

Stag Retention and Use by Arboreal Marsupials in Eucalypt Forests of Southeast Queensland, Australia: Implications for Management¹

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Abstract

Dead standing trees (“stags” in Australia) are critical for wildlife in forests throughout the world. Dynamics of stag recruitment and retention are an interaction of tree mortality, size, deterioration rate, human intervention, and variables related to the structure and physiognomy of the forest. Historically in Australia and elsewhere, timber management involved the removal of stags and resulted in additional stags being lost to fire and wind at greater rates than under “natural” conditions. The current status of stags and the relative importance of live versus dead trees to arboreal mammals were investigated on permanent inventory plots throughout southeast Queensland, Australia. Hollow development was correlated with rates of wood decay and time since death. Density of hollow-bearing trees was 10.2 ± 0.2 stems per hectare (mean \pm SE); approximately 50 percent of the hollow-bearing trees were stags. Proportion of standing dead versus live trees was about 1:30. However, dead versus live tree use by arboreals was difficult to determine. Longevity of all stags was estimated to be 50 to 100 years. Although live hollow-bearing trees are more important to hollow-using wildlife in Australia, stags may provide a significant additional hollow resource in managed stands. Adequate densities and distribution of both live hollow-bearing trees and stags are extremely important to forest wildlife communities in both Australia and North America.

Introduction

Over the last decade, countries around the world have been addressing the issue of ecological sustainable development. In 1992, Australia adopted a National Strategy for Sustainable Development, which promotes using, conserving, and enhancing the community’s resources so that ecological processes are maintained (Australian Forestry Council 1992). Since that time legislation has been enacted to further this goal, including comprehensive planning and assessment systems.

The sound use and management of land, water, and native plants and animals is critical to the long-term productivity and profitability of forestry, the health of the environment, and the viability of rural communities. As such, sustainable natural

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resource management is one of the greatest challenges in the new century. Forest managers are continuously faced with the task of limiting pressures on forest resources (e.g., water and timber production, recreation, biodiversity) as human demands and community expectations increase, and the conservation of biodiversity in forests managed for timber is arguably one of the most complex and controversial management issues. In Australia, the National Forest Policy Statement commits governments and industry to develop management systems that cater effectively to the conservation of all indigenous species throughout their natural ranges.

The forests of eastern Australia provide habitat for a wide assemblage of arboreal vertebrates (Ambrose 1982, Lamb and others 1998, Smith and Hume 1984, Smith and Lees 1998, Taylor and Savva 1988). Many of these species make extensive use of tree cavities, or hollows as they are called in Australia, for denning, roosting or nesting, including 42 percent of mammals, 21 percent of birds, and 28 percent of reptiles and amphibians (Ambrose 1982, Saunders and others 1982). Loss of trees with hollows has been identified as the most significant cause of biodiversity reduction in timber production forests of eastern Australia (Lindenmayer and others 1991a, Loyn 1985). Live trees selected to be retained in harvest areas because they contain hollows or future hollows are referred to as hollow-bearing or habitat trees (Lindenmayer and others 1991b). Dead standing trees—called snags in North America and stags in Australia—can also provide hollows for arboreal wildlife and may be selected for retention, but can be expected to decay and fall more rapidly than live hollow-bearing trees (Borsboom 1991a,b; Wormington and Lamb 1999).

This paper is a collation of existing scientific knowledge of hollow use and habitat tree resources in southeast Queensland, Australia, production forests, compiled from a number of studies conducted over many years. We focus on the number and arrangement of habitat trees (including stags) required to support populations of hollow-dependent vertebrate species, particularly arboreal marsupials. Measurements of hollow trees made in permanent inventory plots within the production forests of southeast Queensland have provided baseline information for silvicultural prescriptions that address both sustainable timber production and the habitat requirements of hollow-dependent fauna. Our objectives are to introduce North Americans to the hollow-using terrestrial fauna of eastern Australia, describe the formation of hollows in Australian forests, quantify the abundance of both live hollow-bearing trees and stags, and discuss the relative importance of stags to arboreal marsupials in eucalypt forests of southeast Queensland.

Study Area

Surveys for hollow-bearing trees took place on state-owned forest lands in southeast Queensland, Australia. The major forest type was inland dry sclerophyll at elevations ranging from 50 to 500 meters. Dominant trees were lemon-scented gum (*Corymbia citriodora*), grey gum (*Eucalyptus propinqua*), brown, red, and pink bloodwood (*Corymbia trachyphloia*, *C. gummifera*, and *C. intermedia*), and broad-leaved red, narrow-leaved red, and grey ironbark (*Eucalyptus fibrosa*, *E. crebra*, and *E. siderophloia*). Sites were often on well-drained soils with level to moderate slopes. Annual rainfall varied between 1 to 2 meters and fell mostly during the warmer months (October-April). Selective tree logging (i.e., harvest of trees above prescribed diameters) and treatment (i.e., killing by ringbarking or poison injection) of decayed and diseased trees were the dominant timber management practices in the region

(Florence and others 1970, Queensland Forest Service 1992). Historically, stags were removed for safety and fire concerns (Crowe and others 1984). These practices, especially the treatment of decayed and diseased trees, are perceived to be the main cause of decrease in numbers of hollow-bearing trees.

Methods

Over the last 50 years, the Queensland Department of Primary Industries, Forestry Division, has established a series of permanent survey plots in native hardwood forests to determine individual tree and forest stand growth rates, as well as other parameters. These plots are located in commercial forests and are managed no differently from the surrounding forest. Periodic measurements (approximately every 5 years) have provided data to calculate periodic annual increment (PAI) of diameter at breast height (DBH); PAI of species can be used to estimate the age of individual trees in the plots. Stand tables and frequency distributions of hollow-bearing live trees and stags were compiled from plot measurement data. Plots were grouped by rainfall, soils, geographical location, species mix, stand productivity, harvesting regime, and silvicultural management history.

In southeast Queensland, 294 permanent plots within 86 state forests, covering a broad range of forest types and totaling 137 ha, were surveyed for habitat trees and arboreal mammals (Ross 1998). We defined a habitat tree as any tree, either alive or dead (i.e., stag), having at least one visible hollow with an entrance diameter >10 centimeters. As many animals use hollows with openings <10 centimeters, our estimate of habitat tree density is conservative. Plots were surveyed for number of live and dead habitat trees. Densities of live and dead habitat trees were calculated from counts on permanent plots, and age was estimated by the PAI and DBH of each tree species. In addition, stags >3 m in height were measured and number of hollows were counted in trees >30 centimeters DBH (Ross 1998). We report means and standard errors for tree and stag densities, measurements, and ages.

At an additional 38 sites in southeast Queensland, surveys for nocturnal arboreal mammals were conducted at night on 1-km transect lines running through permanent plots wherever possible. Twenty of these transects were close to or passed through 20 of the 294 permanent plots. At pre-designated stations, located every 25 meters along transect lines, surveyors waited quietly for about 3 min., and then used a portable spotlight to search the canopy for arboreal marsupials. Living and dead hollow-bearing trees within 30 m of the transect were counted to obtain density of hollow-bearing trees. Other habitat data (e.g., forest type, basal area) were obtained from three 0.25-hectare plots on each transect.⁵

Results

Current Status of Hollow Trees

Of 294 permanent plots surveyed, 242 (82 percent) contained hollow-bearing stems (Ross 1998). Hollow-bearing trees occurred at a mean density of 10.2 ± 0.2 stems per hectare across all forest types, with about 50 percent being stags (*table 1*).

⁵ Unpublished data on file at The University of Queensland, Brisbane, Queensland, Australia.

For trees >30 centimeters DBH, 12 percent of live trees and 93 percent of stags had hollows.

Table 1—Densities (mean \pm standard error) of live and dead (i.e., stags) trees >10 centimeters diameter at breast height on permanent plots located on commercial forest lands in southeastern Australia. Habitat trees are any tree having at least one visible hollow with an entrance diameter >10 centimeters in size (adapted from Ross 1998).

| | Live trees | Stags | Total |
|-----------------------------|------------------|------------------|--------------------|
| Total stems per ha | 250 ¹ | 8.2 ¹ | 258.2 ¹ |
| Hollow-bearing stems per ha | 5.7 \pm 0.3 | 4.4 \pm 0.2 | 10.2 \pm 0.2 |
| Habitat trees per ha | 2.4 \pm 0.2 | 3.0 \pm 0.2 | 5.5 \pm 0.2 |

¹Standard error (SE) was not provided by Ross (1998).

The proportion of hollow-bearing stems in a given size class increased with increasing DBH: 4 percent of trees 30-39 centimeters DBH had hollows, whereas 70 percent of trees 40-90 centimeters DBH contained hollows. These larger trees contained many more hollows on average than smaller trees, and many of these hollows had larger entrance diameters. In general, live stems bore an average of 2.2 hollows overall (all hollows), with an average of 1.0 hollow per tree for entrance diameters >10 centimeters (Ross 1998). Stags averaged 2.8 hollows per stem, with 1.4 hollows per stem for entrance diameters >10 centimeters.

Hollow-bearing trees represented 42 species, the majority being eucalypts or closely related genera. Hollow development appeared to be species dependent, with some species developing hollows earlier in life (i.e., those species more prone to limb breakage) (Wormington and Lamb 1999). No difference was found in the rate of hollow development within forest types (Ross 1998). Hollow development was correlated with rates of wood decay and time since death.

The majority of permanent plots were altered by selective logging, where larger merchantable trees were removed, in addition to treatments that removed a small number of “healthy” (i.e., no deformities) trees and killed most older hollow-bearing trees. Thus stocking rates of stags increased with increasing level of disturbance. Undisturbed stands had a mean stag density of 4.4 stems per hectare, but stands with three to four logging and/or treatment events had 7.4 stags per hectare. In essence, stags comprised 27 percent of the total tree hollow compliment in undisturbed stands as compared to 68 percent in intensively managed stands.

Ross (1998) examined 660 standing dead trees in the permanent plots. The majority of deaths (about two-thirds) were attributed to natural causes (e.g., senescence, wind, fire, drought, or lightning) or silvicultural treatment (about one-third), with the density of treated stags correlated positively with treatment. The effect of silvicultural treatment at our 38 survey sites was to lower the total number of hollow-bearing trees from 14 to 6 per hectare and change the ratio of stags to live hollow-bearing trees from 1:4 to 2:1.⁵

Survey of Arboreal Mammals

Six species of arboreal marsupials were detected in the dry sclerophyll forests of southeast Queensland: common brushtail possum (*Trichosurus vulpecula*), greater glider (*Petauroides volans*), yellow-bellied glider (*Petaurus australis*), sugar glider (*P. breviceps*), squirrel glider (*P. norfolcensis*), and feathertail glider (*Acrobates pygmaeus*). Species diversity and abundance were most dependent upon forest type, but a minimum of four hollow-bearing trees per hectare was also required before all species of arboreal marsupials were detected along a transect at any site. Most sites (22 of 38) contained <2 live hollow-bearing trees per hectare (some contained none), with the majority of hollow-bearing trees being stags. The sites that contained low numbers of live hollow-bearing trees were often the sites with other attributes (e.g., preferred tree species, higher leaf nutrient levels and forest productivity) most suited to arboreal marsupials (i.e., good site characteristics except for low numbers of habitat trees).⁵

Discussion

In Queensland, at least 13 species of arboreal and scansorial mammals, 63 species of birds, 23 species of bats, and 35 species of herptiles may either utilize or be dependent on hollows (Queensland Department of Natural Resources 1998, Smith and Lees 1998). Hollow-dependent fauna are defined as species that rely predominantly (i.e., >50 percent of the time) on tree hollows for shelter, roosting, or nesting at some stage in their life cycle. Three broad guilds of hollow-dependent fauna are recognized in Queensland (Lamb and others 1998). Group 1, which are evenly spaced, territorial species with small or medium daily home ranges and require moderate to high densities (2-12 per hectare) of habitat trees, include mammals such as gliders (*Petaurus* spp. and other genera) and possums (*Pseudocheirus* spp. and *Trichosurus* spp.) and birds such as treecreepers (*Climacteris* spp., *Cormobates leucophaea*), kingfishers (*Todiramphus* spp., *Syma torotoro*), kookaburras (*Dacelo* spp.), rosellas (*Platycercus* spp.), many genera of parrots, and several other species. Group 2 are non-territorial species that breed or roost in clusters and include lorikeets (*Trichoglossus* spp. and others), several additional species of birds, and 28 species of bats. These species require low to high densities of habitat trees, but these trees may be clustered or distributed unevenly. Group 3 are large territorial species with large home ranges, such as cockatoos (*Calyptrorhynchus* spp. and others), several species of owl, and the lace monitor (*Varanus varius*). These large-bodied animals require very large trees with very large hollows, but these trees may be at low densities.

Specific information on the hollow requirements for most Australian species is lacking, and only limited empirical data are available on the density and spacing of habitat trees required by hollow-dependent fauna. As a group, the arboreal marsupials have been the most extensively studied. Estimates for numbers of habitat trees required to sustain populations of arboreal hollow-dependent mammals in southeast Queensland are wide ranging (<1-48 per hectare). However, based on our analyses, we recommend an average of five to eight habitat trees per hectare, which is a reasonable general management goal and follows Lamb and others (1998). They recommended 8-12 habitat trees per hectare to maintain natural densities of hollow users, with at least half that (i.e., 4-6 per hectare) providing an appropriate

compromise for sustaining populations of hollow-dependent fauna in logged forests, though probably below natural densities.

Eyre (1993) and Eyre and Smith (1997) found that yellow-bellied gliders used only one dead standing tree as a den site, as compared with 44 live habitat trees. In contrast, a site in this study that contained very few live hollow-bearing trees had a high abundance of all six species of arboreal marsupials (common brush-tail possum and greater, yellow-bellied, squirrel, sugar, and feathertail gliders). All species except the feathertail glider were observed to use stags regularly for denning.⁵ Silvicultural treatments such as ringbarking or poison injection can increase numbers of stags, as was evidenced on some of our plots that had higher levels of disturbance, but stag longevity is lower than that of live hollow-bearing trees. Thus, the retention of treated stags provided a significant hollow resource in altered areas, but with the caveat that stags are more susceptible to fire, wind, and other disturbances and their longevity is far less than live hollow trees.

Dynamics of natural stag retention is an interaction of tree mortality, stag size, stag deterioration rate, site conditions, and other variables (Cline and others 1980, Raphael and Morrison 1987). In North America, the cavity formation process often involves the activities of primary excavators (woodpeckers, family Picidae) (Conner and others 1976, Mannan and others 1980, Raphael and White 1984). In Australia, however, primary excavator species do not exist, and hollow development in commercially important gum forests is an interaction involving mechanical process (e.g., limb breakage, fire scars), fungal infections, and termite activity (Mackowski 1984, Saunders and others 1982, Wilkes 1982, Wormington and Lamb 1999). The process of hollow formation and the relative importance of live versus standing dead trees is thus a dynamic process dependent on several variables, and differs between Australia and North America, at least with regard to primary cavity excavators. However, Waters and others (1990) reported that nonexcavated hollows (i.e., those formed by limb breakage and decay rather than woodpeckers) were more common in oaks (*Quercus* spp.) than digger pines (*Pinus sabiniana*) in California; hollows in pines were exclusively the work of excavators. Thus, hollow formation in North American hardwoods is probably similar to hollow formation in Australian hardwoods. Nonetheless, adequate densities and distribution of hollow-bearing trees and stags is extremely important to forest wildlife communities on both continents.

One of the challenges in managing stags is determining not only how many stags should be on an area, but in what kinds of distributions (i.e., uniform, scattered, clumped). Different wildlife species not only require different sized stags and hollows, but often different distributions, as noted previously in this discussion. A management program for stags on either continent will be a multifaceted problem, involving a diversity of sizes of stags and hollows distributed across the landscape in a variety of patterns. Clearly, thorough knowledge of the life history requirements for the diversity of species involved is a prerequisite.

The current status of hollow-bearing trees in production forests throughout southeast Queensland is determined largely by past silvicultural management. On our plots, the development and abundance of tree hollows was related to stem size and estimated age. Depending on the species, trees need to reach 145 to >200 years of age to provide adequate hollows, with older trees corresponding to larger hollows (Wormington and Lamb 1999). Recent analyses indicate an overall depletion of the hollow tree resource in native production forests (Ross 1998).

The government of Queensland is required to provide a “Code of Environmental Practice for Native Forest Timber Production,” which includes the retention of habitat trees (Lamb and others 1998). The Technical Advisory Group that was assembled to address management issues pertinent to retention of habitat trees in native forests of Queensland acknowledged that stags were more susceptible to fire and wind-throw than live trees, but did recognize the importance of stags to wildlife. The advisory group recommended that stags be retained unless there were compelling safety or fire management reasons to remove them. Not only does this benefit wildlife, but assists in restoring the multiple functions that dead wood provides to forest ecosystems, including associations with invertebrate and fungi diversity and the role dead wood plays in carbon pathways and recycling of nutrients.

Loss of stags is only part of the concern, however. Loss of forest habitat is probably the greatest concern in Queensland. Over 400,000 ha of native forest cover is currently being cleared per annum. In most cases this is for agriculture and urban expansion, but vast areas have been converted to plantations, particularly exotic pines. The problem has been further compounded by fragmentation of forest cover and edge effects, i.e., where remnant forest exists between exotic or native plantations. These edges are often exposed when the plantation is felled, leading to additional loss of stags to wind throw. Also, the remnant areas are burnt quite regularly to protect the commercial plantation, leading to increased loss of stags.

The information we present is incomplete and clearly preliminary concerning the requirements of hollow-dependent fauna in Queensland forests. Silvicultural practices have the potential to remove or destroy hollow-bearing trees, leaving insufficient younger trees to replace the losses and thereby modifying forest microhabitats, possibly to the detriment of hollow-dependent fauna. Many other parameters, such as alteration of forest structure and composition, successional age, and fire regimes can affect the distribution and abundance of habitat trees, particularly stags. In addition, management recommendations for the retention of habitat trees should be in accordance with the assemblage of hollow-dependent fauna expected to occur on a particular site or forest type (as requirements vary among species), and not applied uniformly across the landscape. The maintenance of forest biodiversity, particularly hollow-dependent fauna, must be undertaken as part of an integrated strategy that includes consideration of the full range of wildlife habitat requirements such as the structure and composition of the forest matrix resulting from timber harvesting and other disturbances. Because the process of hollow development takes a considerable period of time (Mackowski 1984, Wormington and Lamb 1999) and hollows are more prevalent and larger in large trees, it is important that long term considerations be made to ensure a perpetual supply of hollow-bearing trees for hollow-dependent fauna (Gibbons and Lindenmayer 1996).

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