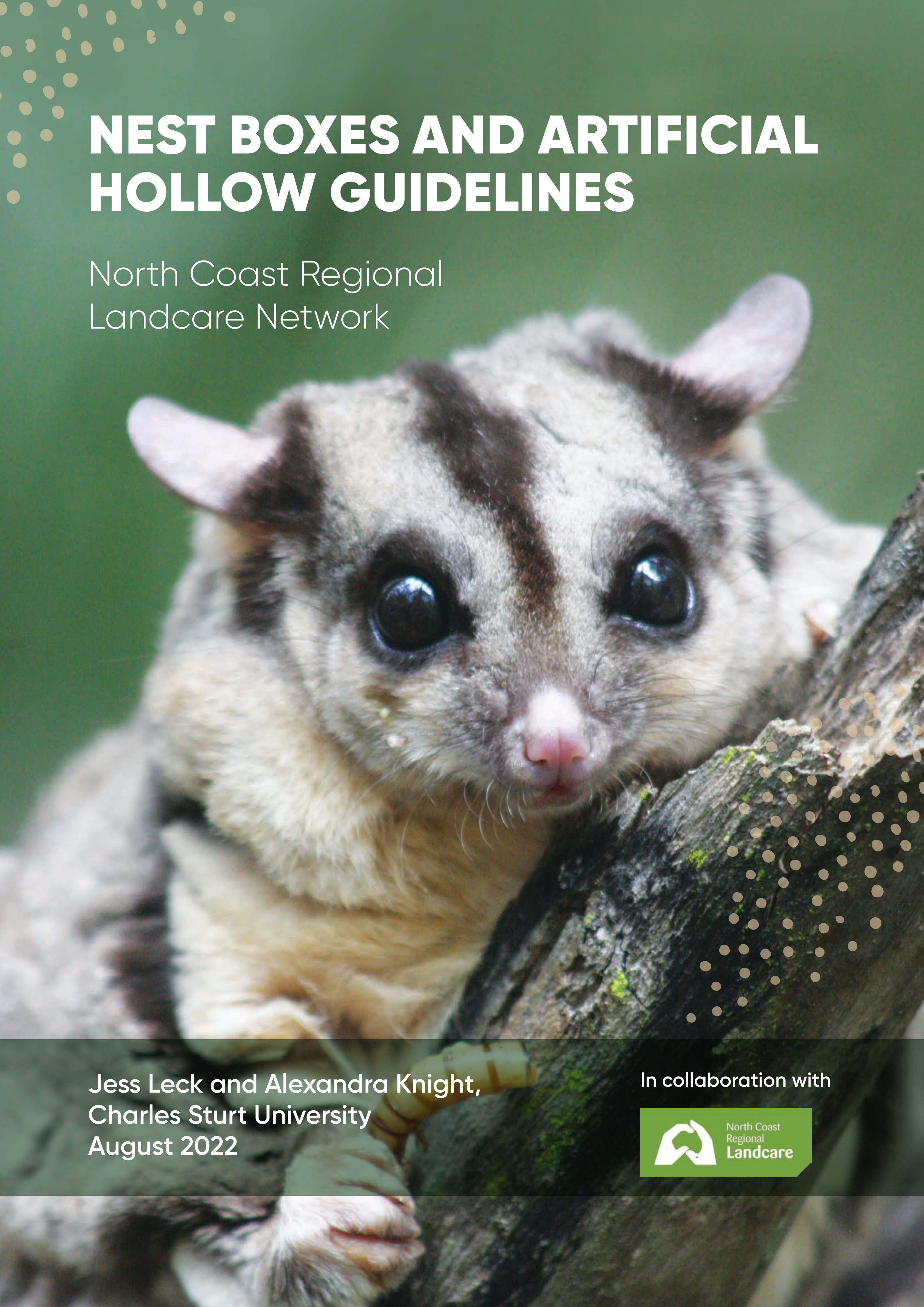

NEST BOXES AND ARTIFICIAL HOLLOW GUIDELINES

North Coast Regional Landcare Network

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In collaboration with

North Coast Regional Landcare

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Using these Guidelines

Nest boxes have been installed by Landcarers and land managers for many years as part of integrated environmental restoration programs and also in ad hoc situations. More recently, carved hollows have also become used in arboreal habitat supplementation programs. Now, information about the features of nest boxes and hollows has advanced and detailed knowledge about use, sizes, installation and thermal qualities is becoming more available.

These guidelines have been prepared to offer up-to-date advice about nest boxes and artificial hollows. By using these guidelines through both design and monitoring phases, Landcarers can contribute to longer term and useful outcomes for Australian hollow-dependent fauna as well as collect consistent data to further our knowledge.

Supplementary artificial habitat: why and when?

Why?

Australian fauna rely on hollows in a variety of ways. Some species, such as nesting birds, prefer one single hollow for their breeding cycle, whilst some mammals, such as the Brush-tailed phascogale, can utilise up to 38 arboreal shelters within their home range in a year (Rhind 2002). Other groups of fauna such as reptiles and amphibians also use hollows. Abundant and diverse hollows are required to support a resilient ecosystem.

The loss of hollow-bearing trees is recognised as a key threatening process by the NSW *Biodiversity Conservation Act 2016*, and is noted in the recovery plans of over 40 listed species. The primary factors contributing to this loss are noted as clearing for development and agriculture, and wildfire. Following two centuries of extensive clearing, and recent wide-spread extreme weather events, community and scientific concern over the availability of this habitat resource is higher than ever.

The installation of artificial habitat can be useful in both provisions of supplementary habitat and scientific monitoring to understand species occurrence, ecology and population dynamics (Beyer & Goldingay 2006). Social analysis has also demonstrated an increase in positive community engagement and social outcomes that can be gained from an inclusive monitoring program for environmental causes (Haythorpe et al 2013).

It should be noted that some species have been identified to not use, or very rarely use artificial habitat. In addition, long term, multigenerational habitat supplementation programs have demonstrated high financial costs, significant labor hours and low occupation rates/diversity. As such, it is stressed that:

Nestbox or hollow provision cannot replace the need for conservation programs that secure natural hollow bearing trees in a landscape.

It is widely recommended that artificial habitat programs form only part of a larger conservation program targeting the reestablishment of natural hollows across the landscape.

When?

Supplementary artificial habitat is most useful when ecosystems are hollow deficient. Historically clear felled or selectively logged regions will have a lower age profile of remaining trees, and thus natural hollows will be rare. Likewise, in recently planted areas, such as restoration sites or linking corridors, natural hollows are likely many decades away from forming naturally. For these reasons hollows are considered a limiting factor in populations of hollow dependent species and supplementation has been shown to increase opportunities for breeding.

In regions which have been recently impacted by intensive disturbances, such as illegal clearing, bushfire, floods or landslides, the biodiversity enhancement potential of supplementary habitat is valuable. In these situations, it is important to support the ecosystem processes which enable ecosystem regeneration. Keystone species, such as frugivores and pollinators play an important role here. The provision of nest boxes and artificial hollows in these relatively bare regions can improve recovery by providing habitat for species such as frugivores and pollinators. By supplementing habitat for these keystone species, we can aid in the recovery of impacted vegetation through increased pollination, seed dispersal, pest control and nutrient cycling.

Finally, the detection of charismatic and threatened species within a landscape can be a powerful engagement tool for communities. These social and capacity building outcomes can be achieved either remotely through video technology in the field, or through individual experiences by volunteers. Where engagement is the goal, accessibility within intact, high-quality habitat is a consideration in the placement of the hollows.

Artificial habitat design: nest boxes or artificial hollows?

Nest boxes have been used for some decades across Australia, often with low usage rates by native species. Given the significant time and financial investment many communities and agencies make to this form of habitat supplementation, it is vital organisations installing these continuously reflect and adapt their practices to ensure program outcomes are being achieved whilst providing high quality habitat and minimising harm.

The installation of traditional nest boxes comes with some important considerations, including life span (~<10 yrs), maintenance cost, and insufficient thermoregulatory and weather resistant qualities. As a result, in recent years investment has been made to create carved artificial hollows within the structure of living trees, which are better able to mimic the natural features of a hollow (Grifiths et al. 2018). While often ruled out due to expense, when ongoing maintenance is considered, carved hollows may be comparable in total cost versus benefit analysis. To determine their effectiveness further research into the long-term utilisation of carved hollows is required. Programs such as those run by NCLN, when using these guidelines, will provide a valuable contribution to answering this question.

These forms of artificial hollow, sometimes termed a 'carved hollow' or 'Hollowhog hollow' are best suited for historically impacted forests, such as those selectively logged, where some larger trees persist. For survival of the host tree, wall thickness must be maintained at 30% of the original diameter of the tree, therefore the size of potential carved hollows, and thus target species, is determined by the availability of mature trees. Availability of these trees within targeted monitoring areas, or sites that meet the above suitability suggestions may be a limiting factor for their usage. The installation of any carved hollow must be done under the guidance of a trained arborist for both placement selection and safety.

In scenarios where carved hollows are unsuitable, such as availability of suitably sized trees, or where installation funding is limited, suitable artificial nest boxes are still considered valuable in landscapes with limited natural hollows. These may include hollows made from salvaged limbs, 3D printed or timber constructed nest boxes (Figure 1). Regardless of material, the thermoregulation ability of any externally mounted nest box should be considered a priority, especially as climate change increases the extent and regularity of temperature extremes. Recent trials of expanded plastic nest boxes have shown an impressive ability for internal thermoregulation. As this is an evolving technology, no recommendations of suppliers can be provided at the time of writing, but these alternatives should be investigated when designing a program.

Figure 1: Different forms of artificial habitat. From left; Log hollow nest box and monitoring camera, Traditional plywood nestbox, 3D printed nest box (Credit David Watson, CSU) and Carved hollow utilising hollowhog tool.

Regardless of material, unsuitable nest box design has been found to be an influencing factor in the low diversity and usage rates of previous nest box studies. Some species, such as Brushtailed possums *(Trichosurus vulpecula)* or Sugar Gliders *(Petaurus norfolcensis)* have been seen to competitively exclude smaller species from nestboxes. The use of smaller entries to exclude larger species, finished with a metal ring to inhibit the opening from being enlarged, has been seen to increase occupation rate of smaller species, and species detection diversity overall.

In addition, historically concern has been raised due to nest boxes providing additional habitat for invasive bird species, such as mynas and starlings. To mitigate this, rear entry box designs have been shown to specifically support arboreal mammal species, as birds will rarely utilize habitat without a visible entrance. Glider species specifically have been shown to preference these rear entry boxes three-fold over parrot boxes over long term studies (Goldinggay et al, 2015).

To date, we are unaware of any design considerations that have been demonstrated to control the invasion rate of nest boxes by European honey bees. This has been seen to be as high as 60% in some previous studies. Some research suggests the lining of the underside of a nest box roof can inhibit bees from attaching their comb, however due to the high degradability of nest boxes, use of polyester carpet is not recommended to minimise microplastics within the environment.

Species-specific designs have been developed for many target species (Table 1). These designs should be considered carefully when designing a nest box monitoring program; when targeting specific species, use a single nest box design, and when creating a general program for biodiversity regeneration, monitoring and/or community engagement, use a wide variety of designs.

Table 1: Species-specific design specifications for nest box construction. Specifications are provided based on traditional nest box design, but should be adapted to suit construction type of choice. Based on recommendations by Biodiversity Conservation Trust (2020) and monitoring data from North Coast Regional Landcare Network nest box program. Revision of species preferences should be undertaken following further rounds of monitoring across the program.

Species / Guild	Dimensions (length x breadth x height)	Diameter of entrance	Depth below entrance	Height above ground	Placement	Source
Feathertail Glider	15x15x45cm	25 mm	100-200mm	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
Sugar / Squirrel Glider	14x15x60 cm	35-45mm, rear entry (e.g. Figure 6)	N/A	3-6 metres	Vertical	Goldingay et al. 2015.
Brush-tailed Phascogale	15x20x40 cm	35mm	300 mm	3-6 metres	Vertical	Franks and Franks 2011.
Insectivorous bats	10x20x45cm	10mm slit	Entrance at bottom	3 metres	Clear flight path (i.e. no vegetation blocking entrance)	Franks and Franks 2011
Glossy Black Cockatoo	30x40x1500 cm (Volume >0.03m3)	200mm	1200mm	8-10metres	Vertical	Franks and Franks 2011
Little Lorikeet	15x15x50cm	55 mm	350 mm	3-5metres	45 degrees	Franks and Franks 2011
Pardalote	12x50x12cm	30mm tube	80mm	5 metres	Horizontal	Franks and Franks 2011
Owlet–nightjar	15x15x15cm (Volume >0.03m3)	70mm	300mm	5 metres	Vertical	Franks and Franks 2011, Goldingay and Stevens 2009
Eastern Pygmy-possum	30-40cm hollow log	30mm	200mm	1 metres	Vertical	Law et al. 2013, Rueegger, Goldingay and Brookes 2012

Installation considerations

Location

The first step in selecting your location is to perform a desktop survey of Atlas of Living Australia (ALA) of the target region and/or species. For target species programs, this will confirm your target species occurs within the area of interest and can be interrogated to identify habitat preferences within the region. For general biodiversity-centric programs this will assist in the selection of a suitable variety of species-specific nest boxes, relevant to what is known to be present in the region.

The specific location of installation sites should be largely determined by the intention of the program:

- **1. To support biodiversity in regenerating forests:**
  For programs looking to increase biodiversity and assist in regeneration, young and recovering forests are the best locations for installation. Both nest boxes and artificial hollows have been shown to have the highest usage rates in habitats that are void of natural hollows. For this reason, young forests, or forests recovering from extensive disturbance, such as extreme bushfire or clearing, are where installation of nest boxes can offer the greatest habitat supplementation. In these scenarios, trees large enough for carved hollows may be limited and external nest boxes are likely most suitable initially.

- **2. Biodiversity monitoring:**
  For programs looking to monitor biodiversity of a region, a proportionate representation of vegetation types within the region of interest should be selected for installation. Each site should have a selection of species-specific designs, corresponding to the species lists from the desktop survey.

- **3. Monitoring of target species:**
  These installation locations should be selected based on preferred habitat for the species, determined from both a desktop survey of ALA, and previous research. Species specific designs of a mix of nest box/hollow designs could be used to provide more information on usage rates across materials.

- **4. Community engagement and social outcomes:**
  These programs should priortise access and minimise disturbance. Sites should be selected for ease of access and high chance of box occupation by wildlife. Locations such as disturbed grazing land and fringing vegetation are highly suitable as access is easily maintained and these landscapes are commonly void of hollows. This will result in high usage rate for engagement opportunities, whilst providing quality linking habitat in fragmented environments.

For all sites, future access must be taken into consideration to make ongoing monitoring viable. This may need more consideration in disturbed habitats, where undergrowth density may be drastically different on future visits. For example, some areas are easily accessible immediately after fire, but as vegetation (particularly the shrubby layer) regrows, access becomes more difficult.

Placement

Placement on the host tree is a vital consideration in the installation process. For carved hollows, this should be determined by a qualified and experienced arborist for tree health. For externally mounted nest boxes, placement should consider exposure, height, predation risk and monitoring requirements.

Due to reduced thermoregulation ability, plywood nest boxes should always be placed in a shaded location, with an eastern aspect in exposed locations, avoiding harsh afternoon sun. Salvaged hollows, made from logs or fallen limbs, often have wider wall depths which mimic those of a natural hollow, for this reason, less temperature fluctuation is experienced and placement can be determined by access, provided shading is available.

Installation height will vary depending on the target species and available host trees within the site. Recommended height ranges are provided in Table 1. In addition to these recommendations, consideration must be given to how monitoring and maintenance will occur. Typical pole mounted cameras can range between 6-9m in access height. Any installation above these heights, for example, targeting large birds of prey, will require an arborist for ongoing maintenance, at a minimum. The additional costs involved in monitoring high sites should be built into the budget for any monitoring program that aims to target these higher canopy dwelling species. Carved habitat may be more suitable at greater heights due to reduced monitoring and maintenance costs, however installation costs are significantly higher with this form.

Invasive predators, such as feral cats, have been shown to learn nest box locations and repeatedly return for hunting attempts (McComb et al. 2018). Some research suggests the use of metal sheeting at the base of the host tree to exclude cats, however, this approach will also exclude native climbing species and is not recommended. If used in a program targeting bird species, maintenance is required, and budget for removal post monitoring should be allocated. The use of rear entry boxes and placement that minimizes horizontal branches that can be used as waiting areas nearby to the nest box is the preferential control for mitigating this form of predation, while allowing natural processes to continue.

Additional considerations

For carved hollows, recent installation experience suggests that a realistic target of completing eight hollows per eight hour day when building larger hollows (greater than a netball size) is achievable. This may be used to cost out this approach based on the hourly rate of an arborist and field team.

Safety of installation and future monitoring teams is a priority during site location and placement selection. This may limit the potential height of installation, or habitat quality.

Monitoring program

Methodology

Any nest box installation program should include an ongoing monitoring program. Ongoing monitoring not only answers vital questions about usage rates and local biodiversity, but also ensures consistent maintenance assessments can be made on each installation. Upon each visit, data is collected on both signs of use, as well as pest species presence, structural repairs needed and overall lifespan of the box.

The design of any monitoring program must first identify the intentions of the program. Monitoring methods will differ depending on your intentions.

For programs designed for the detection of threatened mammal species, remote monitoring with minimal disturbance has been shown to have higher detection rates than physical inspection. In these situations, installation of heat sensitive monitoring cameras is recommended. Cameras should be installed on a nearby tree, facing the nestbox entrance.

For occurrence and population dynamics information on nesting bird species, both remote and physical monitoring yield similar usage detection rates (Reannan et al. 2021). For physical monitoring, the use of a pole camera is recommended.

Finally, where community engagement and education are the priority outcomes, physical inspection will produce greater engagement and social outcomes. The use of a pole camera will have a lesser disturbance impact than physical checking by humans.

For artificial habitat installed at a height of greater than nine meters, checking by a qualified tree climber is recommended. Ongoing monitoring can be achieved by either the installation of wireless cameras, with battery and wifi receiver on the ground, or the use of a short pole camera by a climber. The significant cost of this monitoring and maintenance should be factored in to the budget of the overall program. Where long term funding is not possible, carved hollows are recommended above 6m due to their reduced maintenance costs.

Timing

All monitoring creates disturbance in the landscape, which may reduce likely usage rates in the short to medium term. As such, monitoring frequency should be minimized as appropriate to the length of the overall monitoring program.

A three-month interval is recommended for monitoring programs with interest in the population dynamics of the area, while targeted annual surveys during corresponding breeding seasons is appropriate for nesting birds.

For short term programs, such as those interested in immediate response to bushfire, monitoring cameras are recommend over pole cameras due to their low disturbance vs data collection ratio. In these situations, most camera models should allow for a month in situ monitoring before collection or battery change is required.

For target species programs, mid to late breeding season monitoring rounds will provide high value population data, as well as yield higher rates of occupation overall for hollow breeding species.

For permanently installed wifi cameras at a height, revisitation will have much lower disturbance potential, and will likely be determined by battery life of the technology used.

Data collection

When performing nest box monitoring, physical sightings are relatively rare. In order to increase the value of program outputs, a highly valuable datum to collect is an internal photo at each visit when unoccupied. Long term monitoring of variations in nesting material via internal photos can demonstrate valuable information about habitat usage, including species-specific breeding evidence for some species, e.g. leptospermum leaves in a conical shape in small nestboxes may demonstrate breeding by the Eastern Pygmy Possum *(Cercartetus nanus).* These photos also contain valuable information such as faeces, markings, pests and maintenance requirements. They also may show occupation that was missed at first glance in the field.

In addition to internal photos, other information about variations in in the site condition and signs of use are valuable in understanding the dynamics influencing site utilization. See Appendix 1, Data Sheet example for important variables of interest.

Equipment

When relying on monitoring technology in the field, such as pole cameras or remote cameras, best practice is to have a minimum of one spare for each device. In addition to this, a spare battery for each equipment should be included to allow for charging failures. This is especially vital for remote field days or days with paid team members as this may influence overall outcomes to the project.

Volunteer management

Recommendations for aspects to be included when inducting participants into a monitoring program include:

- Access to monitoring equipment (pole, camera etc) and induction for use
- Data sheet and program data management strategy
- Ethical considerations as below
- Data sensitivity when monitoring threatened species,
- Land access and permissions
- Access details including length and difficulty of track, height and density of vegetation
- Work Health and Safety requirements, including a buddy system when in the field
- Mental health awareness of traumatized landholders and empathy fatigue

Maintenance expectations

It should be noted that many external nest boxes will require maintenance within 10-15 year window. Quin et al (2021) determined that over a 30 year study, 25% of boxes needed a major repair within the 10-15 year window. Across the study, two thirds of boxes needed a repair of some form, such as wire tightening, lid repair, reinstallation or replacement. The most common repair needed was wire tightening, which most often occurred early in the period, while the mean time for structural repairs, such as lid replacements, was 9-11 years. These expectations should be taken into consideration when selecting the type of artificial habitat, the suitability of a site and height of installing an externally mounted nest box.

Adaptive management

Monitoring data from artificial habitat programs offers a unique opportunity to learn and improve restoration and wildlife management. The keys to success here are that data needs to be analysed, and the findings discussed and shared amongst program participants, Landcarers, co-ordinators and facilitators, scientists and government organisations. The considerations and recommendations from this knowledge-sharing then need to be implemented. This approach is fundamental to the 'learning; component of the adaptive management cycle. Learning can occur at any point in the adaptive management cycle of your artificial habitat program, and it's important to share new information and insights with others.

One approach is to review the monitoring data yearly, looking for trends in use, repetitive breeding, habitat preferences and abandonment following monitoring. However, often there are multiple variables which influence artificial habitat use, and it may be difficult to sort out the most important drivers of use from one year or one area alone. We recommend combining and discussing your data with that of other groups, and maintaining your monitoring program over several years, so that you can build better knowledge over a longer time period. Taking into consideration the need for a long-term monitoring program is something that needs to be planned for early on in program design.

Ongoing and long-term monitoring is essential for adaptive management, but difficult to plan for and fund.

For volunteer programs, a sense of ownership of specific boxes can aid in gaining longer-term outcomes, with individuals assigned the same boxes for each monitoring period.

This approach can also help alleviate occupational health and safety concerns, and alleviate the need to find new sites.

Ethical and Licensing Considerations

Animal Care and Ethics

Ensuring the well-being of the animals using nest boxes is an important consideration. In NSW, the welfare of animals used for animal research is protected by the Animal Research Act 1985. Wildlife surveys are considered as animal research and are therefore subject to the provisions of this legislation. The legislation also requires that the conduct of animal research must be consistent with the provisions of the Code.

Monitoring nest boxes with a pole camera or remote camera is the preferred method to ensure native species are cared for. No handling is required and there is a reduced risk of harm to the animals. Flash photography and bright lights may cause stress to animals. You should aim to reduce stress at all times. In particular, the Animal Research Review Panel Guideline 10 states that exposure to light should be for less than 2 minutes.

When monitoring the nest boxes, the camera should be placed inside the entry hole or through the lid, if it can be opened slightly. If an animal is present, the following guidelines must be followed:

- reduce disturbance to the nest box, including movement and light
- the animal must only be exposed to the camera light for a maximum of 2 minutes
- where possible, use a red filter on the camera light
- if young are encountered in the nest box, disturbance and exposure to the light must be kept to a minimum
- if animal seems distressed by the monitoring, cease immediately
- DO NOT handle the animals

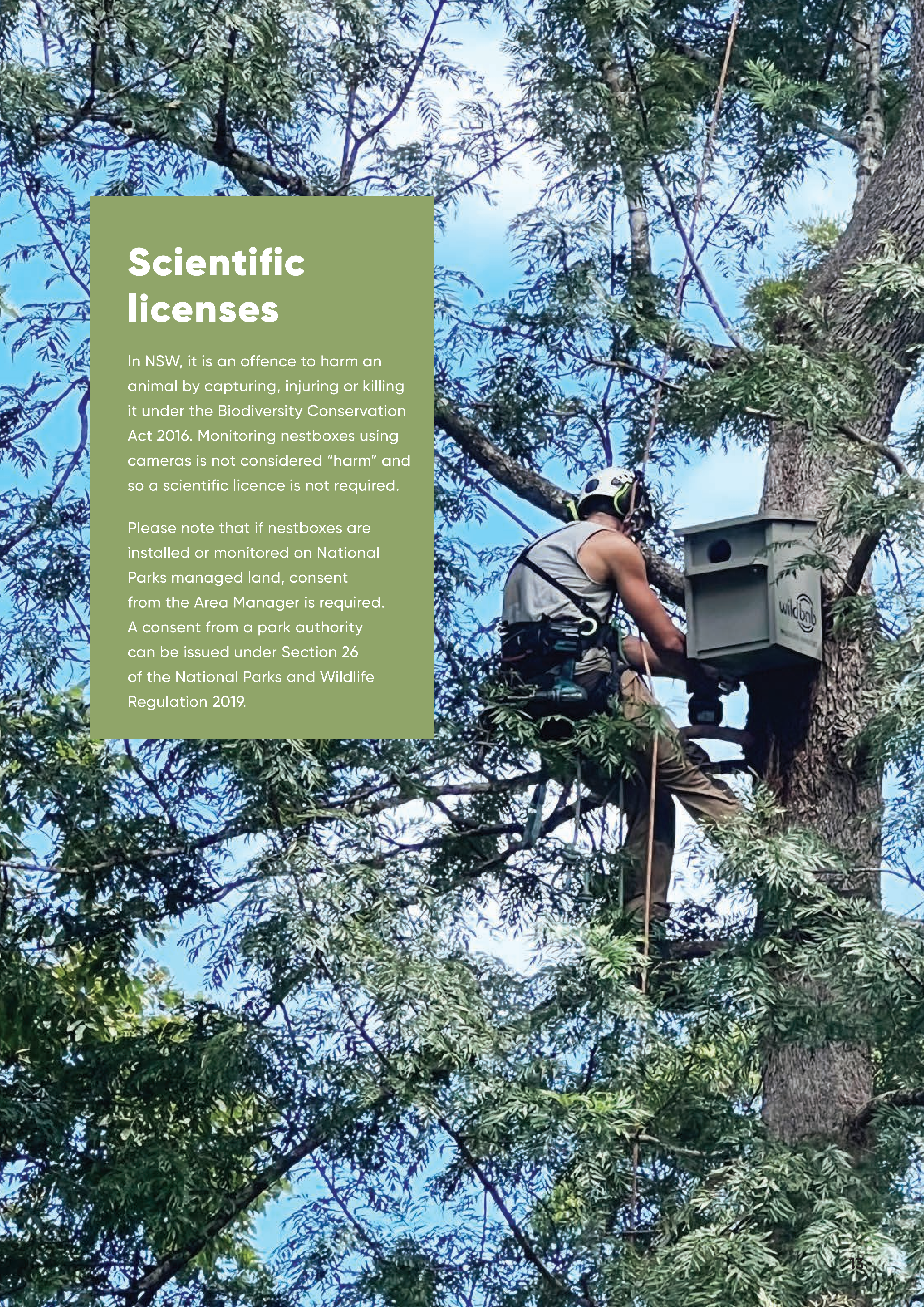
Monitoring programs that cause stress to fauna usually require an Animal Care and Ethics (ACE) approval through an established ACE Committee. If you are undertaking a monitoring program that may cause stress, such as where you are using flash photography or subjecting fauna to camera light for more than two minutes, then ACE approval would normally be required.

ACE committees usually exist in established research organisations such as Universities. Currently, there is no established pathway for organisations such as Landcare to gain ACE approval by themselves. Where ACE approval is needed, we recommend that Landcare partner with an appropriate researcher at an established research organisation before undertaking the work. For more information see: https://www.animalethics.org.au/

Scientific licenses

In NSW, it is an offence to harm an animal by capturing, injuring or killing it under the Biodiversity Conservation Act 2016. Monitoring nestboxes using cameras is not considered “harm” and so a scientific licence is not required.

Please note that if nestboxes are installed or monitored on National Parks managed land, consent from the Area Manager is required. A consent from a park authority can be issued under Section 26 of the National Parks and Wildlife Regulation 2019.



Frequently Asked Questions?

Will it damage the tree?

Carved nest boxes should only ever been installed by trained arborists, familiar with the technique. This will ensure the hollow is constructed in a way which allows the tree to survive and grow around the new cavity, increasing the habitat value over time.

Externally mounted nest boxes should be checked periodically, at least once a year, to ensure they are not damaging the tree and are structurally sound. Installation using tension releasing supports allows for tree growth throughout installation.

How do I secure an externally mounted nestbox?

Nest boxes are mounted to living trees, and thus it is important to allow for continued tree growth after installation. For this reason, externally mounted nest boxes should have sufficient 'slack' in the support wire to allow for this growth. Use of hose pipe or other sturdy padding on this wire will minimize scaring on the supporting side of the tree.

How often should I monitor?

Internally monitoring the nest box creates a disturbance for potential occupants. For maximum chance of usage, this disturbance should be kept to a minimum. Monitoring regimes should be decided during the design of your program, but a minimum of three months between visits is recommended. For longer term studies, this should be pushed out to six months.

What is the best type of nestbox?

In terms of ability to replicate the characteristics of the natural environment, carved hollows within living trees are thought to best achieve this (Griffiths et al, 2018). However, as a new technique, long term studies have not been completed to show a significant increased usage rate. However, this is not to say externally mounted nest boxes do not have value when suitably placed and maintained.

Ultimately the suitable nest box type will be determined by your location, funding and monitoring priorities.

Data sheet

A copy of the excel data sheet template is available from your program manager.

Glossary

Adaptive management
A procedure for implementing management while learning about which management actions are most effective at achieving specified objectives.

Arboreal
Used to describe any animal that is dependent on trees and canopy for any stage of their life history.

Detection
The action or process of identifying the presence of something concealed. Used to describe finding of any evidence of presence, including observations, scats, nesting material.

Externally Mounted Boxes
This is a collective term used to discuss all externally mounted forms of artificial habitat, including wooden, 3D printed and log hollows.

Nest boxes
In this document, the term "Nest Box" is used as an encompassing term for artificial habitat installations. When specific forms or materials are being discussed, these will be termed as "Plywood", "3D Printed", "Carved" or "Log Hollows".

Occupancy
Term used to describe the utilisation of habitat by wildlife.

Thermoregulation
The ability of an object (or individual) to maintain core temperature, within certain boundaries, despite fluctuations in outside temperatures.

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