

Nest-tree selection by the threatened brush-tailed phascogale (*Phascogale tapoatafa*) (Marsupialia : Dasyuridae) in a highly fragmented agricultural landscape

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Abstract. The conservation of roosting and nesting resources is of critical concern for many hollow-dependent species around the world. We investigated the nest-tree requirements of the threatened brush-tailed phascogale (*Phascogale tapoatafa*) in a highly cleared agricultural landscape in south-eastern Australia. We documented the physical characteristics of selected nest trees and describe the spatial and temporal patterns of nest-tree use as revealed by radio-tracking. Nine phascogales (seven females, two males) were radio-tracked between March and July 1999 in an area where most woodland habitat is confined to linear strips along roads and streams or small patches and scattered trees in cleared farmland. Female phascogales were monitored for 13–35 days over periods of 5–15 weeks and two males were monitored for 2 and 9 days respectively. A total of 185 nest-tree fixes was collected and all nests occupied by phascogales were in standing trees. Eighty-three nest trees were identified, ranging in diameter at breast height (DBH) from 25 to 171 cm, with a mean DBH for the trees used by each individual phascogale of >80 cm. Phascogales did not discriminate between canopy tree species in selecting nest trees, but showed highly significant selection for trees in the largest size class. All individuals used multiple nest trees, with the seven females occupying an average of 11.4 nest trees from a mean of 25 diurnal locations. The number of nest trees continued to increase throughout the study, suggesting that more would be identified during a longer or more intensive study. Occupied nest trees were located throughout each individual's home range, highlighting the importance of a continuous spatial distribution of suitable nest trees across the landscape. Nest trees were also located in adjacent farmland up to 225 m from roadside vegetation, demonstrating the value that scattered clumps and even single trees in farmland can have for wildlife conservation.

Introduction

Tree hollows are a critical habitat component for many species of wildlife. The conservation of tree hollows that provide shelter, roosting, nesting or denning opportunities is of concern even in landscapes where the natural habitat remains largely uncleared (e.g. Gibbons and Lindenmayer 2002). The additional complication of habitat loss, fragmentation and conversion to other land-uses has the potential to dramatically alter the abundance, distribution and physical characteristics of tree hollows. Loss or alteration of the abundance and distribution of tree hollows is occurring throughout the world as a consequence of timber harvesting, firewood collection, natural senescence of trees without adequate rates of replacement and clearing of habitat (e.g. Saunders 1979; Bennett *et al.* 1994; Du Plessis 1995; Gibbons and Lindenmayer 1996; Kirby *et al.* 1998; Harper *et al.* 2005). To achieve sustainable management of the tree hollow resource, it is important to understand the pattern of

use by hollow-dependent animals, particularly within modified landscapes.

A typically tree-hollow-dependent marsupial, the brush-tailed phascogale (*Phascogale tapoatafa*) occurs in dry, forested habitats in south-eastern Australia (Cuttle 1983), with other behaviourally analogous phascogale species occupying similar habitat in south-western and northern Australia (Rhind *et al.* 2001; Spencer *et al.* 2001). These forested areas in south-east Australia have undergone extensive clearing and fragmentation for agriculture since European settlement, and in Victoria approximately half of the former phascogale habitat has been eliminated (Menkhorst 1995). In addition, a history of mining, grazing, intensive logging and firewood collection have resulted in a marked change in forest structure, with a large proportion of remaining forest habitat dominated by small trees that do not support suitable hollows (Robinson and Traill 1996; Soderquist 1999). This loss and degradation of habitat is believed to have contributed to the

decline of *P. tapoatafa* (Menkhorst 1995), and the species is now classified as threatened in Victoria under the *Flora and Fauna Guarantee Act 1988*.

Phascogale tapoatafa characteristically nests and shelters alone (Rhind 2003) in tree hollows that have small entrance holes (Soderquist 1993b; Traill and Coates 1993; Rhind 1996; Whitford 2001). The characteristics of the hollow (e.g. depth and volume) influence its suitability for occupation. This may be critical during reproduction when a mother deposits her young (at an age of ~48 days) in the maternity nest while she forages independently (Soderquist 1993b). Information on the use of nest trees by *P. tapoatafa* in south-eastern Australia has originated from the highly disturbed box–ironbark forests (Soderquist 1993b; Traill and Coates 1993). These forests currently support, on average, two large-diameter (>60 cm diameter at breast height: DBH) trees ha⁻¹ (NRE 1998), a major reduction from a density of up to 30 large trees ha⁻¹ that existed before European settlement (Newman 1961). In these areas where the abundance of suitable hollows is low, *P. tapoatafa* has been observed to nest in coppice hollows, tree stumps and ball-shaped stick nests of white-browed babblers (*Pomatostomus superciliosus*) (Traill and Coates 1993). These alternatives were used less frequently than hollows in standing trees (4 of 14 nests identified) and are considered less suitable because they provide inferior thermoregulation capabilities and less protection from predators than typical hollows occurring in large-diameter trees or those higher in the canopy. Adequate thermoregulation is critical to the survival of young deposited in the nest when the mother is out foraging (Soderquist 1993b).

The northern plains region of Victoria has undergone massive habitat loss since European settlement for agriculture and less than 6% tree cover now remains (Bennett and Ford 1997). A network of remnant woodland along roadsides near Euroa (36°45'S, 145°30'E) currently supports a resident population of *P. tapoatafa* (van der Ree *et al.* 2001). Van der Ree *et al.* (2001) found that the home ranges of phascogales in this population were an order of magnitude smaller than values recorded for individuals within continuous forest. In that study (van der Ree *et al.* 2001), we presented preliminary information about the number and diameter of nest trees occupied by nine phascogales. We found that the phascogales always nested in standing trees, used a combined total of 83 different trees during 185 diurnal fixes, and preferentially selected trees with a large DBH (>80 cm DBH) (van der Ree *et al.* 2001). Females used an average of 11.4 trees over a mean of 24.9 days of tracking and the average ratio of the number of days tracked versus number of nest trees was 2.3 (van der Ree *et al.* 2001). The objectives of this paper are to further describe nest-tree use by *P. tapoatafa*, including: (1) the physical characteristics of trees selected by *P. tapoatafa* as nest trees, and (2) temporal and spatial patterns in nest-tree use.

Materials and methods

Study area

The study was undertaken in an area of 30 km², ~10 km west of Euroa, where <5% tree cover now remains (van der Ree *et al.* 2001). Phascogales were studied in remnant woodland along roadsides and unused road reserves dominated by grey box (*Eucalyptus microcarpa*), with a diverse age structure of trees (van der Ree and Bennett 2001; van der Ree *et al.* 2001). The mean density of large trees (>70 cm DBH) in linear habitats where *P. tapoatafa* was studied was 22.0 ± 0.65 (s.e.) trees ha⁻¹, more than 10 times the mean density of large trees on public lands in box–ironbark forests nearby (NRE 1998).

Trapping and radio-tracking techniques

Trapping and radio-tracking methods are detailed in van der Ree *et al.* (2001) and briefly summarised here. Animals were captured in large aluminium Elliott traps (Elliott Scientific, Melbourne) baited with a mixture of peanut butter, rolled oats and honey and mounted in trees at a height of 2–5 m. Traps were placed at intervals of ~200 m along 27 km of roadside and unused road reserve. Trapping to capture animals for radio-telemetry was conducted in March–April 1999 and again in July–August 1999 to remove collars.

All phascogales trapped were fitted with tuned-loop single-stage radio-transmitters with lightweight brass collars covered by heatshrinkable plastic (Sirtrack, New Zealand), each weighing 4.0–4.5 g (<4.0% of bodyweight). Radio-tracking was undertaken on foot using a collapsible 3-element Yagi antenna and Regal 2000 Receiver (Titley Electronics, Ballina, New South Wales). Once a tree occupied by a phascogale was identified, it was tagged with a unique two-letter code and its location recorded. The accuracy of locations was high as the actual tree occupied by an animal could usually be identified. The accuracy of radio-tracking locations was verified by stagwatching (where observers positioned beneath hollow-bearing trees count animals as they emerge at dusk) at a small number of identified nest trees. Nest trees were identified during daylight hours and each phascogale was usually tracked to its nest tree for four days per fortnight between March and June 1999. To calculate the rate of change and distance between consecutive nest trees, only data collected on consecutive days were used for this analysis. At the conclusion of the radio-tracking study, animals were recaptured and radio-collars removed.

Nesting range

The spatial distribution of all nest trees identified for each phascogale was used to calculate the nesting range (after Lindenmayer *et al.* 1997). The area and length of the nesting range were calculated according to the methods described by van der Ree *et al.* (2001) for home range, thus allowing for direct comparison between the total (foraging) home range and the nesting range for each individual phascogale. Home-range estimates used in this study are based on 100% of fixes, in order to compare total foraging range to nesting range.

Nest tree and habitat assessment

The species of all trees occupied by *P. tapoatafa* during the day was recorded and their DBH measured to the nearest centimetre using a diameter tape. Dead trees could not be identified to species and were recorded as dead trees. Data on the tree species composition of the surrounding habitat are described in van der Ree *et al.* (2001).

Results

Radio-tracking effort

Seven female phascogales were radio-tracked to den trees during daylight hours for 13–35 days (mean = 24.9) during March–July 1999 (Table 1). The two males were radio-

Table 1. Radio-tracking details and estimates of area and length of nesting range for *Phascogale tapoatafa* radio-tracked near Euroa

A fix is considered 'consecutive' if a nest-tree fix was obtained on the previous day. Percentage change and direction of change (+/-) between home range (100% of fixes from van der Ree *et al.* 2001) and nesting range are given in parentheses. Results for Male I are not shown because just two nest-tree locations were collected

Animal	Tracking period in 1999	No. of diurnal fixes	No. of consecutive fixes	No. of nest trees identified	Nesting range	
					Area (ha)	Length (m)
Female A	31.iii–11.vii	35	25	13	6.84 (-19.7)	2585 (-3.2)
Female B	5.iv–24.vi	27	18	14	4.55 (-27.9)	1185 (0)
Female C	5.iv–11.vii	32	23	19	7.74 (-8.1)	2335 (-4.9)
Female D	7.iv–11.vii	30	21	11	1.19 (-70.0)	890 (-37.5)
Female E	27.v–27.vi	13	9	5	2.14 (-15.7)	655 (-7.7)
Female F	31.iii–25.v	20	14	7	3.97 (-10.4)	955 (-14.3)
Female G	31.iii–24.v	17	11	11	3.87 (-20.5)	1695 (-2.3)
Male H	26.v–21.vi	9	5	7	19.71 (-15.7)	7130 (-8.7)
Female mean		24.9	17.3	11.4	4.33 (-24.6)	1471 (-10.0)
Total / s.e. ^A		185	127	83 ^B	0.89	284

^AStandard error given for the area and length of nesting range, totals for remaining columns.

^BSix trees were used by two individuals during the course of the study.

tracked for just two and nine days, respectively, after fitting the transmitter because their radio-signals were lost owing to long-distance movements. A total of 185 diurnal fixes was obtained from the nine individuals.

Influence of sampling effort on the number of identified nest trees

The number of nest trees identified for each female phascogale increased with the duration of tracking (Fig. 1). The overall number of nest trees used by phascogales continued to increase throughout the study period, indicating that more nest trees would be identified during a longer or more intensive study.

Nest-tree characteristics

Most nests (94%) were in living trees, of which grey box was the most numerous ($n = 70$), followed by red box (*E. polyanthemos*, $n = 4$), Blakely's red gum (*E. blakelyi*, $n = 2$), red stringybark (*E. macrorhyncha*, $n = 1$) and river red gum (*E. camaldulensis*, $n = 1$). Five dead trees were used. Phascogales used nest trees of each species (treating dead trees as a separate species) according to their availability within the linear remnants and woodland fragments ($\chi^2 = 6.81$, d.f. = 7, $P > 0.25$) (Fig. 2).

Spatial and temporal patterns in nest-tree use

For each individual phascogale, nest trees were typically distributed throughout their home range (Fig. 3). Sixty-three nest trees (76%) were along roadsides; of the remaining 20 trees occurring in paddocks, seven were single isolated trees and 13 occurred within small woodland fragments (typically <1 ha in area). The distance from roadside habitat to nest trees in paddocks was 20–225 m (mean 101 ± 14 (s.e.)). The distance of open ground to be traversed to reach

the nest tree, assuming phascogales travelled via the most direct route from the nearest roadside, was 0–150 m (mean 66 ± 10 (s.e.)).

In comparison with the 100% home-range estimate for each individual (van der Ree *et al.* 2001), the nesting range was, on average, 24.6% smaller in size and 10.0% shorter in length (Table 1). Thus, occupied nest trees occur throughout most of the home range and were not clumped centrally within an animal's range.

For most individuals, one nest tree was used for 20–30% of the time, with the remaining nest trees being used less frequently (Fig. 4). Female F displayed the greatest nest tree

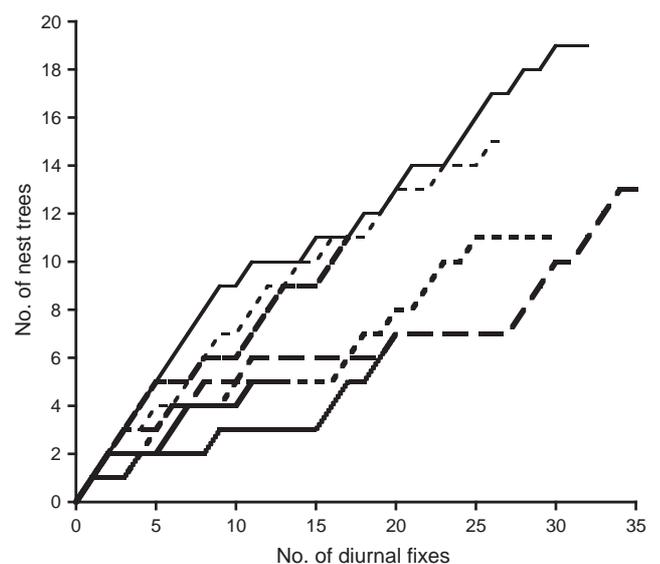


Fig. 1. Cumulative number of occupied nest trees in relation to number of telemetry fixes for each of seven female *P. tapoatafa* radio-tracked in linear habitats.

fidelity during the tracking period, with 13 of 20 fixes from the same tree.

About 69% of diurnal fixes (127 of 185) were collected on consecutive days. Of the 127 consecutive fixes, *P. tapoatafa* (both sexes combined) changed nest trees on 84 occasions (66%). The mean distance between nest trees used on consecutive days when animals switched was 232 m (s.e. = 34).

Discussion

Characteristics of occupied nest trees

Diurnal nests occupied by *P. tapoatafa* in remnant woodland at Euroa were typically in living trees with a large diameter. Importantly, *P. tapoatafa* selected large-diameter (>70 cm DBH) trees significantly more often than they occurred within the landscape. Large-diameter trees have been identified as important or preferred nest sites for a range of hollow-dependent species (e.g. Saunders *et al.* 1982; Lunney *et al.* 1988; Taylor and Savva 1988; Cowan 1989; Lindenmayer *et al.* 1991; Nelson and Morris 1994; Lumsden *et al.* 2002), including *P. tapoatafa* (Rhind 1996). The number, size and diversity of hollows within a tree typically increase with tree diameter and age (Bennett *et al.* 1994; Soderquist 1999; Harper *et al.* 2004, 2005), and thus large trees are more likely to provide a suitable hollow for occupation than a tree with a small diameter. Various factors potentially influence the suitability of hollows for *P. tapoatafa*, including: entrance size (Soderquist 1993b; Traill and Coates 1993; Rhind 1996), internal dimensions of the hollow (Soderquist 1993b), thermoregulatory capacity of the hollow (Soderquist 1993b; Rhind 2003), and spatial distribution of suitable hollows and the presence of other individuals (Rhind 2003). It is unlikely that all trees with hollows will be suitable for occupation by *P. tapoatafa* because one or more of the above factors may not be met. There needs to be ongoing recruitment of stems into each size-class to ensure that an adequate number of potential nest trees are available over time. However, land

uses (primarily grazing) in agricultural landscapes prevent seedlings from establishing in many locations, which in the longer term will result in fewer trees and hollows (e.g. Saunders *et al.* 2003).

Spatial and temporal patterns in nest-tree use

The use of multiple nest sites, an apparent preference for particular trees as nest trees, use of core nest trees, and regular shifting between trees, are traits common to many species of hollow-dependent arboreal marsupial (Henry and Craig 1984; Kehl and Borsboom 1984; Suckling 1984; Lindenmayer and Meggs 1996; Lindenmayer *et al.* 1996; Rhind 1996, 2003; Jackson 2000). Complex patterns in nest-tree selection, as shown by *P. tapoatafa*, are not well understood, but several hypotheses can be proposed.

First, the use of multiple nests may reduce the risk of predation because predators must inspect numerous sites that are occupied on an unpredictable basis. Second, regular switching between multiple hollows may also reduce ectoparasites in nests, as evidenced by the unusually high ectoparasite loads carried by phascogales when mothers and their litters are forced to occupy a maternal nest for several months (Soderquist 1993a). A negative correlation was found between the abundance of ectoparasites on pallid bats (*Antrozous pallidus*) and their frequency of roost switching (Lewis 1996). Third, occupation of multiple nest trees across the home range may assist in defence of the territory. Phascogales typically defaecate in their nest cavity, which then potentially serves as a territorial marker (Soderquist 1995). Fourth, different species of tree and hollows of different form and dimension are likely to possess varying thermal properties (e.g. humidity, temperature) (Tidemann and Flavel 1987; Kalcounis and Brigham 1998). Thus, animals may shift trees and/or hollows depending on the prevailing weather conditions. Finally, individuals can reduce energetic costs by having multiple hollows distributed across their foraging range. After a night of foraging, individuals can choose to nest in a nearby hollow, rather than return to a distant primary hollow at dawn. This may be particularly relevant at Euroa and in other fragmented landscapes where habitat is restricted or patchily distributed (e.g. long, linear strips of habitat). Phascogales at Euroa essentially nested over their entire foraging range, with the size of the nesting range almost equivalent to the total home range.

Most nest trees (76%) occurred along roadsides, with a small proportion located in scattered trees or small woodland fragments in paddocks. Nest trees were up to 225 m from roadsides, typically requiring individuals to traverse cleared areas with treeless gaps of up to 150 m. However, most nest trees used by *P. tapoatafa* could be reached by travelling through continuous strips of woodland (i.e. roadside vegetation), with the remainder requiring the crossing of cleared ground. A similar situation was observed in Western Australia where an undescribed *Phascogale* sp. associated

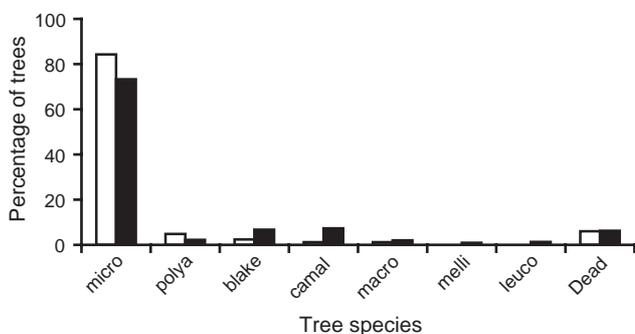


Fig. 2. The percentage of nest trees used by *P. tapoatafa* (open columns) and available trees (shaded columns) of each species. The tree species are *E. microcarpa* (micro), *E. polyanthemus* (polya), *E. blakelyi* (blake), *E. camaldulensis* (camal), *E. macrorhyncha* (macro), *E. melliodora* (melli), *E. leucoxyton* (leuco) and dead trees.

with farms readily nested in ‘paddock trees’ and travelled across open ground for distances of up to 300 m (Rhind 1996). These findings highlight the value of scattered clumps of trees and even single trees in farm paddocks as foraging habitat, stepping-stones for movement and nesting sites for species such as *P. tapoatafa*.

Timing of the study

This study was undertaken just before the breeding season, a time when males actively search for and monitor the reproductive status of females (Soderquist 1995). Thus, it is not surprising that the two males could be monitored for only a short time before they disappeared, presumably outside the

study area (van der Ree *et al.* 2001). The relatively short duration of radio-tracking in this study underestimates the number of nest trees actually used, because for most individuals the rate of increase in the cumulative number of occupied nest trees did not reach an asymptote during the study (Fig. 1).

Implications for land management

The use of nest trees by *P. tapoatafa*, as revealed in this study, has implications for at least four aspects of forest and woodland management. First, it highlights the critical importance of large trees. Suitable hollows are most commonly found in large trees and phascogales preferentially select them for

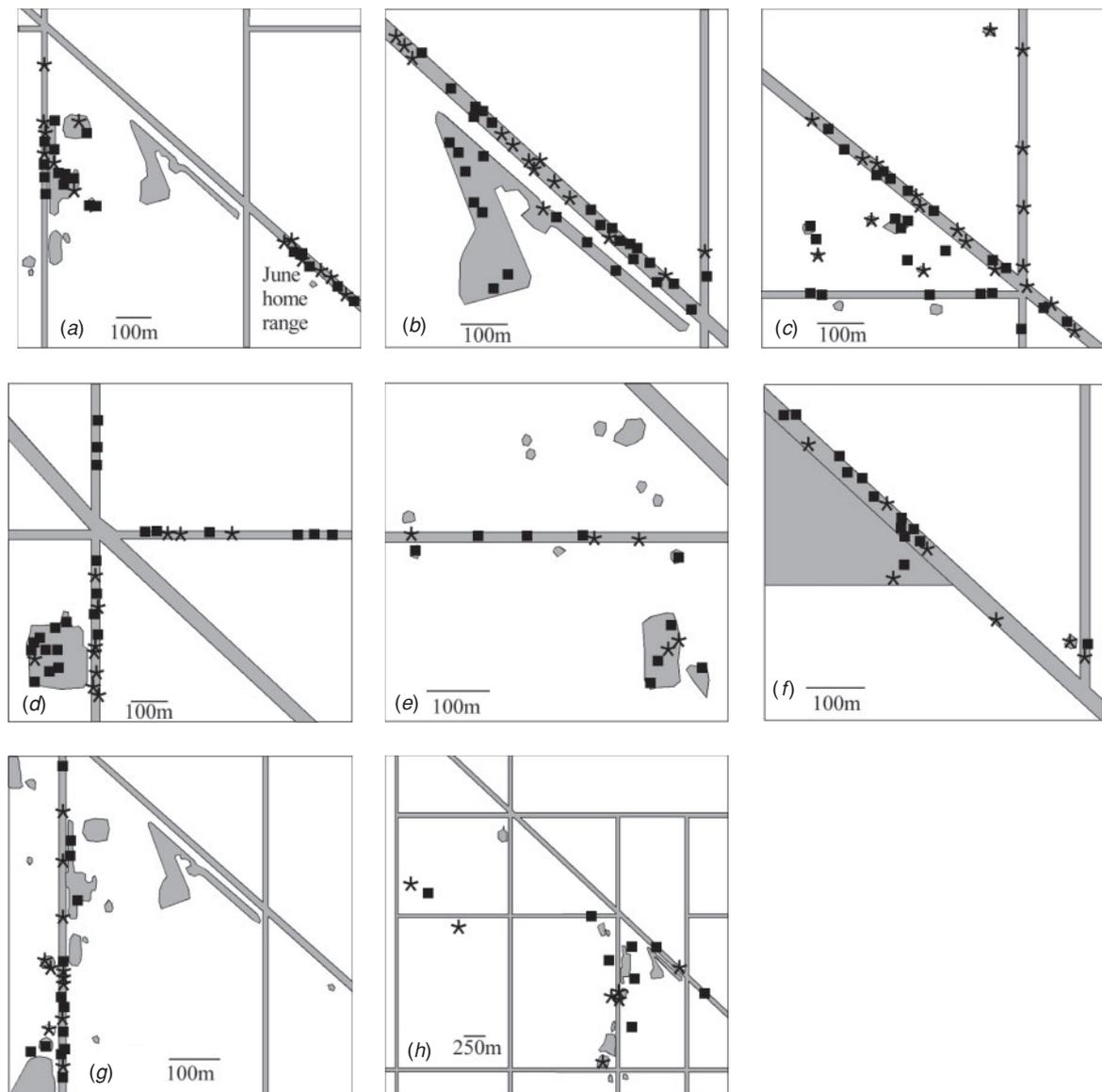


Fig. 3. Location of nest trees (denoted by asterisks) among nocturnal radio-tracking fixes (solid squares) for seven female phascogales (a–g) and one male phascogale (h). Remnant woodland vegetation is denoted by grey shading and cleared agricultural land by white. Note that the map scale differs between the male and females.

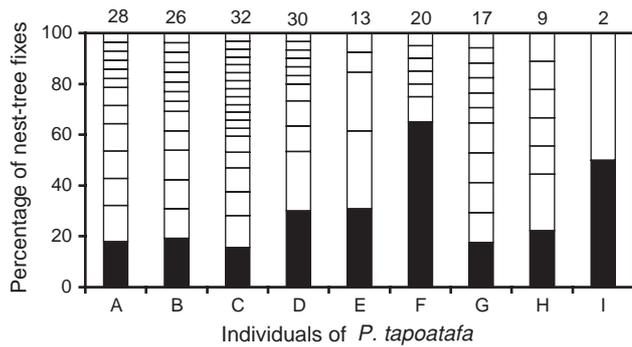


Fig. 4. Proportional use of different nest trees by individual female (A–G) and male (H, I) *P. tapoatafa*. Numbers above each column represent the total number of tracking days on which the nest tree could be identified to a single tree. The lengths of the column segments indicate the proportion of diurnal locations in each nest tree, and the most frequently occupied tree is indicated by shading.

occupation. The average diameter of nest trees used by each individual phascogale was >80 cm DBH. On the basis of a growth increment of ~3.5 mm per annum (NRE 1998), such trees are more than 200 years old and predate European settlement in this area by at least five decades.

Second, the study supports previous observations in highly modified box–ironbark forests and the jarrah forests of Western Australia that individuals require multiple nest trees (Traill and Coates 1993; Rhind 2004). The seven females in our study were tracked for a mean of 24.9 days and during this time each occupied an average of 11.4 nest trees (Table 1; van der Ree *et al.* 2001). Clearly, a high density of large hollow-bearing trees is an essential habitat requirement for this species.

Third, the spatial distribution of nest trees throughout each individual's home range (Fig. 3) suggests that suitable nest trees will be of greatest benefit when they are evenly distributed across the landscape, rather than clumped. These findings are directly relevant to the conservation of phascogales, because throughout the range of this threatened species prevailing land uses have resulted in marked changes to the structure of many of the dry forests and woodlands upon which its survival depends.

Finally, high-quality nest trees for phascogales and other hollow-dependent species are more abundant in remnant vegetation along roadsides (van der Ree and Bennett 2001), watercourses and some other small patches of habitat than in many of the larger blocks of woodland in the region. Large trees also provide high-quality foraging habitat (see van der Ree *et al.* 2001). Therefore, the comparatively low density of large trees in most of the larger blocks of publicly owned woodland at present may limit the abundance of phascogales, and potentially other hollow-dependent species. Further research to quantify the effect of few large-diameter trees on wildlife and experimental techniques to accelerate tree growth or hollow development are required. Finally, mea-

asures to further prevent the incremental loss of existing hollow-bearing trees resulting from natural or human-accelerated senescence are also required.

Acknowledgments

We thank Mark Venosta for assistance with trapping and radio-tracking and for access to unpublished data. We are most grateful to Ray Thomas for accommodation in the field, and Jim Tehan and Bob Hemming for unrestricted access to their properties. Thanks also go to Rod Anderson, Kim Lowe and Jenny Nelson of the Department of Sustainability and Environment who facilitated the project, and to Michael Harper and two anonymous referees for comments on the manuscript. Trapping and radio-tracking were conducted under Flora and Fauna Permit Number 10000430 and Deakin University Animal Experimentation and Ethics Committee (Approval Number A5/96).

References

- Bennett, A. F., and Ford, L. A. (1997). Land use, habitat change and the conservation of birds in fragmented rural environments: a landscape perspective from the Northern Plains, Victoria, Australia. *Pacific Conservation Biology* **3**, 244–261.
- Bennett, A. F., Lumsden, L. F., and Nicholls, A. O. (1994). Tree hollows as a resource for wildlife in remnant woodlands: spatial and temporal patterns across the Northern Plains of Victoria, Australia. *Pacific Conservation Biology* **1**, 222–235.
- Cowan, P. E. (1989). Denning habits of common brushtail possums, *Trichosurus vulpecula*, in New Zealand lowland forest. *Australian Wildlife Research* **16**, 63–78. doi:10.1071/WR9890063
- Cuttle, P. (1983). Brush-tailed Phascogale. In 'The Australian Museum Complete Book of Australian Mammals'. (Ed. R. Strahan.) pp. 34–35. (Australian Museum: Sydney.)
- Du Plessis, M. A. (1995). The effects of fuelwood removal on the diversity of some cavity-using birds and mammals in South Africa. *Biological Conservation* **74**, 77–82. doi:10.1016/0006-3207(95)00016-W
- Gibbons, P., and Lindenmayer, D. B. (1996). Issues associated with the retention of hollow-bearing trees within eucalypt forests managed for wood production. *Forest Ecology and Management* **83**, 245–279. doi:10.1016/0378-1127(95)03692-X
- Gibbons, P., and Lindenmayer, D. B. (2002). 'Tree hollows and wildlife conservation in Australia.' (CSIRO Publishing: Melbourne.)
- Harper, M. J., McCarthy, M. A., van der Ree, R., and Fox, J. C. (2004). Overcoming bias in ground-based surveys of hollow-bearing trees using double sampling. *Forest Ecology and Management* **190**, 291–300. doi:10.1016/j.foreco.2003.10.022
- Harper, M. J., McCarthy, M. A., and van der Ree, R. (2005). The abundance of hollow-bearing trees in urban dry sclerophyll forest and the effect of wind on hollow development. *Biological Conservation* **122**, 181–192. doi:10.1016/j.biocon.2004.07.003
- Henry, S. R., and Craig, S. A. (1984). Diet, ranging behaviour and social organization of the yellow-bellied Glider (*Petaurus australis* Shaw) in Victoria. In 'Possums and Gliders'. (Eds A. P. Smith and I. D. Hume.) pp. 331–341. (Australian Mammal Society: Sydney.)
- Jackson, S. M. (2000). Home-range and den use of the mahogany glider, *Petaurus gracilis*. *Wildlife Research* **27**, 49–60. doi:10.1071/WR98046
- Kalcounis, M. C., and Brigham, R. M. (1998). Secondary use of aspen cavities by tree-roosting big brown bats. *The Journal of Wildlife Management* **62**, 603–611.

- Kehl, J., and Borsboom, A. (1984). Home range, den tree use and activity patterns in the greater glider, *Petauroides volans*. In 'Possums and Gliders'. (Eds A. P. Smith and I. D. Hume.) pp. 229–236. (Australian Mammal Society: Sydney.)
- Kirby, K. J., Reid, C. M., Thomas, R. C., and Goldsmith, F. B. (1998). Preliminary estimates of fallen dead wood and standing dead trees in managed and unmanaged forests in Britain. *Journal of Applied Ecology* **35**, 148–155. doi:10.1046/j.1365-2664.1998.00276.x
- Lewis, S. E. (1996). Low roost-site fidelity in pallid bats: associated factors and effect on group stability. *Behavioural Ecology and Sociobiology* **39**, 335–344. doi:10.1007/s002650050298
- Lindenmayer, D. B., and Meggs, R. A. (1996). Use of den trees by Leadbeater's possum (*Gymnobelideus leadbeateri*). *Australian Journal of Zoology* **44**, 625–638. doi:10.1071/ZO9960625
- Lindenmayer, D. B., Cunningham, R. B., Tanton, M. T., Smith, A. P., and Nix, H. A. (1991). Characteristics of hollow-bearing trees occupied by arboreal marsupials in the montane ash forests of the central highlands of Victoria, south-east Australia. *Forest Ecology and Management* **40**, 289–308. doi:10.1016/0378-1127(91)90047-Y
- Lindenmayer, D. B., Welsh, A., Donnelly, C. F., and Meggs, R. A. (1996). Use of nest trees by the mountain brushtail possum (*Trichosurus caninus*) (Phalangeridae: Marsupialia). I. Number of occupied trees and frequency of tree use. *Wildlife Research* **23**, 343–361. doi:10.1071/WR9960343
- Lindenmayer, D. B., Welsh, A., and Donnelly, C. F. (1997). Use of nest trees by the mountain brushtail possum (*Trichosurus caninus*) (Phalangeridae: Marsupialia). III. Spatial configuration and occupancy of nest trees. *Wildlife Research* **24**, 661–677. doi:10.1071/WR96112
- Lumsden, L. F., Bennett, A. F., and Silins, J. E. (2002). Selection of roost sites by the lesser long-eared bat (*Nyctophilus geoffroyi*) and Gould's wattled bat (*Chalinolobus gouldii*) in south-eastern Australia. *Journal of Zoology* **257**, 207–218. doi:10.1017/S095283690200081X
- Lunney, D., Barker, J., Priddel, D., and O'Connell, M. (1988). Roost selection by Gould's long-eared bat, *Nyctophilus gouldi* (Chiroptera: Vespertilionidae), in logged forest on the south coast of New South Wales. *Australian Wildlife Research* **15**, 375–384. doi:10.1071/WR9880375
- Menkhorst, P. W. (1995). Brush-tailed phascogale. In 'Mammals of Victoria'. (Ed. P. W. Menkhorst.) pp. 58–60. (Oxford University Press: Melbourne.)
- Nelson, J. L., and Morris, B. J. (1994). Nesting requirements of the yellow-tailed black-cockatoo, *Calyptorhynchus funereus*, in *Eucalyptus regnans* forest, and implications for forest management. *Wildlife Research* **21**, 267–278. doi:10.1071/WR9940267
- Newman, L. A. (1961). 'The Box-Ironbark Forests of Victoria, Australia.' (Forests Commission of Victoria: Melbourne.)
- NRE (1998). 'Box-Ironbark Timber Assessment Project.' (Department of Natural Resources and Environment: Melbourne.)
- Rhind, S. G. (1996). Habitat tree requirements and the effects of removal during logging on the marsupial brush-tailed phascogale (*Phascogale tapoatafa tapoatafa*) in Western Australia. *Western Australian Naturalist* **21**, 1–22.
- Rhind, S. G. (2003). Communal nesting in the usually solitary marsupial, *Phascogale tapoatafa*. *Journal of Zoology* **261**, 345–351. doi:10.1017/S0952836903004308
- Rhind, S. G. (2004). Direct impacts of logging and forest management on the brush-tailed phascogale *Phascogale tapoatafa* and other arboreal marsupials in a jarrah forest of Western Australia. In 'Conservation of Australia's Forest Fauna (2nd edn)'. (Ed. D Lunney.) pp. 639–655. (Royal Zoological Society of New South Wales: Sydney.)
- Rhind, S. G., Bradley, J. S., and Cooper, N. K. (2001). Morphometric variation and taxonomic status of brush-tailed phascogales, *Phascogale tapoatafa* (Meyer, 1793) (Marsupialia: Dasyuridae). *Australian Journal of Zoology* **49**, 345–368. doi:10.1071/ZO01002
- Robinson, D., and Traill, B. J. (1996). 'Conserving Woodland Birds in the Wheat and Sheep Belts of Southern Australia.' (Royal Australian Ornithologists Union.)
- Saunders, D. A. (1979). The availability of tree hollows for use as nest sites by white-tailed black cockatoos. *Australian Wildlife Research* **6**, 205–216. doi:10.1071/WR9790205
- Saunders, D. A., Smith, G. T., and Rowley, I. (1982). The availability and dimensions of tree hollows that provide nest sites for cockatoos (Psittaciformes) in Western Australia. *Australian Wildlife Research* **9**, 541–556. doi:10.1071/WR9820541
- Saunders, D. A., Smith, G. T., Ingram, J. A., and Forrester, R. I. (2003). Changes in a remnant of salmon gum *Eucalyptus salmonophloia* and York gum *E. loxophleba* woodland, 1978 to 1997. Implications for woodland conservation in the wheat-sheep regions of Australia. *Biological Conservation* **110**, 245–256. doi:10.1016/S0006-3207(02)00223-9
- Soderquist, T. R. (1993a). Maternal strategies of *Phascogale tapoatafa* (Marsupialia: Dasyuridae). I. Breeding seasonality and maternal investment. *Australian Journal of Zoology* **41**, 549–566. doi:10.1071/ZO9930549
- Soderquist, T. R. (1993b). Maternal strategies of *Phascogale tapoatafa* (Marsupialia: Dasyuridae). II. Juvenile thermoregulation and maternal attendance. *Australian Journal of Zoology* **41**, 567–576. doi:10.1071/ZO9930567
- Soderquist, T. R. (1995). Spatial organization of the arboreal carnivorous marsupial *Phascogale tapoatafa*. *Journal of Zoology* **237**, 385–398.
- Soderquist, T. R. (1999). Tree hollows in the box-ironbark forest. Analyses of ecological data from the box-ironbark timber assessment in the Bendigo Forest Management Area and Pyrenees Ranges. Department of Natural Resources and Environment, Melbourne
- Spencer, P. B. S., Rhind, S. G., and Eldridge, M. D. B. (2001). Phylogeographic structure within *Phascogale* (Marsupialia: Dasyuridae) based on partial cytochrome *b* sequence. *Australian Journal of Zoology* **49**, 369–377. doi:10.1071/ZO00080
- Suckling, G. C. (1984). Population ecology of the sugar glider, *Petaurus breviceps*, in a system of fragmented habitats. *Australian Wildlife Research* **11**, 49–75.
- Taylor, R. J., and Savva, N. M. (1988). Use of roost sites by four species of bats in state forest in south-eastern Tasmania. *Australian Wildlife Research* **15**, 637–645. doi:10.1071/WR9880637
- Tidemann, C. R., and Flavel, S. C. (1987). Factors affecting choice of diurnal roost site by tree-hole bats (Microchiroptera) in south-eastern Australia. *Australian Wildlife Research* **14**, 459–473. doi:10.1071/WR9870459
- Traill, B. J., and Coates, T. D. (1993). Field observations on the brush-tailed phascogale *Phascogale tapoatafa* (Marsupialia: Dasyuridae). *Australian Mammalogy* **16**, 61–65.
- van der Ree, R., and Bennett, A. F. (2001). Woodland remnants along roadsides – a reflection of pre-European structure in temperate woodlands? *Ecological Management & Restoration* **2**, 224–226.
- van der Ree, R., Soderquist, T. R., and Bennett, A. F. (2001). Home range use by the brush-tailed phascogale *Phascogale tapoatafa* (Marsupialia: Dasyuridae) in high-quality, spatially limited habitat. *Wildlife Research* **28**, 517–525. doi:10.1071/WR00051
- Whitford, K. R. (2001). Dimensions of tree hollows used by birds and mammals in the jarrah forest: improving the dimensional description of potentially usable hollows. *CALMScience* **3**, 499–511.