NEFA BACKGROUND PAPER
The Importance of Old trees
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Old trees are the primary storehouses of carbon, provide essential hollows for animals to nest and den in, provide the most abundant nectar and seed, and are of the highest aesthetic appeal. These values appreciate with age. Since European settlement most of our oldest trees have been lost, with only scattered old trees left across agricultural lands and within logged forests. Those surviving are of immense value.

Numerous Australian animals depend on the food and shelter provided by old trees for their survival. Lindenmayer *et. al.* (2014) consider *"The irreplaceable roles of large old trees make them a "keystone structure"—a disproportionately important provider of resources crucial for other species"*.

Losses of large old trees is a world-wide problem, as noted by Lindenmayer et. al. (2012) *"populations of large old trees are rapidly declining in many parts of the world, with serious implications for ecosystem integrity and biodiversity. ... Just as large-bodied animals such as elephants, tigers, and cetaceans have declined drastically in many parts of the world, a growing body of evidence suggests that large old trees could be equally imperilled".*

The NSW Scientific Committee (2007) has identified *Loss of Hollow-bearing Trees* as a Key Threatening Process. The maintenance of large old hollow-bearing trees in perpetuity is the single most important requirement for the survival of the numerous animal species that rely on their hollows for denning, nesting or roosting**.** Despite minimum requirements being specified for the retention of hollow-bearing trees there is a war of attrition being waged against them because the Forestry Corporation regard hollow-bearing trees as a waste of space rather than an environmental asset. The small numbers of mature trees required to be protected for their abundant nectar and to grow into the hollow-bearing trees of the future are being logged as the Forestry Corporation becomes increasingly desperate for large sawlogs (see **Protecting Habitat Trees**).

Loyn (1985) considers species most reliant upon old growth to be those utilising old trees for feeding, such as some honeyeaters and mistletoe birds which feed on mistletoe nectar or fruit, some insectivorous birds which feed from old eucalypt bark or among canopy foliage and some arboreal mammals which feed on sap and invertebrates from large eucalypt trunks and branches or on canopy foliage in tall eucalypts.

Older trees produce significantly more flowers and seeds than young trees and thus are of particular importance to fauna relying on these food sources. For Mountain Ash trees Ashton (1975) found:

> *The mature forest produced 2.15-15.5 times as many flowers as the pole stage trees, and 1.5-10 times as many as the spar stage forest. Estimates of the fruit set following the late autumn flowering of 1954 indicate that that of the mature forest was 1.6 times as great as that in the spar stage forest and 3.5 times as great as that in the pole stage forest.*

The abundance of flowers and seeds provided by trees directly affects their suitability for foraging by animals. For example, Kavanagh (1987) found that Yellow-bellied Gliders mainly used medium to large trees for feeding on flowers (as well as sap and honeydew) because they had the greatest number of flowers on which to forage for nectar. Similarly Koch (2003) found that south-eastern Red-tailed Black Cockatoos preferentially selected stringybark trees with larger girth and canopy volume as these were correlated with crop size. He considered that the abundance of seed directly affected breeding success.

As well as being important for fauna, in this era of global warming big old trees are increasingly important for their ability to sequester and store carbon (see **Sequestering and Storing Carbon in Forests**) and regulate stream flows (see **How Forests Regulate Stream Flows**). For example Roxburgh *et.al.* (2006) found:

> *In mature forests, large diameter trees greater than 100 cm d.b.h. comprised 18% of all trees greater than 20 cm d.b.h. and contained 54% of the total above-ground carbon in living vegetation. ... The influence of large trees on carbon stock therefore increases with their increasing size and abundance.*

This review focuses on the importance of old-trees in providing the hollows essential for so many native animals and the need to provide for replacement trees as they die.

The need for tree-hollows

A plethora of forest animals depend upon the trunk and branch hollows provided by big old trees for their survival. In NSW at least 46 mammals, 81 birds, 31 reptiles and 16 frogs, are reliant on tree hollows for shelter and nests, of these, 40 species are listed as threatened on Schedule 1 and Schedule 2 of the Threatened Species Conservation Act (NSW Scientific Committee 2007). Animal species that use tree hollows include most possums and gliders, numerous bats, various ducks, most owls, Australian Owlet-nightjar, tree creepers, tree martins, all cockatoos, most parrots, some kestrels and falcons, Laughing Kookaburras, some kingfishers, Dollarbirds, and various lizards and snakes.

Seventy species (28%) of vertebrates use hollows in north-east NSW (Gibbons & Lindenmayer 2002). The loss of the hollows provided by large old trees has been identified as a primary threat to a variety of priority species in north east NSW (Environment Australia 1999, Appendix 1); 4 mammals (non-flying), 20 bats, 3 birds, 2 frogs, 3 reptiles and 4 snakes. Numerous other species have been identified as threatened by the loss of other resources (i.e. seeds, nectar, nest sites) provided in greater abundance by older trees and many by the increased transpiration of young trees and consequent reductions in water availability (Environment Australia 1999).

Animals do not select hollows at random; factors such as entrance size and shape, depth, degree of insulation and location greatly affect the frequency and seasonality of hollow use. Many species use multiple hollows which they move between, for example a Brush-tailed Phascogale has been found to use 27-38 different hollows (Gibbons & Lindenmayer 2002). Brigham *et. al.* (1998) found that Owlet-nightjars move approximately 300m between roost sites every 9 days on average, with individuals using 2-6 different cavities over 1-4 months, noting "*our results suggest that birds may be loyal to a group of 2-6 trees in a relatively confined area*".

A single hollow may be used by more than one species in a year, sometimes concurrently. Many species will exclude other individuals of the same species from the vicinity of their nesting hollows, some may only defend a few metres around their nest while others may defend a clump of trees (Gibbons & Lindenmayer 2002), and many are territorial with defended territories of a few hectares or hundreds of hectares. A few species prefer to nest colonially in clumps of trees (Gibbons & Lindenmayer 2002). Fewer arboreal marsupials have been recorded from sites where hollow-bearing trees are clumped compared to being evenly distributed, which has been attributed to social and territorial behaviour (Gibbons & Lindenmayer 2002).

Gibbons and Lindenmayer (2002) documented that relatively undisturbed woodlands contain 7–17 hollow-bearing trees per hectare, and undisturbed temperate and sub-tropical eucalypt forests 13–27 per hectare. Only some hollows have appropriate entrance sizes and depths for fauna, with only 43-57% of hollows found to be used by fauna, and 49-57% of hollow-bearing trees used (Gibbons and Lindenmayer 2002). Large dead trees are utilised by many animals, representing 18-19% of hollow-bearing trees on some sites (Gibbons and Lindenmayer 2002).

Based on a number of assumptions, various estimates of the numbers of hollow-bearing trees occupied by vertebrate fauna have been made, with 6-13 per hectare in north east NSW, 4.5-9 per ha in south-east Queensland, and 7-14 per ha in East Gippsland (Gibbons & Lindenmayer 2002). Based on their estimates Gibbons & Lindenmayer (2002) assumed that *"hollow-bearing trees in forests are likely to be occupied at a rate of around 6-15 per hectare".*

Once the availability of hollows becomes limiting, competition with more aggressive species, introduced birds (ie Common Myna and Common Starling) and the European Honey Bee can exclude the more vulnerable species. For example, the Greater Glider has been found to be absent from sites supporting less than 6 hollow-bearing trees per hectare (Gibbons & Lindenmayer 2002).

As noted by the NSW Scientific Committee (2007):

> *The density of hollow-bearing trees required to sustain viable populations of vertebrates is a function of the diversity of competing fauna species at a site, population densities, number of hollows required by each individual over the long-term, and the number of hollows with suitable characteristics occurring in each tree. These factors vary spatially among habitats and temporally throughout the year with, for example, the demand for nests increasing greatly during the spring breeding season (Calder et al. 1983). Accurately estimating hollow requirements in a given habitat is currently difficult due to the lack of this baseline information,*

The need to protected these old hollow-bearing trees was recognised by the Forestry Corporation with management plans in the late 1980's including prescriptions varying from retention of clumps of 5 habitat trees per 15 ha to 5 per 5 ha Retention rates was the focus of much debate during the preparation of EIS's, with the stalemate broken by the Minister's determination of the Wingham EIS in 1994, which required that in Dry Hardwood forest, an average of four habitat trees per hectare shall be retained and in Moist and New England Hardwood forest, an average of six habitat trees per hectare shall be retained. It also required that clusters of vegetation around the habitat trees shall be retained and that sufficient recruitment trees shall be retained in order to sustain the prescribed density of habitat trees in perpetuity. This prescription was applied in all subsequent EIS determinations.

The current retention requirements for hollow-bearing trees in north-east NSW's public forests are 10 hollow-bearing trees per 2 hectares where they still exist. This is 19-38% of the average natural stocking of hollow-bearing trees. This outcome was a trade-off between the science and the resource demands of the Forestry Corporation. It still envisions a major loss of hollow-dependent animals, as noted by Smith (1999);

> *Current prescriptions require the maintenance of at least 5 habitat trees per hectare. This is less than 30% of the average stocking of habitat trees in unlogged native forest. Loss of habitat trees is the single greatest cause of biodiversity reduction in logged forests. If all habitat trees in unlogged native forest were fully utilized a 70% reduction in abundance of hollow dependent fauna could be expected in logged forest under current standards. … This finding suggests that current standards for habitat tree retention are inadequate to maintain the natural diversity of hollow dependent fauna in logged forests. However, retention of higher densities of habitat trees is likely to significantly reduce timber yields.*

Provision of tree-hollows

Generally speaking, small hollows begin to develop once a eucalypt is 120-180 years old, and the large hollows required by many species after a tree is over 220 years old (ie Gibbons & Lindenmayer 2002). Most hollows develop in branches, though also occur in the main trunk. Depending on the species and site conditions most eucalypts may live for 300-500 years, with a few eucalypts reputed to live for over a thousand years, providing their lives are not cut short.

For blackbutt forests Mackowski (1987) found that only hollows in trees greater than 100 cm. dbh (diameter at breast height) (144 years old) were utilised by wildlife, and that larger species *"such as ducks, cockatoos and owls"* were restricted for nesting to the larger hollows only found in blackbutt > 140 cm dbh (> 224 years old). Mackowski found that the large hollow bearing trees would only persist for 80 or so years, necessitating replacement large hollowing-bearing trees to become available.

Kavanagh (2002) found that for nesting, Masked Owls utilised trees 100-191 cm dbh, Sooty Owls trees 124-183 cm dbh, and Powerful Owls trees 77-180cm dbh, with most nests located in riparian zone forest on minor (1st order) streams.

The NSW Scientific Committee (2007) notes:

> *Although large hollow-bearing trees are numerically rare, vertebrate species strongly select for them as nest and roost sites. Of 228 hollow-bearing trees examined after felling in East Gippsland, Victoria, the mean DBH of trees used by vertebrates was 151±9 (SD) cm for E. fastigata, 125±7 cm for E. cypellocarpa, 114±8 cm for E. obliqua and 92±11 cm for E. croajingolensis (Gibbons et al. 2002).*

Trees species vary in their propensity to develop hollows, with some developing numerous hollows as they age and others developing very few (Gibbons & Lindenmayer 2002, Munks et. al. 2007, Gibbons *et. al.* 2010). In natural forests the density of old hollow-bearing trees also varies with topography, with relatively productive sites on more moderate slopes and moister sites supporting higher numbers of trees with hollows (Gibbons & Lindenmayer 2002, Munks et. al. 2007, Gibbons *et. al.* 2010). Some animals also preferentially utilise hollows near water or feeding areas (Gibbons & Lindenmayer 2002).

Gibbons and Lindenmayer (2002) documented that relatively undisturbed woodlands contain 7–17 hollow-bearing trees per hectare, and undisturbed temperate and sub-tropical eucalypt forests 13–27 per hectare. In dry Tasmanian *Eucalyptus obliqua* forests Munks *et. al.* (2007) recorded a density of potential hollow bearing trees of 28 per hectare, with this declining to 16 per hectare in the dry *E. delegatensis* forest. Smith (1999) identified the averaged structure of natural native forests according to tree size class and site productivity in eastern NSW.

Smith (1999) Number of stems (all species) per hectare in increasing diameter classes in unlogged or "old-logged" forests.

Productivity Class	20-39 cm dbh	40-59 cm dbh	60-79cm dbh	80-99 cm dbh	>100 cm dbh
1 low	69	24	10.8	2.5	-
2 low-mod	80	50	16.7	6	1.3
3 mod-high	87	57.4	31.6	11.5	5
4 high	64	44.7	14.3	7.6	11.9

1. Shading depicts where significant numbers of hollows with an entrance >10 cm diameter and estimated depth >25 cm were recorded.
2. Size classes are based upon diameter at breast height (dbh).

Maintaining tree-hollows in perpetuity

Natural forests are usually multi-aged with cohorts of different sized trees resulting from past disturbance events (usually wildfire). They thus allow for succession as existing hollow-bearing trees die and collapse. Logging targets many of the mature trees for removal, leaving a potential hiatus in replacement trees capable of providing tree-hollows when existing ones collapse or burn. As noted by Gibbons and Lindenmayer (2002):

> *Hollow-bearing eucalypts are extremely long-lived 'organisms'. Eucalypts typically have a life span of 300-500 years, and dead trees may provide hollows for a further 100 years. The age at which they 'reproduce' hollows (typically 150-250 years) represents one of the slowest 'reproductive cycles' for any organism. Failure to replace hollow-bearing trees as they are lost will result in prolonged temporal gaps in the resource that will not only reduce the area of suitable habitat for hollow-using fauna, but could also fragment populations of species unable to occupy areas lacking hollows. The dispersal of hollow using species also will be impaired".*

Lindenmayer *et. al.* (2014) recognise that:

> *... drivers of large old tree loss can create a "temporary extinction," that is, a prolonged period between the loss of existing large old trees and the recruitment of new ones (Gibbons et al. 2010b). The length of a temporary extinction may vary (e.g., 50 to 300+ years) ... Temporary extinction has the potential to drive species strongly dependent on large old trees to permanent local or even global extinction. In other cases, existing large old trees may be doomed to eventual extinction because the animals that dispersed their seeds have disappeared".*
>
> *...*
>
> *Policies must be implemented long before problems result from the loss of large old trees. This is because, unlike many other organisms with a shorter life history, once old trees are gone, it can take centuries to restore them.*

This problem has long been recognised and a concerted push from NEFA saw a significant increase in prescribed numbers of hollow-bearing trees begin to be adopted as an outcome of the NSW EIS process, starting in 1994. It was not until 1996 that prescriptions for hollow-bearing trees and recruits were applied across State forests in north-east NSW as an outcome of the Interim Assessment Process. These prescriptions are fundamentally flawed in that they only require the retention of one recruitment tree for each hollow-bearing tree and do not account for natural and increased mortality following logging.

In natural forests there is a self thinning process that results in significant mortality as trees mature (Mackowski 1987, Smith 1999). There is also a high likelihood of mortality due to other factors. As noted by Mackowski (1987 p124) *"the frequent occurrence of fire in this site height blackbutt forest precludes a 100% chance of survival - a proportion will be damaged, or weakened, or burnt down by each fire. These trees are also subject to the risk of lightning and windstorm damage."*

Logging significantly increases tree mortality. After logging the retained trees are more vulnerable to windthrow and post-logging burning (Saunders 1979, Recher, Rohan-Jones and Smith 1980, Mackowski 1987, Smith and Lindenmayer 1988, Milledge, Palmer and Nelson 1991, Smith 1991a, Gibbons and Lindenmayer 2002). Gibbons and Lindenmayer (2002) note *"studies consistently show that the number of hollow-bearing trees that occurs on logged sites is negatively associated with the number of harvesting events*", and *"logging may result in a pulse of mortality among retained trees after each cutting event"*.

In all audits undertaken by NEFA some trees marked for retention as hollow-bearing trees and recruits have been found to have been damaged in the logging, had the soil compacted around their roots, or are already burnt out at the base and unlikely to remain standing for long. Many trees retained as recruits are found to be too young, deformed or suppressed and unlikely to develop into hollow-bearing trees. Logging debris is often left stacked against the bases of retained trees, forming funeral pyres for post-logging burns. (see **Protecting Habitat Trees**)

In Mountain Ash and Alpine Ash forests Gibbons and Lindenmayer (2002) identify that 18% of the total population of hollow-bearing trees collapsed over a 5 year period (3.6% per annum). Gibbons and Lindenmayer (2002) also report that *"14% and 37% of trees retained on logged sites were killed 2-5 years after low- and high-intensity slash burning respectively"*, and that the probability of a retained tree surviving after a single logging event was 0.63.

Parnaby *et. al.* (2010) assessed the impacts of a single low-intensity prescription burn in the Piliga forests on hollow-bearing trees, finding mean collapse rates of 14% to 26%, noting *"The collapse of burnt, hollow-bearing trees on individual plots ranged from 0 to 50%, and exceeded 20% on 13, of the 29 plots".*

On top of logging and prescribed burning induced mortality of natural disturbance regimes still apply, though these too are accentuated by logging impacts, for example in south-east NSW 87% of retained trees were killed following a wildfire (Gibbons and Lindenmayer 2002).

This problem is also recognised by the NSW Scientific Committee (2007):

> *Trees retained during harvest are susceptible to damage from logging operations and post-harvest burning, or can suffer poor health owing to changes in abiotic conditions (Gibbons and Lindenmayer 2002). Consequently, retained trees are prone to early mortality, especially with repeated exposure to harvesting events over their lifespan. Prescriptions for forestry operations also stipulate that young trees are retained for long-term replacement of hollow-bearing trees, typically with one recruit for every hollow-bearing tree. The age structure in natural forests, where recruitment and loss of mature trees is at equilibrium, indicates that only a small proportion of younger trees survive to reach maturity. A ratio of one-to-one will be inadequate in itself to sustain the stipulated minimum densities of hollow-bearing trees in harvested areas*

To maintain habitat trees in perpetuity there is a necessity to account for natural and logging/burning induced tree-deaths when prescribing retention rates for both hollow-bearing trees and recruitments sufficient to maintain the prescribed number of habitat trees over long time frames (Recher, Rohan-Jones and Smith 1980, Mackowski 1984, 1987, Recher 1991, Scotts 1991, Traill 1991). Mackowski 1987 assessed the retention requirements for all age classes to maintain 3 hollow bearing trees per hectare in blackbutt forests after accounting for natural mortality, extrapolating from this, to maintain each hollow-bearing tree >100 cm dbh it is necessary to retain 5.2 trees 20-100 cm dbh to account for natural attrition.

TABLE 4.5. COASTAL BLACKBUTT RETENTION RATES REQUIRED TO MAINTAIN 10 HABITAT TREES PER TWO HECTARES IN PERPETUITY. The assumption is made that there will be 50% mortality of recruitment trees every 80 years. Adapted from Mackowski 1987.

Diameter (dbhob) cm.	Age yrs	Time-span in size class yrs	Mackowski's requirements for 3 Habitat Trees per Hectare over 100cm	Requirements to retain 10 Hollow-bearing Trees per Two Hectares
20-60	16-68	52	11.5	38.3
60-100	68-144	76	4	13.3
100-140[A]	144-224	80	2	6.6
140-180[B]	224-304	80	1	3.3

A - stage at which hollows suitable for small wildlife form.
B - stage at which hollows suitable for large wildlife form.

Mackowski (1984) considered *"The general pattern of hollow formation in many gum type eucalypts, ironbarks, bloodwoods and stringybarks is similar to that described for Blackbutt. Tallowwood and Brushbox have similar crown architecture characteristics to Blackbutt but have substantially different suites of organisms involved in the succession towards hollows, leading probably to much older age at hollow formation."*

Many forests have been denuded of habitat trees. To enhance such forests for nature conservation and maintenance of ecosystem functioning they need to be managed for the return of adequate stockings of habitat trees (Mackowski 1987). Mackowski (1987 p134) states *"where adequate hollow trees have not been retained in the past, a greater proportion of larger recruits should be selected (rather than evenly distributed between 60 & 100 cm dbhob) to facilitate the early return of hollow trees and the immigration of hollow dependant wildlife if it occurs nearby."*

Regrettably, the 1999 Threatened Species Licence removed the need to restore hollow-bearing trees (to 10 per 2 hectares) in north-east NSW's coastal forests, instead only requiring the remaining numbers of hollow-bearing trees, with one recruitment each, to be retained. With each logging event the numbers are declining.

Hollow-bearing trees, and with them hollow-dependent species, have already been decimated within vast tracts of forests. The problems such fauna are facing is expected to exponentially worsen as the few remaining large old hollow-bearing trees (in both forests and pastoral lands) die-out without replacement trees being available. The full ramifications of irreversible changes already set in place will take a century or more to become fully manifest.

Lindenmayer *et. al.* (2014) warn *"Existing policies are failing. New polices and management actions are required to conserve existing large old trees, provide for their recruitment, and maintain an age structure for tree populations that ensures a perpetual supply of large old trees thereby sustaining the critical functional properties that such trees provide. Without urgent action this iconic growth stage and the biota and ecological functions associated with it are in danger of being seriously depleted or even lost in many ecosystems".*

On public lands trees over 100 years old have survived the worst ravages of the industrial logging and widespread clearfelling that has increasing occurred on State Forests since the 1950s. Such trees are in the stages of developing hollows and are a rare and valuable wildlife resource. As well as being important for sustaining populations of hollow-dependent fauna, such trees are part of our natural heritage and the relatively few that remain should be retained.

Lindenmayer *et. al.* (2014) consider *"A critical step in large old tree management is to stop felling them where they persist and begin restoring populations where they have been depleted"*.

Protecting Habitat Trees

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