NSW GOVERNMENT | Biodiversity Conservation Trust

Biodiversity Conservation Trust Guideline for Artificial Hollows

For private land conservation agreements | August 2020

Contents

Glossary

Term	Definition
Accredited assessor	In individual accredited to apply the Biodiversity Assessment Method under the NSW Biodiversity Offset Scheme and assess impacts on biodiversity at development sites and biodiversity stewardship sites.
Artificial Hollow	A hollow structure that aims to mimic a natural tree hollow. This may be an artificially constructed nest box, salvaged fallen hollow or habitat augmentation approaches such as chainsaw hollows, that have been found to be used as refuge or breeding habitat for hollow-dependent fauna.
Biodiversity Assessment Method (BAM)	The BAM is a scientific document that outlines how an accredited person assesses impacts on biodiversity at development sites and stewardship sites.
BCT	Biodiversity Conservation Trust
Biodiversity Stewardship Agreement (BSA)	An agreement for landholders wishing to generate and sell biodiversity credits under the Biodiversity Offsets Scheme. They provide permanent conservation and funded management of the biodiversity values on the land.
Conservation Agreement (CA)	An agreement relating to land for the purpose of conserving or studying the biodiversity of the land. May or may not have funding to undertake management actions. Includes all conservation agreements administered by the BCT.
Conservation area	An area of land to which a private land conservation agreement applies.
GPS	Global Positioning System
Hollow	Cavities formed in the trunk or branches of a living or dead tree.
Management plan	Refers to the management plan included in the conservation or biodiversity stewardship agreement. This plan identifies the management actions required to be undertaken in the conservation area.

Plant Community Type (PCT)	The master community-level classification of approximately 1,500 NSW vegetation types in the NSW Government's BioNet Vegetation Classification. Used in NSW's planning and assessment tools and vegetation mapping programs.
Wildlife Refuge Agreement (WRA)	An agreement between the BCT and the landholder to protect and manage wildlife habitat on an area of land.

Objective

Natural tree hollows (or cavities) provide essential shelter and breeding opportunities for a range of fauna species including mammals, birds, reptiles and frogs. Many of these species are threatened. The protection of habitat trees is often a priority for private land conservation, however in many modified landscapes old trees no longer exist. Allowing for the natural development of hollows in modified landscapes can be a slow process. Installing artificial hollows in the form of nest boxes, salvaged fallen hollows, stag relocation or more recently, chainsaw hollows, has been a method employed to provide additional habitat for species that depend on hollows for nesting or roosting. The utilisation of these structures by target species and their durability over time largely depends on construction materials, design specifications and the method of installation (Goldingay et al. 2018).

In some circumstances, and if implemented appropriately, providing habitat for hollow-dependent fauna through artificial hollows may be used to achieve biodiversity conservation goals such as supporting threatened species. However, the installation of artificial hollows is considered an interim solution while natural hollows form, and landholders installing artificial hollows must make a long-term commitment to monitor their use and undertake maintenance as required.

The NSW Biodiversity Conservation Trust (BCT) works in partnership with landholders to establish private land conservation agreements to conserve and manage high-value biodiversity on private land. These guidelines have been developed for landholders with private land conservation agreements to help determine whether installation of artificial hollows as a management action will achieve conservation objectives and if so, identify the most appropriate artificial hollow type for the target species and site conditions.

The guidelines aim to provide greater consistency in identifying fauna species for which this management action is appropriate, outline artificial hollow specifications for different species, and identify circumstances where funding of artificial hollows is supported by the BCT.

Introduction

The NSW Biodiversity Conservation Trust (BCT) partners with landholders to conserve and manage biodiversity on private land by establishing conservation and biodiversity stewardship agreements. Biodiversity values in conservation areas and stewardship sites are maintained, enhanced or restored through a range of management actions.

In NSW, at least 46 mammals, 81 birds, 31 reptiles and 16 frogs depend upon the availability of natural hollows for shelter and breeding (see Appendix 1 for examples). However, threats including past and current land uses have contributed to the ongoing loss of hollow-bearing trees. The loss of hollow bearing trees is listed as a key threatening process for NSW wildlife. Natural hollows take a long time to form. As trees experience damage over time, larger, older 'habitat trees' tend to have more hollows per tree, and a greater range of different sized hollows (Whitford 2002, Goldingay 2011). Large hollows are particularly rare and occur mostly in trees over 220 years old (Gibbons and Lindenmayer 2000).

When the availability of natural hollows is limited, the addition of artificial hollows[1] has been identified as a management action to provide supplementary habitat for a range of different hollow-dependent species, such as bats, birds and marsupials (see examples in Appendix 1). It should be noted however, that scientific evidence indicates some hollow dependent species do not, or rarely use artificial hollows (examples in Appendix 1). In conservation areas lacking or under-resourced in natural hollows, the BCT supports the installation of artificial hollows if the site is deemed suitable for the specific target hollow-dependent species, and there is evidence that the target species uses artificial hollows. Artificial hollows may include suitably constructed nest boxes, salvaged fallen hollows or, where suitable, the creation of hollows within existing trees.

This guideline aims to help landholders determine whether the addition of artificial hollows might be appropriate as a management action to improve biodiversity within their site. Information in this guideline is based on current research and knowledge of species use of artificial hollows in specific ecosystems. This guideline outlines principles and circumstances for when the addition of artificial hollows may be appropriate, and provides landholders with optimal design specifications, minimum construction standards and installation techniques for artificial hollows targeting native fauna.

Acknowledging that each site presents unique circumstances, these guidelines should be used as a framework that can be tailored to a variety of situations and target species. Regular monitoring, as part of a long-term adaptive management strategy will be used to evaluate the conservation outcomes from installing artificial hollows, and their cost-effectiveness. This information will be essential to help guide decision-making and inform adaptive management.

[1] *The term 'artificial hollow' is defined in the Glossary for the purpose of this guideline.*

Figure 1 Nest box designed for parrot species (Source: SMEC Australia with permission from Transport for NSW)

Are artificial hollows appropriate for a conservation area?

The first step to determine whether the installation of artificial hollows may help achieve biodiversity conservation outcomes, is to identify the hollow-dependent species that occur, or potentially occur on the site. In addition to published reports, field surveys and database searches (e.g. NSW BioNet, Atlas of Living Australia), anecdotal records can be used to inform what hollow-dependent species are present on a site. For all biodiversity stewardship agreements (BSAs) and for some conservation agreements (CAs), field surveys will be required to inform this. For landholders with a conservation agreement, BCT staff can help you identify potential species. For BSAs, hollow-dependent species would be identified by BAM Accredited Assessors.

It is important to note that artificial hollows are not a suitable substitute for natural hollows for all hollow-dependent species. The BCT will generally support the installation of artificial hollows where evidence indicates use by the target species. A list of hollow-dependent threatened species in NSW and evidence for artificial hollow use is provided in Appendix 1.

If you have a conservation agreement and have identified one or more hollow-dependent species potentially occurring on the site, the decision tree in Figure 2 can be used to determine if artificial hollows are an appropriate management action for your site. For BSAs, the decision tree in Figure 3 can be used to guide whether the installation of artificial hollows may be an appropriate management action, and whether the installation of artificial hollows may generate biodiversity credits for the target species. BCT staff or (for BSAs) a BAM accredited assessor can help you work through the decision trees.

Decision making tree for conservation agreements and wildlife refuge agreements

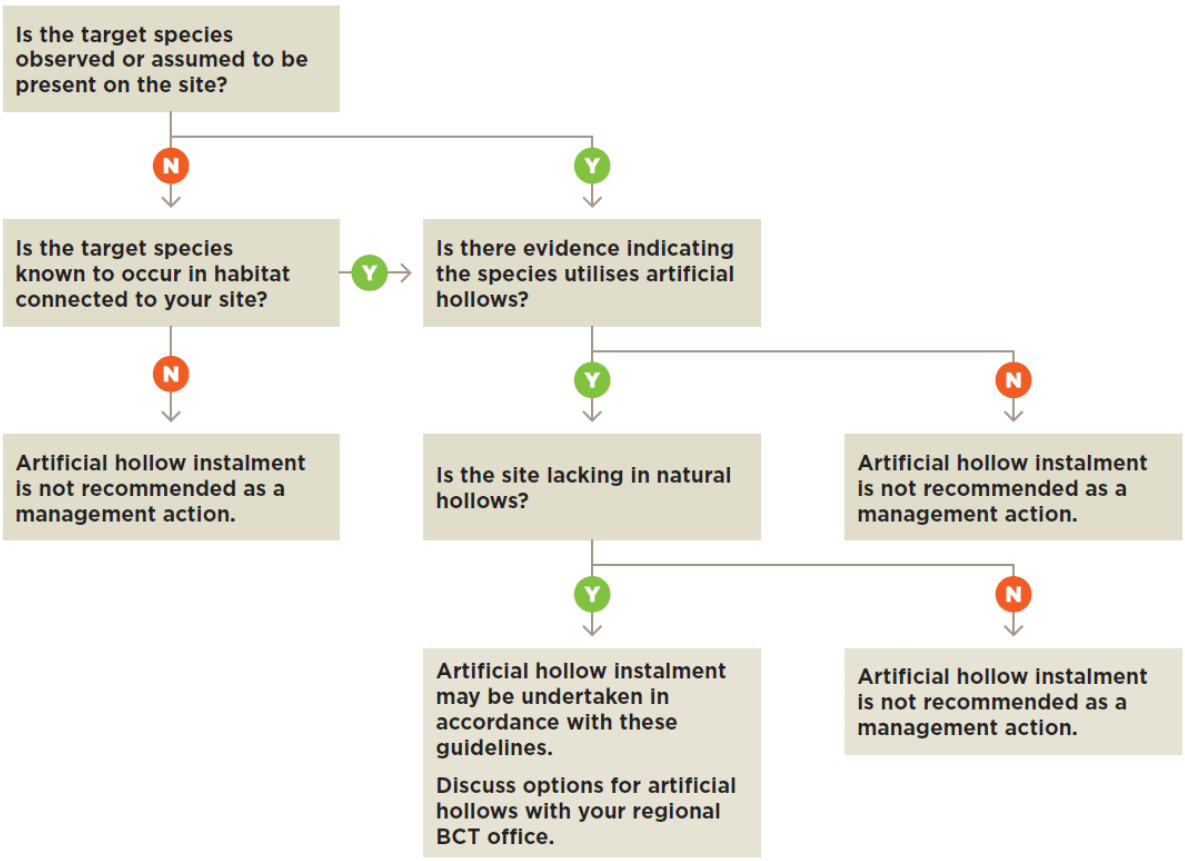


Figure 2 Decision making tree for conservation agreements and wildlife refuge agreements

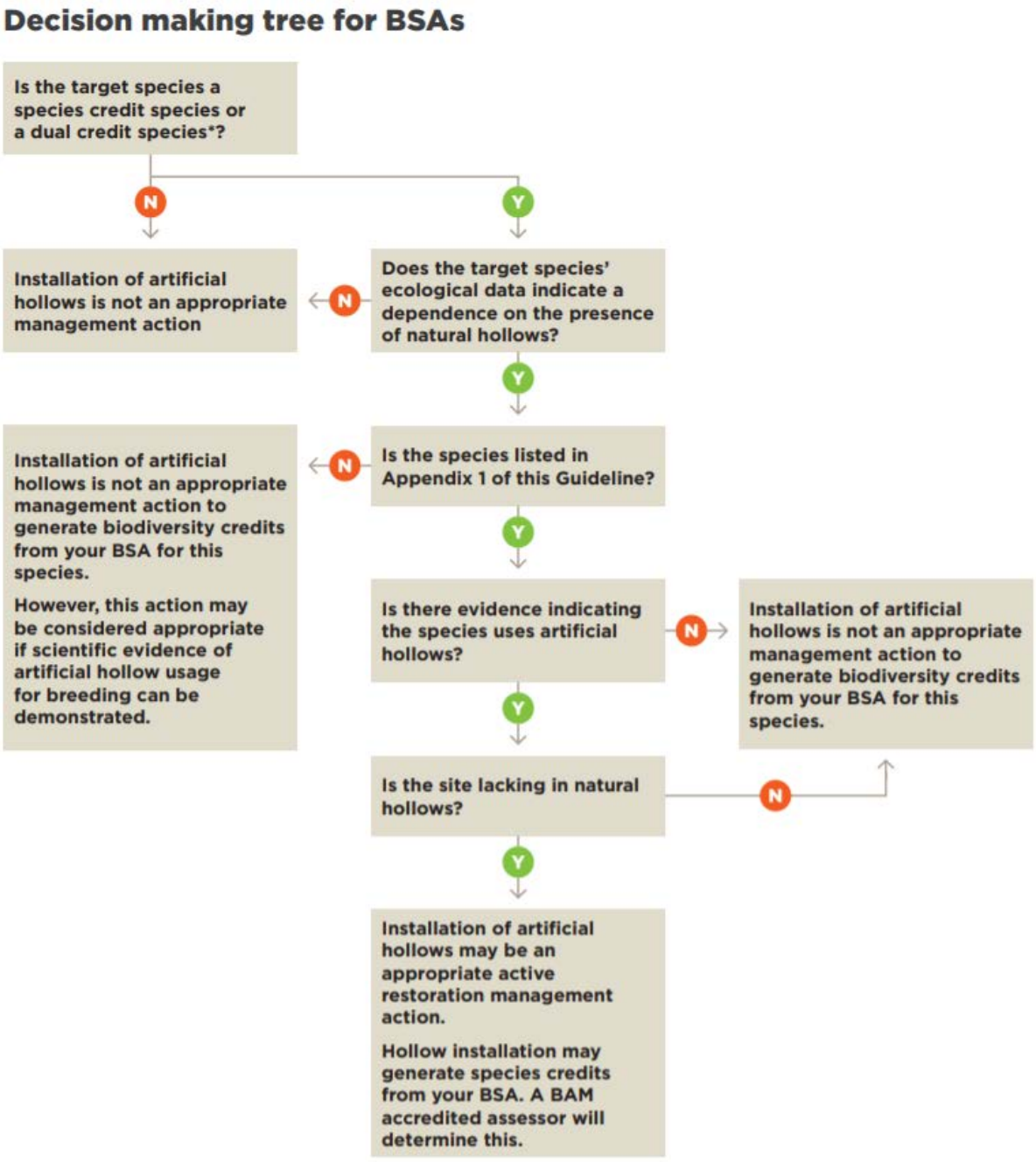


Figure 3 Decision making tree for BSAs (Refer to the Biodiversity Assessment Method (OEH 2017))*

Principles of installing artificial hollows

The installation of artificial hollows to support hollow-dependent species in private land conservation agreements should be guided by the following principles:

1. The installation of artificial hollows contributes to a broader, longer term strategy of supporting the development of natural hollows at the site. Artificial hollows are to be maintained or replaced until sufficient natural hollows develop.

2. Artificial hollows should only be installed if it is appropriate for the site[2].

3. Artificial hollows should only be installed in trees that do not have existing functional hollows.

4. Artificial hollows should only be installed where a target species has been identified as potentially inhabiting the vegetation at the site and when there is evidence to suggest the target species will utilise artificial hollows for breeding or shelter.

5. The design of artificial hollows should be based on specifications for the target species in these guidelines, unless BCT is provided with scientifically rigorous justification as to why another specification should be used.

6. The number of artificial hollows installed in a designated area will be determined by the BCT based on an onsite assessment and guided by the large tree benchmark for the Vegetation Class on the site[3].

7. The placement of artificial hollows, including spacing and degree of clustering, should be guided by knowledge of the target species.

8. Optimise positive outcomes through careful planning, clear objectives, measurable targets, appropriate artificial hollow design and installation, and positioning in a suitable location.

9. Ongoing monitoring[4] should be used to determine if conservation objectives have been achieved and to guide adaptive management.

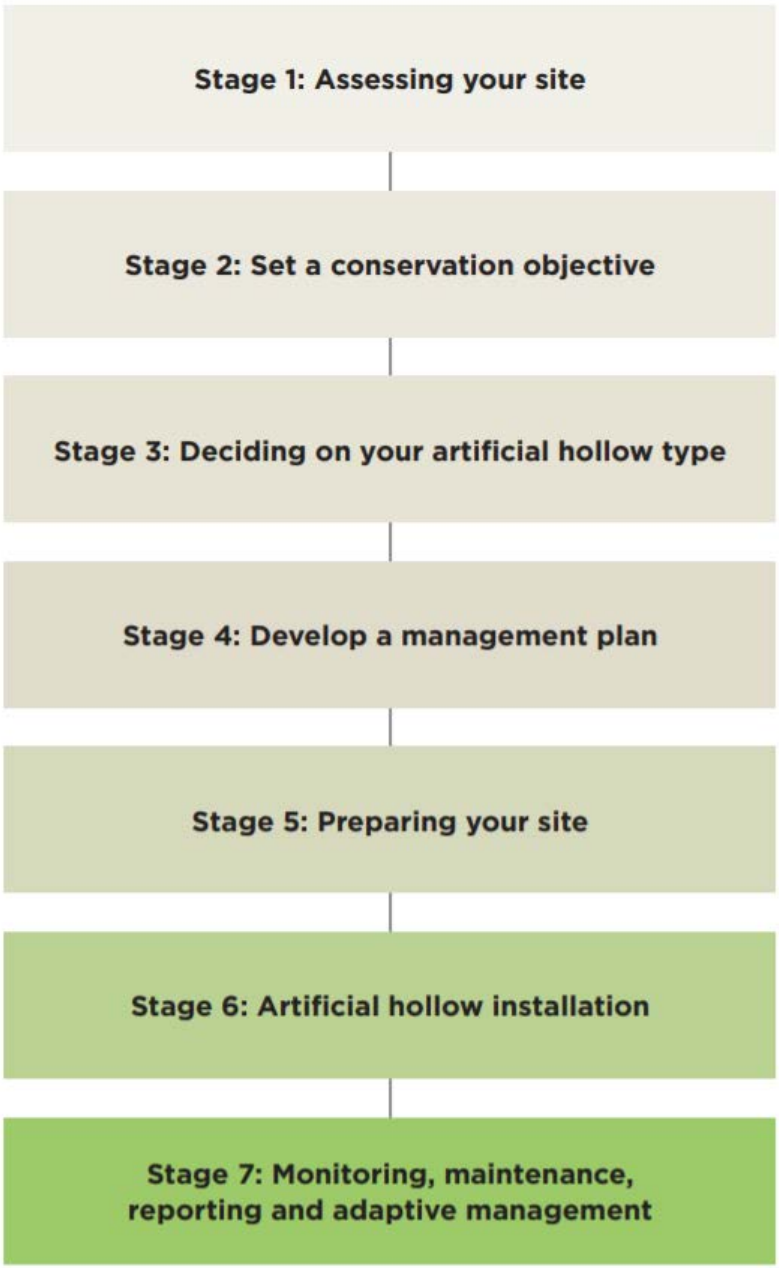
[2] *Refer to the artificial hollow framework*

[3] *Or an appropriate benchmark determined by BCT staff, consultant ecologist or BAM accredited assessor.*

[4] *Refer to the artificial hollow framework - Stage 7 – Monitoring, maintenance, reporting and adaptive management*

BCT artificial hollow framework

This section provides an overarching framework for the stages of planning and implementing artificial hollows as a management action for a private land conservation agreement. This framework can be applied once it has been determined by using the decision trees in Figure 2 or Figure 3 that artificial hollows are suitable for your site. BCT staff or a BAM accredited assessor can support you in working through this framework and if required, link you with professionals in artificial hollow planning, building and installation. More detailed information about each stage is provided in the following sections.



Stage 1 – Assessing your site

An initial site assessment will assist in determining whether your conservation area is suitable for the installation of artificial hollows to provide habitat for hollow-dependent fauna. This involves:

- Assessing past disturbance history
- Determining the Vegetation Class and Plant Community Types (PCTs) on your site
- Considering your site in the context of the surrounding landscape
- Estimating the number of natural hollows currently present on your site

Table 1 provides more detail on why this site information is important to inform specific management actions for artificial hollows on your site. These factors are key considerations to ensure the conservation objectives can be met.

See the Literature Cited and Further Reading section for other resources that may assist in assessing your site.

Table 1 Assessing site context

Action	Explanation
Past disturbance	Biodiversity assessment reports, historical aerial photographs and vegetation mapping can be used to understand the past disturbance of a site. If selective logging or vegetation thinning has occurred, it is likely that the number of large trees (with associated hollows) are absent or in low numbers.
Determine the Vegetation Class and PCTs on your site (BCT officer or BAM accredited assessor)	Large tree benchmarks for the Vegetation Class can help determine the number of artificial hollows that should be installed[5]. PCT's can also be used by a BCT officer or BAM accredited assessor to help determine the target species for the site. PCT's and their condition may also be used to delineate management zones, whereby the area designated for artificial hollows can be identified as a management zone and documented in your management plan.
Determine locality context	What kind of landscape bounds the property? For example, is there connecting vegetation, busy roads, water bodies or neighbouring fences with barbed wire immediately adjacent to the site? This information will help identify areas that may or may not be suitable for installing artificial hollows. Consider target species movement through the landscape, availability and location of habitat

[5] A more appropriate hollow benchmark may be determined by BCT staff, a consultant ecologist or an accredited assessor, and/or if your target species is known to utilise clusters of hollows. BCT staff can assist identify whether this is the case.

Action	Explanation
	resources, and potential dangers such cleared land exposing target species to predators.
Estimating natural hollow density	An estimate of the density of natural hollows present on a site will be determined through large tree counts across vegetation classes or PCTs during the site assessment. This measure recognises the importance of services provided by large trees (including natural hollows) and minimises variability in hollow counts by site assessors. An average large tree density will be calculated for each PCT. For BSA sites, a BAM accredited assessor will collect large tree data when undertaking BAM vegetation plots to determine the PCTs at a site. If there are a high number of existing natural hollows within the site or adjacent to the site, the installation of artificial hollows may not be an appropriate management action considering cost effectiveness.

Stage 2 – Set a conservation objective

Each conservation area may have multiple conservation objectives that will be used to identify appropriate management actions to maintain or improve biodiversity. As a landholder you will have to determine if providing habitat for hollow-dependent species that occur on or near your site, is one of the conservation goals you aim to achieve.

Artificial hollow installation contributes to a broader longer-term conservation objective of supporting the restoration of natural hollows over time.

The decision about what conservation objective to set should be based on the purpose of your agreement, an understanding of the current habitat available for target hollow-dependent species on the site, consideration of cost versus benefit, the ability to manage current threats (such as pest species), and the capacity for the management actions to support the restoration of natural hollows over time.

For a small grant your objective may be to:

- Provide habitat for a range of different hollow-dependent species on a site that is lacking in natural hollows
- Improve habitat connectivity for highly mobile hollow-dependent species populations
- Aid the detection of hollow-dependent species believed to inhabit the site.

For a conservation agreement your objective may be to:

- Provide habitat (nesting or roosting) for a target threatened species known to occupy your site or connecting habitat
- Provide breeding habitat in the absence of natural hollows for a hollow-dependent threatened bird species known to forage in the vegetation type of your site
- Provide habitat for a highly mobile threatened species known to utilise the vegetation type of your site but not recorded specifically at the site.
- Provide habitat for the hollow-dependent prey of a target threatened species e.g. installing nest boxes for possums or gliders that are a food resource for Powerful Owls.

BCT staff in consultation with relevant experts such as fauna habitat specialists can assist landholders in determining if habitat enhancement through artificial hollows is appropriate to achieve your objective.

For a BSA site your objective may be to:

- Provide breeding habitat for a threatened species known to inhabit your site (habitat enhancement) and generate species credits

A BAM accredited assessor can help you determine if habitat enhancement through artificial hollows is appropriate to achieve your objective and determine conditions under which species credits may be generated.

Stage 3 – Determining the artificial hollow type

The type of artificial hollow selected should be appropriate for the target species and budget. As determined in Stage 2, the installation of artificial hollows is likely to be in response to one of two scenarios:

1. Providing additional habitat for hollow-dependent fauna in areas where natural tree hollows are lacking – artificial hollows of different sizes will be installed to target a range of hollow-bearing species likely to utilise the site.
2. Encouraging the presence or reintroduction of one or more target threatened species – only artificial hollows specifically designed to suit the target threatened species will be installed.

For BSAs, credits are only issued in line with the BAM (OEH 2017). Scenario 1 will not be used to generate credits.

Specifications for artificial hollows aim to mimic dimensions of natural hollows that the target species is known to occupy. Specifications typically include the size and shape of entrance hole, internal cavity size, placement height on the tree, orientation, and material type.

Consider the costs associated with building or buying artificial hollows and installing them, along with the number of artificial hollows proposed for your site. Monitoring and maintenance requirements including possible replacement should also be factored into the consideration of costs.

Types of artificial hollows

Table summarises the main types of artificial hollows that are considered appropriate. Further details about each type is provided in Appendix 2.

Table 2 Summary of artificial hollow types available for installation

Type	Description	Effectiveness	Cost	Risk
Manufactured	Installation of pre-fabricated 'nest boxes' built to standard specifications dependent on the target species.	Low – High (dependent upon targeted species, design specifications and material quality).	Moderate	Nest boxes not of suitable quality for target species; provide short term habitat only if not maintained; High maintenance if poorly made with an attachment that does not allow for tree growth.

Type	Description	Effectiveness	Cost	Risk
Salvaged	Hollows are cut from felled hollow-bearing (habitat) trees, capped if necessary, and attached to non-habitat trees.	Moderate (evidence for several species).	Low - Moderate	Hollows inappropriately sourced.
Chainsaw / drilled	Hollows cut into standing trees or existing hollows modified to improve access.	Moderate (evidence for several species).	High in short-term. Low in long-term	Requires technical training and certification to install; tree health potentially compromised; entrance plates falling off or entrance closed by tree growth

Stage 4 – Develop a management plan

Information collected in Stages 1-3 will help determine suitable management actions. Development of the management plan will involve planning and prioritising management actions and setting realistic targets within clear timeframes to reach conservation objectives. BCT staff, ecological consultants, or (for BSAs), BAM accredited assessors can assist landholders in this process.

The management plan should include:

- the number and type of artificial hollows required for each management zone,
- the location of suitable trees for installation (closer proximity to water and food resources may increase occupation and subsequent breeding success),
- installation technique and who would install the artificial hollows (refer to Stage 6),
- measures to protect the artificial hollows from fire,
- monitoring and reporting requirements for your site (refer to Stage 7 and Appendix 3),
- relevant triggers for the repair and replacement of artificial hollows, including managing unwanted occupants (refer to Stage 7), and
- costs associated with management actions including construction, installation, monitoring and maintenance.

Spacing / Density

It is recommended that multiple artificial hollows be provided to reduce hollow competition and allow individuals to occupy alternative hollows within their home range. For example, a single glider will utilise numerous hollows and a single phascogale up to 40 hollows across its large home range). To

prevent overcrowding and maximise coverage, artificial hollows targeting the same species should be adequately spaced. Spacing between hollows targeting different species is less important.

Each conservation area may be occupied or visited by a suite of hollow-dependent species, each of which have preferences regarding hollow dimensions, location and density. Density of hollows is not well researched for many species and may be regionally variable for species that occur across parts of NSW. Optimal density and spacing for target species within a conservation area should be discussed with BCT staff, an ecologist or a BAM accredited assessor.

Input from appropriately qualified professionals

Landholders must seek the advice of the BCT or an ecologist with expertise in the ecological requirements of the target species to determine the appropriate artificial hollow type, specifications and installation location. Landholders are also encouraged to seek advice from suitably qualified experts or contractors. These will be determined based on the target species and site condition.

For chainsaw hollows it is important to first consult with an ecologist with understanding of the roosting behaviour of the target species, to determine the appropriate hollow specifications. A qualified professional such as an arborist will then be required to determine if the tree can support this type of hollow and create it.

Protecting artificial hollows from fire

Bushfires pose a significant risk to fauna occupying artificial hollows. Management actions such as raking leaf litter (e.g. leaves, twigs and bark) away from the base of the tree can reduce the risk of the tree being destroyed by fire.

Stage 5 – Preparing your site

Preparation of your site is important for the successful installation of artificial hollows. Before beginning installation, you should:

- Obtain and prepare artificial hollows including the attachment of a unique identification number for monitoring. Identification can be in the form of a number printed on the bottom of a nest box/salvaged hollow, a tag attached directly to the trunk of the tree or another durable method.
- Review your management plan to confirm requirements for specific management zones.
- Assess the safety risks of the chosen method of installation.
- Employ the services of a qualified professional if required.

Stage 6 – Artificial hollow installation

When installing artificial hollows, safety should always be considered. It is a potentially hazardous activity with a significant chance of injury from risks such as, but not limited to, working at heights, lifting heavy items and using tools.

Artificial hollow installation technique and location will be dependent on the hollow type and site conditions. See Appendix 2 for more information about the installation technique and location for each type of artificial hollow.

After determining a suitable location for hollow installation, orient the hollow in a suitable direction to protect it from prevailing weather and extreme temperatures. In hotter regions, for example, nest boxes may become too hot for target species to inhabit if they are not in a shaded position during the hottest part of the day.

When determining the height of the artificial hollow, consider the requirements for monitoring and the optimal height for the target species, including placement to avoid attack by predators. For example, if cats are present in the area, wrapping a metal sheet around the base of the tree will prevent them from accessing the artificial hollow. Recommended hollow heights for a range of species are provided in Appendix 2, Table 5.

Stage 7 – Monitoring, maintenance, reporting and adaptive management

The success of an artificial hollow installation program is uncertain. Even with best practice implementation, artificial hollows can deteriorate and thus need maintenance or replacement, non-target exotic species such as European honeybees can take up residence, and other factors may prevent use by the target species', warranting relocation of the artificial hollow elsewhere. Occupancy by target species is often low (Lindenmayer et al, 2017). Ongoing monitoring is essential to determine how effective the installation of artificial hollows has been in supporting the target species, and to build our general understanding of the circumstances under which investing in artificial hollows may be worthwhile.

Monitoring

The responsibility of monitoring and reporting on the installation of artificial hollows is shared between the landholder and BCT staff.

A monitoring form such as that provided in Appendix 3 must be completed by the landholder following the installation of artificial hollows to provide baseline information. This includes for each artificial hollow, a unique identifier, the location of the tree (using a GPS), the type of hollow and the date of installation. A georeferenced photo of each artificial hollow should be taken and stored for comparison over the monitoring period and to assist the landholder and BCT staff locate the hollow in subsequent years. Photographs are also encouraged as part of the monitoring program and can be provided to the BCT for assistance with identifying species and reporting.

Annual inspections of each hollow should then record on the monitoring form any observations of species activity around the hollows, the condition of each hollow and tree, and any maintenance of

the hollow required and/or performed (Appendix 3). Any clear occupancy by non-target species should be included. Outside the formal monitoring period, opportunistic sightings of non-target species occupying nest boxes should be reported to the BCT.

Damage to hollows should be repaired as soon as is practicable.

As a guide, if there is no evidence of the target species using the artificial hollow over three years, it should be relocated elsewhere within the conservation area. Monitoring of chainsaw hollows should also involve observations of tree health, and changes to the hollow entrance.

If occupancy monitoring is required, this should be done in consultation with BCT staff or an ecologist to minimise disturbance to hollow occupants and aid species identification. Factors including the best time of day and year to monitor should be considered, depending on the behaviour of the target species. For example, monitoring is often performed at dawn or dusk. Care should be taken during nesting season to avoid disturbing incubation. Hinged lids on nest boxes can be used for inspections if access to the box is available. Cameras mounted on a pole can be used where access is limited, or the lid of the hollow cannot be removed (e.g. chainsaw hollows).

Maintenance

When condition of the artificial hollow deteriorates to a level that makes it unsuitable for the target species, maintenance is required (Table 3). Some minor damage may be possible to repair while the artificial hollow is in position, but the safest practice for any major repairs is to remove the hollow from the tree to undertake maintenance at ground level. Record any required maintenance or maintenance undertaken in the monitoring form (Appendix 3).

Table 3 Condition of artificial hollows

Condition	Description	Action
Good	No damage or minimal damage that does not affect the function of the hollow.	None
Moderate	Minor damage, but the hollow still provides suitable habitat for the target species. Examples: lid slightly loose, sides warping due to moisture	Undertake minor repairs if not occupied. Continue to monitor
Poor	Major damage to artificial hollow making it no longer suitable for occupation by the target species Examples: Tree attachment failing, missing lid	Repair or replace

Figure 4 Nest boxes in good (left), moderate (middle – peeling lid) and poor (right – fallen from tree, no lid and honeycomb present) condition (Source: SMEC Australia with permission from Transport for NSW)

Nest boxes may require replacing if they become occupied by European honeybees. While bees may move out of nest boxes after a period of time, native wildlife may refuse to use a box previously occupied by bees.

Figure 5 Repair of minor damage to a nest box (Source: SMEC Australia with permission from Transport for NSW)

Reporting

Artificial hollows that are funded by the BCT will have reporting requirements to track the progress and success of management actions. Monitoring must be consistent with the BCT Ecological Monitoring Module and include, at a minimum:

- Inspection dates
- Condition of artificial hollows
- Any evidence of occupancy including species identification where possible
- Details of maintenance and management undertaken.

Monitoring information provided by the landholder (e.g. species observations, hollow and tree condition, and the details of any maintenance required or performed), should be included in the report.

During each monitoring period, BCT staff or an ecologist will also assess the success of the artificial hollow installation against the specific conservation objectives identified in Stage 2.

Frequently Asked Questions

Will the BCT fund the installation of artificial hollows?

The BCT would only fund the procurement and installation of artificial hollows in accordance with these guidelines i.e. in situations where i) natural hollow densities are considered a limiting factor for target native species to utilise the area (i.e. if hollow densities are below benchmark levels for the Vegetation Class), and ii) where there is evidence indicating successful use of artificial hollows by the specific target species. For conservation agreements, BCT ecologists will assess the appropriateness of including management actions that involve the use of artificial hollows during the site assessment. For biodiversity stewardship agreements, the BAM accredited assessor will determine if artificial hollows are an appropriate active restoration management action and, if relevant, the conditions under which species credits may be generated.

There are a number of pathways through which landholders can seek support from the BCT for implementing conservation management actions in their conservation area: fixed price offers, conservation tenders, co-investment partnerships and conservation partners grants. Whether funding is available to undertake artificial hollow installation and management in accordance with this guideline will be dependent on the specific suite of management actions or activities that are identified for each individual mechanism. If funding is available, landholders must cost these management actions as accurately as possible

Why are tree hollows important?

Many species of wildlife depend on tree hollows for shelter, nesting and breeding. They provide protection from the weather and potential predators.

What are artificial hollows used for?

Artificial hollows are used to supplement natural tree hollows when they are absent or low in number. Specifically designed artificial hollows can also be used to monitor and detect the presence of particular species.

What animals use tree hollows?

In NSW, terrestrial vertebrate species that are reliant on tree hollows for shelter and nests include at least 46 mammals, 81 birds, 31 reptiles and 16 frogs (Gibbons and Lindenmayer 1997, Gibbons and Lindenmayer 2002). Appendix 1 lists threatened species that use tree hollows.

How often do I need to check the artificial hollows?

External condition of nest boxes and salvaged hollows should be checked at least once every 6-12 months to ensure they are still in suitable condition and not damaging the tree. Internal occupants should be inspected less often, as determined by the management plan specific to the site, and, if

applicable for a BSA, the specific reporting requirements for generating species credits. Disturbance should be minimised to prevent occupants from vacating the artificial hollow.

Does the nest box need to be cleaned?

Occupants of the nest boxes will generally maintain the contents of the artificial hollow and it is not necessary to remove any material found inside. Disturbance, including removal of nesting material, may result in the animal abandoning the hollow.

What happens if pests are in the artificial hollows?

Sometimes non-target native species or unwanted pest species take over artificial hollows, making them unavailable for use by the target species. Pests may include the European Honeybee (*Apis mellifera*), Common Myna (*Acridotheres tristis*) and Common Starling (*Sturnus vulgaris*).

Unwanted pest species should be documented and managed. This may include removing and relocating the relevant nest box or participating in a pest management program run by local council or Local Land Services. There is some evidence to suggest that European Honeybees may relocate from artificial hollows over time and should not be removed, however this is not always the case. Some native wildlife will not occupy a nest box that has been previously inhabited by bees, and the nest box may require replacing. BCT staff or an ecologist can assist in determining suitable management responses. Reporting unwanted occupants to the BCT provides useful information on the effectiveness of artificial hollows for target species and supports adaptive management.

Literature Cited and Further Reading

Berris, K., Barth, M., Mooney, T., Paton, D., Kinloch, M., Copley, P., Maguire, A., Crowley, G. and Garnett, S. (2018). From the brink of extinction: successful recovery of the glossy black-cockatoo on kangaroo Island. In S. Garnett, P. Latch, D. Lindenmayer, & J. Woinarski (Eds.), *Recovering Australian Threatened Species-a Book of Hope* (pp. 75-84). Australia: CSIRO Publishing.

Beyer, G.L. and Goldingay, R.L. (2006) The value of nest boxes in the research and management of Australian hollow-using arboreA5:A31al marsupials. *Wildlife Research* 33, 161–174.

Bladon, R.V., Dickman, C.R. and Hume, I.D. (2002) Effects of habitat fragmentation on the demography, movements and social organisation of the eastern pygmy-possum (*Cercartetus nanus*) in northern New South Wales. *Wildlife Research* 29, 105–116

Courtney, J. and Debus, S. (2006). Breeding habits and Conservation status of the musk lorikeet *Glossopsitta concinna* and little lorikeet *G. pusilla* in Northern New South Wales. *Australian Field Ornithology* 23(3), 109-124.

Duran, R., Luck, G.W. and Matthews, A. (2009) Nest-box use by arboreal mammals in a peri-urban landscape. *Wildlife Research* 36: 565-573.

Franks, A. and Franks, S. (2006). *Nest boxes for wildlife: A practical Guide*. Bloomings Books, Melbourne, Australia.

Franks, A. and Franks, S. (2011) *Nest boxes for wildlife: A practical guide*. Bloomings Books Pty Ltd, Toorak, Victoria.

Gibbons, P. and Lindenmayer, D.B. (1997) *Conserving hollow-dependent fauna in timber production forests.* Environmental heritage monograph series no. 3. NSW National Parks and Wildlife Service, Sydney.

Gibbons, P. and Lindenmayer, D.B. (2002), *Tree Hollows and Wildlife Conservation in Australia*, CSIRO Publishing, Melbourne.

Gibbons, P., Lindenmayer, D.B., Barry, S.C., Tanton, M.T. (2000) Hollow formation in eucalypts from temperate forests in south-eastern Australia. *Pacific Conservation Biology*. 6: 218-228.

Goldingay, R.L. (2011). Characteristics of tree hollows used by Australian arboreal and scansorial mammals. *Australian Journal of Zoology*. 59: 277-294.

Goldingay, R.L. and Keohan, J. (2018) Population density of the eastern pygmy-possum in a heath–woodland habitat. *Australian Journal of Zoology* 65(6) 391-397

Goldingay, R.L., Grimson, M.J. and Smith, G.C. (2007) Do feathertail gliders show a preference for nest box design? Wildlife Research 34, 484–490Goldingay, R.L. and Stevens, J.R. (2009) Use of artificial tree hollows by Australian birds and bats. *Wildlife Research.* 36: 81-97.

Goldingay, R.L., Quin, D.G., Talamo, O. and Mentiplay-Smith, J. (2020b) Nest box revealed habitat preferences of arboreal mammals in box-ironbark forest. *Ecological Management and Restoration*. doi:10.1111/emr.12412 (https://doi.org/10.1111/emr.12412)

Goldingay, R.L., Rohweder, D. and Taylor, B.D. (2020a), Nest box contentions: Are nest boxes used by the species they target?. *Ecological Management and Restoration*. doi:10.1111/emr.12408 (https://doi.org/10.1111/emr.12408)

Goldingay, R.L., Ruegger, N.N., Grimson, M.J. and Taylor, D.T. (2015) Specific nest box designs can improve habitat restoration for cavity-dependent arboreal mammals. *Restoration Ecology* 23(4) 482–490

Goldingay, R.L., Thomas, K.J. and Shanty, D. (2018) Outcomes of decades long installation of nest boxes for arboreal mammals in southern Australia. *Ecological Management and Restoration*. 19(3): 204-211.

Griffiths, S.R., Lentini, P.E., Semmens, K., Watson, S.J., Lumsden, L.F. and Robert, K.A. (2018). Chainsaw-carved Cavities Better Mimic the Thermal Properties of Natural Tree Hollows than Nest Boxes and Log Hollows. *Forests.* 9(5): 235.

Harper, M.J., McCarthy, M.A. and van der Ree, R. (2005) The use of nest boxes in urban natural vegetation remnants by vertebrate fauna. *Wildlife Research.* 32: 509-516

Hicks, R.K. (1997) 'Purple-crowned Lorikeets roosting and possibly nesting in metal pipes', *Australian Bird Watcher.* 17,216-217.

Higgins, P.J. (Ed.) (1999), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 4, Oxford University Press, Melbourne.

Hurley, V.G. and Stark, E.M. (2015) *Characteristics and uptake of simulated natural cavities for Major Mitchell's Cockatoo (Lophochroa leadbeateri leadbeateri) in Slender Cypress-pine*. Department of Environment, Land Water and Planning, Mildura.

Law, B., Chidel, M., Britton, A., Brassil, T. (2013) Response of eastern pygmy possums, Cercartetus nanus, to selective logging in New South wales: home range, habitat selection and den use. *Wildlife Research* 40, 470-481.

Le Roux, D.S., Ikin, K., Lindenmayer, D.B., Bistricer, G., Manning, A.D. and Gibbons, P. (2016). Effects of entrance size, tree size and landscape context on nest box occupancy: Considerations for management and biodiversity offsets. *Forest Ecology and Management*. 366: 135-142

Lindenmayer, D., Crane, M., Blanchard, W., Okada, S. and Montague-Drake, R. (2016) Do nest boxes in restored woodlands promote the conservation of hollow-dependent fauna? *Restoration Ecology.* 24(2), 244-251

Lindenmayer, D.B., Crane, M., Evans, M.C., Maron, M., Gibbons, P., Bekessy, S. and Blanchard, W., (2017) The anatomy of a failed offset. *Biological Conservation* 210, 286-292.

Lumsden, L., Nelson, J. and Lindeman, M. (2008) *Ecological research on the Eastern Long-eared Bat Nyctophilus timoriensis (south-eastern form). A report to the Mallee Catchment Management Authority*. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Melbourne, Australia.

Macak, Phoebe V. (2020) Nest boxes for wildlife in Victoria: An overview of nest box distribution and use [online]. *The Victorian Naturalist*, 137(1): 4-14.

McNabb, E and Greenwood, J. (2011) A Powerful Owl Disperses into Town and Uses an Artificial Nest-box. *Australian Field Ornithology* 28, 65–75.

Moore, T., de Tores, P. and Fleming, P.A. (2010) Detecting, but not affecting, nest-box occupancy. *Wildlife Research* 37: 240-248.

OEH (2017) *Biodiversity Assessment Method*. Office of Environment and Heritage, Sydney.

Rhind, S. and Ellis, M.V. (2019) '*Making cooler nestboxes: the need, the design and the trail*'. Unpublished data presented at the NSW ECA Conference Workshop 2019.

Rueegger, N., Goldingay, R.L., Law, B. and Gonsalves, L. (2019) Limited use of bat boxes in a rural landscape: implications for offsetting the clearing of hollow-bearing trees. *Restoration Ecology*. 27(4): 901–911

Rueegger, N.N., Goldingay, R.L. and Brookes, L.O. (2012) Does nest box design influence use by the eastern pygmy-possum? *Australian Journal of Zoology.* 60, 372–380.

Rueegger, N.N., Goldingay, R.L., Law, B. and Gonsalves, L. (2020) Testing multichambered bat box designs in a habitat-offset area in eastern Australia: Influence of material, colour, size and box host. *Pacific Conservation Biology.* 26(1), 13-21.

Sandpiper Ecological (2016) *Pacific Highway Upgrade: Sapphire to Woolgoolga. Progress Report: Nest Box Monitoring – Operational Phase, Year 1(2015)*. Report prepared for NSW Roads and Maritime Services

Scida, M. and Gration, R. (2018) Monitoring the threatened brush-tailed phascogale (*Phascogale tapoatafa tapoatafa*) at Sugarloaf Reservoir, Victoria. *Australian Mammalogy.* 40, 307-311

Soderquist, T. R., Traill, B. J., Faris, F. and Beasley, K. (1996). Using nest boxes to survey for brush-tailed phascogales Phascogale tapoatafa. *Victorian Naturalist.* 113: 256-261.

Thomson, C.N. (2006) A Trial of the Use of Artificial Nest-boxes for the Masked Owl *Tyto novaehollandiae* near Newcastle, New South Wales. *Australian Field Ornithology.* 23, 192–197.

Travers, S. K., Dorrough, J., Oliver, I., Somerville, M., Watson C. J., and McNellie M. J. (2018) Using tree hollow data to define large tree size for use in habitat assessment, *Australian Forestry*. 81(3): 186-195, DOI: 10.1080/00049158.2018.1502736

Triggs, B. (2004) Tracks, Scats and Other Traces: *A Field Guide to Australian Mammals*. Oxford University Press, Australia

Whitford, K.R. (2002) Hollows in jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) trees: I. Hollow sizes, tree attributes and ages. *Forest Ecology and Management*. 160(1-3): 201-214.

Appendix 1: List of hollow-dependent threatened species in NSW[6] and evidence[7] of artificial hollow use

Table 4 List of hollow-dependent threatened species in NSW and evidence of artificial hollow use. (Status: VU = Vulnerable, EN = Endangered)

Scientific Name	Common Name	Status	Evidence of species using artificial hollows	Evidence of species not using artificial hollows
Birds				
Cacatua leadbeateri	Major Mitchell's Cockatoo	VU	Hurley and Stark 2015 (Victorian sub-species) Macak 2020	No evidence found
Callocephalon fimbriatum	Gang-gang Cockatoo	VU	No evidence found	No evidence found
Calyptorhynchus lathami	Glossy Black-cockatoo	VU	Goldingay and Stevens 2009 (Kangaroo Island sub-species in Berris et al. 2018)	No evidence found
Calyptorhynchus banksii	Red-tailed Black-cockatoo	VU	Goldingay and Stevens 2009	No evidence found

[6] From the NSW Scientific Committee Final Determination for the Loss of Hollow-bearing trees as a Key Threatening Process Listing, last updated December 2019.
[7] Based on a review of scientific literature of Australian studies. Not all sources may have been identified through the review of available databases.

Scientific Name	Common Name	Status	Evidence of species using artificial hollows	Evidence of species not using artificial hollows
Climacteris picumnus	Brown Treecreeper (eastern subsp.)	VU	No evidence found Note: SoS* lists 'nest box installation' as a Recovery Strategy action	Negligible count (2 of 324 boxes), Lindemayer et al. 2017
Cyclopsitta diophthalma coxeni	Double-eyed Fig-parrot	EN	No evidence found	No evidence found
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	VU	The Purple-crowned Lorikeet *Glossopsitta porphyrocephala* roosts and possibly nests in artificial cavities (Hicks 1997; Hutchinson 1998)	Nest-boxes or artificial hollows maybe worth trialling, although the preference of wild lorikeets for knotholes in the living bark of trunks and limbs, with apparently precise microclimate and other characteristics of the nest-chamber, may mean that boxes are reluctantly accepted or are less successful (perhaps related to hygiene issues) (Courtney and Debus 2006)
Neophema pulchella	Turquoise Parrot	VU	Goldingay and Stevens 2009 (moderate use)	No evidence found
Neophema splendida	Scarlet-chested Parrot	VU	No evidence found	No evidence found
Nettapus coromandelianus	Cotton Pygmy-Goose	EN	No evidence found	No evidence found
Ninox connivens	Barking Owl	VU	No evidence found Note: NSW draft Recovery Plan supports investigation of the need for and efficacy of hollow supplementation.	No evidence found
Ninox strenua	Powerful Owl	VU	McNabb and Greenwood 2011	No evidence found

Scientific Name	Common Name	Status	Evidence of species using artificial hollows	Evidence of species not using artificial hollows
Polytelis anthopeplus monarchoides	Regent Parrot (eastern subsp.)	EN	No evidence found	No evidence found
Polytelis swainsonii	Superb Parrot	VU	Ongoing studies with chainsaw hollows	Negligible count (1 out of 324 boxes), Lindemayer et al. 2017
Tyto novaehollandiae	Masked Owl	VU	Thomson 2006 (juvenile only)	No evidence found
Tyto tenebricosa	Sooty Owl	VU	No evidence found Note: Approved NSW Recovery Plan states “The potential for artificial hollows (nest-boxes) to fast-track habitat development for owls should be investigated.”	No evidence found
Mammals				
Cercartetus concinnus	Western Pygmy-possum	EN	No evidence found Note: OEH SoS* draft action plan lists nest box installation as a recovery action.	No evidence found
Cercartetus nanus	Eastern Pygmy-possum	VU	Beyer and Goldingay 2006 Rueegger at al. 2012 Law et al. 2013 Goldingay and Keohan 2018	No evidence found
Chalinolobus nigrogriseus	Hoary Wattled Bat	VU	No evidence found	No evidence found

Scientific Name	Common Name	Status	Evidence of species using artificial hollows	Evidence of species not using artificial hollows
Chalinolobus picatus	Little Pied Bat	VU	No evidence found	No evidence found
Dasyurus maculatus	Spotted-tailed Quoll	VU	No evidence found	No evidence found
Falsistrellus tasmaniensis	Eastern False Pipistrelle	VU	Goldingay and Stevens 2009 (possible use)	No evidence found
Mormopterus beccarii	Beccari's Freetail-bat	VU	No evidence found	No evidence found
Mormopterus norfolkensis	Eastern Freetail-bat	VU	Rueegger et al. 2020	No evidence found
Mormopterus " sp 6"	Hairy-nosed Freetail bat	EN	No evidence found	No evidence found
Myotis macropus (formerly *M. adversus*)	Southern Myotis (formerly Large-footed Myotis)	VU	Unpublished evidence of use of artificial habitat in culverts	No evidence found
Nyctophilus bifax	Eastern Long-eared Bat	VU	No evidence found	Rueegger et al. 2019
Nyctophilus timoriensis	Greater Long-eared Bat	VU	No evidence found	Rueegger et al. 2019 It appears that most roost sites are used just for a single day and large distances are travelled at night, with consecutive roost sites generally within four km (Lumsden et al. 2008).
Petaurus australis	Yellow-bellied Glider	VU	Goldingay et al. 2020a	Goldingay unpublished data

Scientific Name	Common Name	Status	Evidence of species using artificial hollows	Evidence of species not using artificial hollows
Petaurus norfolcensis	Squirrel Glider	VU	Beyer and Goldingay 2006 Sandpiper Ecological 2016 Goldingay et al. 2020a	No evidence found
Phascogale tapoatafa	Brush-tailed Phascogale	VU	Beyer and Goldingay 2006 Sandpiper Ecological 2016 Scida and Gration 2018 Goldingay et al. 2020b	No evidence found
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	VU	Rueegger et al. 2020	No evidence found
Scoteanax rueppellii	Greater Broad-nosed Bat	VU	No evidence found	No evidence found
Vespadelus baverstocki	Inland Forest Bat	VU	No evidence found	No evidence found
Reptiles				
Hoplocephalus bungaroides	Broad-headed Snake	EN	No evidence found	No evidence found
Hoplocephalus bitorquatus	Pale-headed Snake	VU	No evidence found Note: SoS* notes a critical action for this species: “erect suitably designed nest-boxes microbat/glider style) in locations lacking tree hollows (e.g. young stands), and in areas in or close to known riparian habitat, to provide shelter for the species. Ensure that nest boxes are monitored regularly to	No evidence found

Scientific Name	Common Name	Status	Evidence of species using artificial hollows	Evidence of species not using artificial hollows
			evaluate their uptake and effectiveness.”	
Hoplocephalus stephensii	Stephens' Banded Snake	VU	No evidence found	No evidence found
Amphibians				
Litoria littlejohni	Littlejohn's Tree Frog	VU	No evidence found	No evidence found
Litoria piperata	Peppered Frog	VU	No evidence found	No evidence found
Litoria subglandulosa	Glandular Frog	VU	No evidence found	No evidence found

* NSW Government Saving Our Species program (https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/saving-our-species-program)

Appendix 2: Types of artificial hollows

Manufactured nest boxes

Over previous decades the nest box has been the standard approach to provide artificial hollows to target species in both natural and controlled habitats (e.g. aviaries and wildlife enclosures). They vary widely in both design and construction, with associated differences in suitability and longevity. The standards provided below seek to maximise both for target species within a conservation area.

Design

A standard nest box design typically includes a hinged, sloping lid, a suitably sized entrance hole, interior dimensions specific to targeted fauna and an incised ladder to allow for easy exit (e.g. Figure 6). Small holes (5-7 millimetres) are to be drilled into the bottom corners of the box for drainage.

In particularly exposed sites, artificial nest boxes painted white, with an affixed painted plywood sleeve, can prevent boxes from overheating and increase the likelihood of occupation. The sleeve can be affixed approximately 20mm away from the nest box wall and 40mm from the roof, overhanging the walls by 30-40mm, and with a gap between its top and sides to let hot air to escape (Rhind and Ellis unpublished data)

Dimensions relevant for native species are provided in Table 5. Note that entrance size is the main determinant of species use. Other hollow dimensions (length, breadth and width) need to be no smaller than the minimum specifications provided, so the box is large enough to contain individuals or groups. Other design specifications for target species may be suitable. If design specifications differ to those provided in Table 5 you should consult with BCT prior to artificial hollow construction.

Note that the species to be targeted within any conservation area should be those identified as appropriate according to these guidelines. Consultation with the BCT to determine target species is essential prior to nest box construction or purchase. Some relevant references are provided in the bibliography at the end of this guideline.

Figure 6 Glider box with rear (tree-facing) entry (Source: www.nestingboxes.com.au)

Table 5 Nest box specifications for target fauna species

Species / Guild	Dimensions (length x breadth x height)	Diameter of entrance	Depth below entrance	Height above ground	Placement	Source
Feathertail Glider	15x15x45 cm	25 mm	100-200 mm	2 metres	Vertical	Goldingay et al. 2007
Yellow-bellied Glider	25x30x55 cm	70-80 mm	400 mm	6-8 metres	Vertical	Franks and Franks 2011; Goldingay (pers. comm*)
Sugar / Squirrel Glider	14x15x60 cm	35-45 mm, rear entry (e.g. Figure 6)	N/A	3-6 metres	Vertical	Goldingay et al. 2015; Goldingay (pers. comm)
Brush-tailed Phascogale	15x20x40 cm	35 mm	300 mm	3-6 metres	Vertical	Franks and Franks 2011; Goldingay (pers. comm)
	20x20x27 cm	50 mm with internal partition	0 mm	4-8 metres	Vertical	Scida and Gration 2018

Species / Guild	Dimensions (length x breadth x height)	Diameter of entrance	Depth below entrance	Height above ground	Placement	Source
Insectivorous bats	10x20x45 cm	10 mm slit	Entrance at bottom	3 metres	Clear flight path (i.e. no vegetation blocking entrance)	Franks and Franks 2011
Glossy Black Cockatoo	30x40x1500 cm	200 mm	1200 mm	8-10 metres	Vertical	Franks and Franks 2011
	Volume >0.03 m^3	>120 mm	Entrance on front/towards top	>6 metres	Vertical	Goldingay and Stevens 2009
Little Lorikeet	15x15x50 cm	55 mm	350 mm	3-5 metres	45 degrees	Franks and Franks 2011
Pardalote	12x50x12 cm	30 mm tube	80 mm	5 metres	Horizontal	Franks and Franks 2011

Species / Guild	Dimensions (length x breadth x height)	Diameter of entrance	Depth below entrance	Height above ground	Placement	Source
Owlet – nightjar	15x15x15 cm	70 mm	300 mm	5 metres	Vertical	Franks and Franks 2011
	Volume >0.03 m^3	>50 mm	Entrance on front/towards top	Various	Vertical	Goldingay and Stevens 2009
Eastern Pygmy-possum	17x17x25 cm	15 mm slot		1.5-2 metres		Bladon, Dickman and Hume 2002
	13x10x10 cm	25-45 mm	60 mm	1 metre	Vertical	Rueegger, Goldingay and Brookes 2012
	30-40 cm hollow log	30 mm	-	-	Vertical	Law et al. 2013

Construction Materials

High quality materials are imperative to ensuring a maximum lifespan for nest boxes. Many commercially-made nest boxes last little more than a decade. The minimum requirement is marine grade plywood of greater than 18 mm thickness. However, hardwood is recommended as long as it can be sourced sustainably (i.e. not felled for nest box purposes or taken from where it is providing valuable ground habitat elsewhere). ‘Log hollows’ can be created using an intact log such as those designed for small gliders in Figure 7.

Figure 7 Log hollows carved from solid logs (Source: Steve Griffiths)

Installation

To prevent nest boxes dislodging from host trees (particularly thick-barked species) and to allow for future tree growth, installation should utilise the *Habisure*™ system or similar (see Figure 8). If the nest box or salvaged hollow is not suitable for this hanging system (e.g. heavy and dangerous to install), high quality stainless steel fixings can be used to attach the artificial hollow to the tree (e.g. Figure 9). Consider monitoring the security of the attachment over time and any impacts on tree health. Boxes should be installed with a north to north-easterly aspect to maximise exposure to winter sunlight and minimise exposure on summer afternoons.

Each box should be sequentially labelled prior to installation for ease of identification and reference during monitoring, and GPS coordinates recorded (as per Stage 7 of the artificial hollows framework).

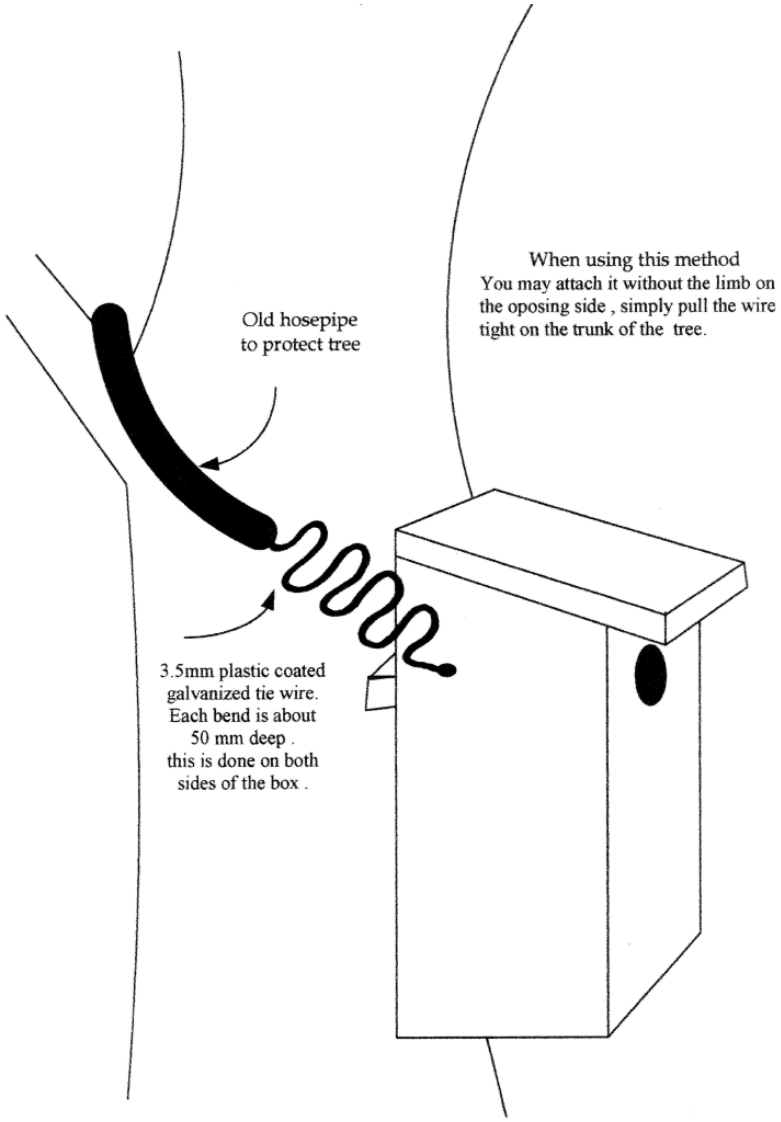


Figure 8 Installation using the Habisure™ System (Source: Hollow Log Homes www.hollowloghomes.com)

Figure 9 Installation of carved hollow logs using stainless steel fixings (Source: Steve Griffiths)

Salvaged nest boxes

Felled timber with naturally formed hollows provide a ready-made alternative to standard nest boxes. As natural hollows, they are more likely to produce favourable conditions for target species and provide a better 'feel' when installed in the host tree compared to manufactured nest boxes.

Design

Ideally, a salvaged hollow will include a pre-formed entrance and can be cut above and below the hollow to provide a natural lid and base. However, many natural hollows would simply provide the 'shell' and require a cap to be installed at either end, and an entrance hole to be created (Figure 10). Salvaged hollows can also be combined with a constructed hollow (Figures 11 and 12). Any requirements to modify the salvaged hollows should incorporate design specifications for target species provided in Appendix 2, Table 5.

Figure 10 These salvaged hollows would need to be capped (Source: www.instructables.com)

Figure 11 Example of a salvaged hollow combined with a constructed hollow (Source: James Brazill Boast)

Figure 12 Salvaged hollows used to supplement constructed hollows (Source: James Brazill Boast)

Construction Materials

It is imperative that hollows salvaged for this process are sustainably sourced. In this regard, no hollow (standing or fallen) should be collected from elsewhere in the conservation area for this purpose. An example of a sustainably sourced hollow would be from a construction site, where the hollows would otherwise be destroyed following tree-felling, or those salvaged from sustainable forestry practices.

As per manufactured nest boxes, salvaged hollows should be hardwood of an appropriate thickness (>18 mm). Any capping requirements should use marine grade plywood as a minimum and be sealed with waterproofing to reduce warping and splitting.

Installation

It is recommended that a suspension mechanism similar to the *Habisure*™ system be incorporated into the salvaged hollow design (Figure 8). Specifications regarding height and aspect should be as per manufactured nest boxes and tailored for target species listed In Appendix 2.

For larger hollows, a more elaborate attachment mechanism involving galvanised strapping or cables/turnbuckles would be necessary, however the BCT would only recommend such installations in exceptional circumstances. Central Coast Council's *Guideline for the Relocation of Large Tree Hollows* provides some interesting examples and can be viewed at http://www.cwcewa.com.au/s/Guideline-for-Relocation-of-Large-Tree-Hollows.pdf

Chainsaw hollows

As an alternative way to mimic natural hollows, recent techniques to create hollows within existing trees have been developed. Studies have found that 'chainsaw hollows' cut directly into live trees

regulate temperature more effectively than nest boxes, log hollows or salvaged hollows (Griffiths et al. 2018), and high utilisation of the hollows by local native species have been recorded. These hollows are also more likely to provide long-term habitat with potentially lower maintenance requirements compared to standard nest boxes or salvaged hollows.

Design

Given the nature of the practice, chainsaw hollows are most appropriate for targeting small to medium sized species including microbats, gliders, and small parrots (e.g. lorikeets, rosellas). An ecologist with understanding of the roosting behaviour of the target species, should provide input regarding specific hollow specifications. Design of the hollow may differ between practitioners (generally arborists), however they fundamentally require the removal of a section of a healthy, mature tree, with either the entrance left open (for parrots) or a small section re-attached (the 'entrance' plate or 'face' plate) to leave a small entrance for gliders or microbats (Figure 13). There is little information on the longevity or durability of entrance plates, so this should be monitored. Consider using hard wood for the entrance plate, as green wood from the cut tree can shrink over time.

Construction Materials

As the hollows are carved directly into the tree, no construction materials are necessary. It is however recommended that trees be selected that allow for created hollows to meet spatial requirements for targeted species (Appendix 2) whilst not risking the health or structural integrity of the tree.

Installation

To prevent tree failures and for safety considerations, chainsaw hollows are only to be created by adequately qualified arborists (AQF Level 5 or equivalent) and only mature trees >40cm trunk diameter are suitable. An initial tree health assessment should be conducted by the arborist in any case). Chainsaw hollows may therefore involve higher upfront costs for qualified assistance compared to nest boxes, however ongoing costs outside of monitoring are likely to be lower than nest boxes.

Interested landholders should contact the BCT for further details.

Figure 13 Glider hollow creation within a living Sugar Gum (Eucalyptus cladocalyx) (Source: Griffiths et al. 2018)

Appendix 3: Sample monitoring form

The form on the following page provides an example of a suitable form for recording data from a monitoring period. A description of the details required are provided in the table below.

Entry	Required details
Identifier	Unique identifier (e.g. number) for each artificial hollow or tree.
Target species	Target species or group the hollow is designed for.
Location	Use a GPS to record: Zone, Easting and Northing OR Latitude and Longitude.
Installation date	Date artificial hollow was installed.
Species observations	Record observations of any species using the box, or evidence that the artificial hollow is being used for breeding or shelter. Record any evidence of occupancy by non-target species.
Photo IDs	For any photos taken of the hollow, record a unique file name for the photo
Artificial hollow condition	Condition of artificial hollow at the time of inspection (refer to 'Maintenance' in Stage 7).
Tree Health	Condition of the tree in which the artificial hollow occurs. Consider indicators such as foliage cover, disturbance and damage.
Maintenance and/or management	The status of any maintenance required to the artificial hollow e.g. type of maintenance required, date repaired and the nature of the repair. Record any actions performed to manage target species or the outcomes of previous actions.

Site: _____ Observers(s): _____ Inspection date:_____

Identifier	Target species	Location	Installation date	Species observations	Photo IDs	Artificial hollow Condition	Tree Health	Maintenance and/or management
Unique number of hollow	Target species/group	Easting/northing OR Latitude/longitude		e.g. Signs of occupation or breeding by target species, occupation by non-target species (e.g. bees)		Good/Moderate/Poor	Good/Moderate/Poor	Maintenance actions for artificial hollow Actions to manage non target species and outcomes (if applicable)