e.g., wood-cement).

- However, note that there are trade-offs when manipulating designs to reduce maximum temperatures as these may produce microclimates that are not conductive to pup development (Crawford and O'Keefe 2021).

Placement of artificial roost boxes

- Some studies have suggested that placing boxes on snags or poles may be beneficial because this exposes boxes to more sunlight (Mering and Chambers 2014), and because boxes may be more obvious to bats when placed on snags/poles (compared to, for example, when attached to trees where they may be somewhat obscured). However, a review of artificial roost box placement found that when comparing what the boxes were attached to (e.g., to a pole/tree/building/snag), uptake of boxes appears to vary between studies and locations (Mering and Chambers 2014).
- Place the box higher than a person can reach (for obvious reasons).
- Most roost cavities found in the Southern South Island beech forest in indigenous forest are 10 m or higher[2] (Sedgeley and O'Donnell 1999); roosts in other habitat types may be closer to the ground.
- Predator proof! Place a predator proof band around the tree above and below the box distant enough so that predators cannot reach the box for a tasty bat snack. And make sure that the potential predator cannot reach the box via another tree. You might need to prune the host tree to achieve this.

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[2] Eighty-five percent of roost cavities found in the Eglinton Valley were over 10 m above the ground.

- Placing them where there are likely to be few natural roosts is probably most useful (Mering and Chambers 2014). Putting them in indigenous forest may be wasting resources because there are probably already many natural roost sites available.

- Place where bats are detected regularly. This might make it more likely that bats encounter the artificial roosts, e.g., along a river where there are trees. In addition, installing artificial roosts near natural or already occupied artificial roosts may facilitate discovery (Robinson et al. 2023).

- Give bats space to leave – open air space is needed in front of the box.

Inspection and Maintenance

- Inspect and maintain boxes annually (Chambers, Aim et al. 2002).

- Maintenance should include:
    - removal of bird nesting material and other non-target species (including insects) that compete with bats for space,
    - ensuring boxes are still correctly secured to their tree (or pole etc), and,
    - maintaining predator-proof bands are still effective.

- At sites where maintenance did not occur for several years, we have evidence of bat roost boxes being unavailable/unsuitable for use by bats because they had fallen to the ground or turned upside down, predator-exclusion methods were no longer effective, and boxes had rotted (A. Styche, Department of Conservation, pers. Comm., 6 September 2021). In one New Zealand-based study of artificial roost use, some roost boxes were filled with nesting material between checks, and were therefore unavailable for bats to use (Jones, Borkin et al. 2019).

- Close inspections and repairs should take place when bats are not present.

- Plan inspections and repairs during May-October (when bats are not heavily pregnant, or lactating, or have non-volant young, that is young that are dependent and unable to fly).

Other design considerations

- Designs could consider ways to minimise the likelihood of use by non-target species (such as other mammals, birds, or insects), so that boxes are available for bats to use (Mering and Chambers 2014).

- Bat boxes can be useful sources of information in research projects (Mering and Chambers 2014). Adding a lid with a hinge to the top of the artificial roost box should be considered so that populations can be easily accessed if research[3] takes place in the future.

Common artificial roost designs

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[3] research into New Zealand bats generally requires a research permit (under the Wildlife Act 1953) from the Department of Conservation.

We know that long-tailed bats have used artificial roost boxes in two locations where natural roosts are likely to be rare: Hamilton and Geraldine (Jones, Borkin et al. 2019). The artificial bat houses that long-tailed bats are using in Hamilton, New Zealand, are based on a Kent design.

There are plans for these and similar designs, as well as other useful advice, at this link:

https://batboxes.wordpress.com/advice-about-bat-boxes/

The dominant species using the boxes in the Melbourne research project linked above are *Chalinolobus gouldii* – Gould's wattled bat (Griffiths, Bender et al. 2017). These are closely related to long-tailed bats – the same genus, but we don't know if they have the same requirements when roosting.

Long-tailed bats have also used other artificial bat roost box types (Jones, Borkin et al. 2019). These can be purchased from overseas. One example is the Schwegler bat boxes.

https://www.schwegler-natur.de/fledermaus/?lang=en

An example of a multi-chambered design is shown in Tuttle, Kiser et al. (2013): https://merlintuttle.com/wp-content/uploads/2016/03/BHBuildersHdbk13_Online.pdf

Alternatives to artificial roost boxes

There is value in investigating methods other than artificial roost boxes for the provision of roosts for bats in the short-term (Crawford and O'Keefe 2021).

Alternatives considered worthy of further investigation by researchers (Crawford and O'Keefe 2021, Griffiths 2021) include:

- the retention and creation of snags
- carving or using a chainsaw to cut hollows directly into live or standing dead trees.

Carved/Chainsawn hollows

Chainsawn hollows have been found to provide microclimates closer to those of natural roosts than those provided by artificial roost boxes (Griffiths, Lentini et al. 2018).

Australian trials that created hollows by carving or chainsawing hollows into live, healthy, trees have found that trees will grow wound-wood that will/may eventually close over entrances (Dr S. Griffiths, La Trobe University, Melbourne, pers. comm., 22 September 2021). This research found that cavities that were carved with vertical fissure entrances were all closed by wound-wood within two years of cavity creation and required cutting back of the bark and cambium from the entrance slit for them to continue to be available as potential roosts (Dr S. Griffiths, La Trobe University, Melbourne, pers. comm., 22 September 2021). Trialling the cutting of cavities into dead standing trees may be worth investigating.

We recommend that when carved/chainsawn hollows are created they follow dimensions identified as physical characteristics of natural tree roosts used by long-tailed bats as in Sedgeley and O'Donnell

(1999). We suggest that replicating these dimensions may be the best effort to mimic natural cavities, if the recommended research does not take place[4].

The following characteristics were obtained from research in southern beech forest by Sedgeley and O'Donnell (1999). This four-year research project assessed 149 roost cavities found by capturing 73 individual long-tailed bats and radiotracking them to locate their roosts over four years.

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[4] as noted above, research into how to mimic natural roost thermodynamics is critical if artificially-created roosts are to be used as a replacement for natural roosts Crawford, R. D. and J. M. O'Keefe (2021). "Avoiding a conservation pitfall: Considering the risks of unsuitably hot bat boxes." Conservation Science and Practice: e412.

An image illustrating specific orientations of dimensions is shown as Figure 1, which is copied from Sedgeley and O'Donnell (1999).

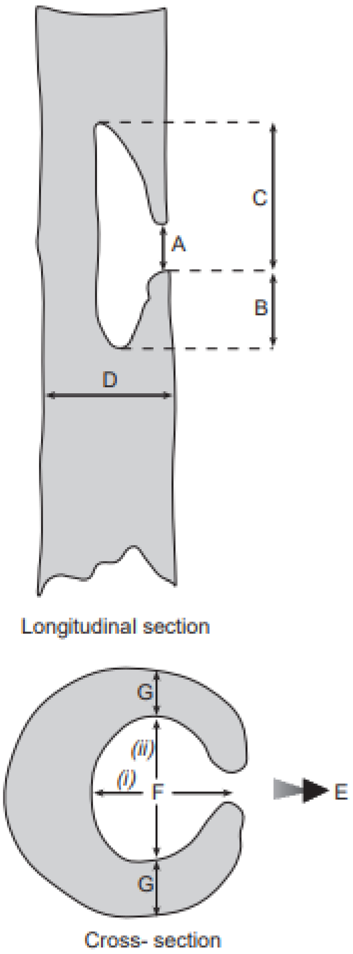

Fig. 1. Measurements taken from roost cavities and available cavities: A, the area of the entrance hole (height × width); B, cavity depth; C, cavity height; D, the tree diameter at cavity height (DCH); E, the direction the entrance faced; F, the cross-sectional area of the internal cavity (width *i* × width *ii*); and G, the cavity wall thickness (DCH − width *ii* ÷ 2).

On average, roost cavity entrances were 15 m above the ground with an entrance area of 100 cm^2. Internal dimensions follow from Sedgeley and O'Donnell (1999); letter notation matches that in Figure 1:

Cavity characteristics: letter notation following Figure 1	**Mean**	**S.D.**
Distance to nearest vegetation	7 m	4.9
Entrance Height from ground	15 m	5.9
Entrance area (height x width): A	100 cm^2	85.0
Internal cavity depth: B	14 cm	18.2
Internal cavity height: C	43 cm	36.7
Diameter at cavity height (DCH): D	66 cm	26.8
Inside cross section: F	405 cm^2	318.6
Wall thickness: G	24 cm	11.8
Volume	26731 cm^3	32835

Roosts were in areas that had slightly less surrounding vegetation overall compared to random locations, with relatively clear air space above and below roost entrances (Sedgeley and O'Donnell 1999). All cavities should be carved so that they remain dry.

Dimensions, orientation, height, tree species, and location should all be recorded so results from different projects can be compared in the future.

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