THE USE OF HOLLOWS BY BIRDS AND MAMMALS IN DEAD RIVER RED GUM AND BLACK BOX TREES AT DISHER CREEK, MURRAY RIVER NATIONAL PARK, SOUTH AUSTRALIA

JODY ADAM GATES

ABSTRACT

Hollow availability and use was determined for 64 dead river red gums *Eucalyptus camaldulensis*, and 22 dead black box trees *Eucalyptus largiflorens*, at Disher Creek, a disused evaporation basin in the Murray River National Park. All trees were found to have at least one hollow and a significant positive relationship existed between diameter at breast height (DBH) and number of hollows. Overall 49% of the trees and only 13% of potential hollows were occupied with 61 nests recorded in the 86 trees. Red-rumped Parrots *Psephotus haematonotus*, Common Starlings *Sturnus vulgaris*, and Tree Martins *Cecropsis nigricans*, accounted for 85% of these nests. Bats were recorded in six trees and no arboreal mammals were observed within the study site. Although data for comparisons are limited I suggest that the availability of hollows was not limiting birds and that other factors relating to the degraded nature of the study site were more likely to be limiting hollow use.

INTRODUCTION

Throughout the world hollows in trees provide shelter and nesting places for many animals. This is particularly so in Australia where mature eucalypt trees provide an array of holes of varying sizes which are used by a suite of fauna that has evolved to live in them (Tidemann and Flavel 1987). Almost 350 species of Australian vertebrates use tree hollows in some way, including 119 species (17%) of birds, and 92 species (42%) of mammals (Ambrose 1982). The importance of hollows to animals in Australia has been recognised for some years (e.g. Cowley 1971; Tyndale-Biscoe and Calaby 1975). However, relatively few studies of the availability of this resource for wildlife have been undertaken (see Saunders *et al.* 1982; Ambrose 1982; Calder *et al.* 1983; Lindenmayer *et al.* 1990a, 1990b, 1990c; Joseph *et al.* 1991; Milledge *et al.* 1991; Traill 1991; Bennet *et al.* 1994). Practices such as agriculture and timber production have significantly reduced the number of hollows available for animals in Australia and overseas (Mannan *et al.* 1980; Saunders *et al.* 1982; Davis *et al.* 1983; Burbidge 1985; Zarnowitz and Manuwal 1985; Tidemann and Flavel 1987; Lunney *et al.* 1988; Taylor and Savva 1988; Lindenmayer *et al.* 1990a, 1990b, 1991).

Most genera of Australian trees provide hollows, and eucalypts in particular are noteworthy for producing large numbers of hollows of varying sizes. It is generally recognised that in Australia termites and fungus are the main agents in hollow formation (Ambrose 1982; Saunders *et al.* 1982; Mackowski 1984). Termites in particular play a significant role in excavating decayed wood, speeding hollow development and increasing the size of hollows (Newton John 1992). However, the frequency of hollows in different species of tree is unknown (Saunders *et al.* 1982) and little is known about the densities of hollows in intact woodlands, as most research has occurred in remnants (see Bennet *et al.* 1994). Newton John (1992) studied the occurrence of hollows in river red gums *Eucalyptus camaldulensis* in the Barmah State Forest in Victoria and found that 44% of trees had hollows, and only trees greater than 150 cm diameter at breast height (DBH) contained hollows. At Outlet Creek in Wyperfeld National Park Oldroyd *et al.* (1994) found that all trees in river red gum/black box *E. largiflorens* woodland with a DBH of greater than 31 cm had hollows. At this site river red gums averaged 2.07 (±0.06) suitable hollows per tree and black box averaged 1.5 (±0.13) suitable hollows. Not surprisingly larger trees had significantly more hollows ($r = 0.51$, $p < 0.001$) (Oldroyd *et al.* 1994). It was determined that there were approximately 11 000 hollows per square kilometre in this woodland (Oldroyd *et al.* 1994). No other data on hollow densities from intact woodlands were found in the literature, however, Bennet *et al.* (1994) include detailed data on the number of hollows and hollow-bearing trees from a wide range of remnants across the northern plains of Victoria. Bennet *et al.* (1994) recognised six woodland types, including river red gum and black box woodlands, and overall only 10% of trees had hollows, with a mean of 16.7 hollow-bearing trees per site. The majority of hollows (68%) were found in trees with a diameter >70 cm, however, only 8% of trees were of this size (Bennet *et al.* 1994). Marked differences in the abundance of hollow-bearing trees between woodland types were observed by Bennet *et al.* (1994) and this clearly makes comparisons between studies and between different sites difficult.

Trees that contain hollows are invariably very old. Mackowski (1984) determined that wildlife hollows do not form in blackbutt trees *E. pilularis* less than 200 years old and the longevity of these species is estimated at 300 years. Research emphasis has been placed on the requirements of the larger and more conspicuous obligate hollow nesters, in particular, cockatoos. Saunders *et al.* (1982) estimated that the minimum age of remnant salmon gums *E. salmonophila* that contained a large enough hollow for a cockatoo was 130 years old. Similarly, Mawson and Long (1994) reported that trees used for nesting by four species of parrot and the Long-billed Corella *Cacatua pastinator pastinator* were invariably very large and very old. The minimum age of any nest tree recorded was 73 years for the parrots, and 167 years for the corellas, while the lowest average age recorded for any species of tree used by the parrots was 275 years, and for the corellas was 440 years (Mawson and Long 1994). However, a large number of Australian birds other than parrots and cockatoos also require hollows for nesting, and as many of these species are smaller (e.g. treecreepers), hollows of a suitable size for smaller birds and mammals may form in younger trees.

Clearly the adverse impact of agriculture and forestry on fauna that are dependent on hollows is well known and now emphasis is on the legacy of these practices – the remaining remnants. The fact that these remnants remain in a radically altered landscape would indicate that they are likely to be a crucial resource for wildlife. At Disher Creek (Figure 1), in the Murray River National Park, a large number of remnant river red gum and black box trees were killed by the operation of an evaporation basin. Trees were also harvested in the past as indicated by the numerous stumps present across the site. This study was undertaken to investigate the habitat value of the dead trees at Disher Creek which have the potential to provide an important resource in the form of tree hollows. The aim of the study was to estimate potential hollow availability and the use of hollows by birds and mammals, and to make recommendations on the suitability of harvesting firewood from the site. This paper reports the findings on hollow availability and use.

METHODS

The Study Site

Disher Creek was used as an evaporation basin for 18 years and permanent inundation and/or increased soil salinities killed many of the river red gums and black box trees within, and adjacent to, the basin during this period. Small patches of healthy vegetation persist across the site on elevated areas and on the margins of the Murray River. The understorey of lignum *Muehlenbeckia florulenta* and a saltbush *Atriplex nummularia* was also killed and only a few live specimens of these remain on the site. The evaporation basin ceased operation in 1983, and since then measures have been undertaken to partially restore the original hydrology of Disher Creek. These measures have changed the conservation value of the Disher Creek wetland complex from low (Thompson 1986) to high (South Australian NPWS 1992), particularly for waterbirds. The study site was located within the northern section of the old evaporation basin and covered approximately 60 ha (Figure 1). Only a few mature trees and saplings survive, and no seedlings were observed in this area. Approximately 75% of all the dead trees are river red gums with black box trees comprising the remainder. The trees were identified as such because all live trees in the vicinity belonged to these two species. The differences in form between the trees and the presence of rough 'box-type' bark on some black boxes made it easy to distinguish the two species. The study site is dissected by numerous shallow channels which reflect the pattern of water flow across the site during high river flows. A dense ground cover is present in the channels and consists of chenopods and other salt tolerant species. Baldoo *Atriplex lindleyi* appears to be the most abundant ground cover species across the site.

Five transects were established to sample the study site. Four transects comprised river red gums and one transect comprised black box trees. Transects were located arbitrarily after surveying the area on foot, and were placed at varying distances from Disher Creek (Figure 2). Along each transect the number of hollows per tree was counted, and a running mean of the number of hollows per tree was used to determine an adequate sample size for each transect. When a plot of the running mean of hollows against the number of trees stabilised, an adequate sample size of trees within each transect had been reached. This resulted in 64 river red gums and 22 black box trees being sampled. Hollows were counted from the ground with the aid of binoculars, and were defined as any opening in the trunk or branch of a tree which could possibly be used by birds and mammals. Since climbing the dead trees was impractical, detailed inspection of hollows was not possible. The circumference at breast height of each tree was measured and converted to DBH, and trees were numbered with spray paint for identification, allowing data on occupancy of hollows to be related to individual trees and their attributes. The occupancy rate for each species of tree was determined by dividing the number of nests by the number of hollows for each individual tree.

The use of hollows was recorded during 11 days in August and September 1992. Observations of use by birds usually began at 0700 h, with approximately 45 minutes spent at each transect depending upon weather conditions and the amount of bird activity. The order in which transects were observed was rotated to eliminate bias associated with the increased bird activity in the early morning. A total of 6.5 to 7.2 hours was spent observing each transect, with an overall total of 34 hours for all transects. The clumped distribution of the trees ensured that each transect could be viewed from two or three vantage points, with up to 10 trees

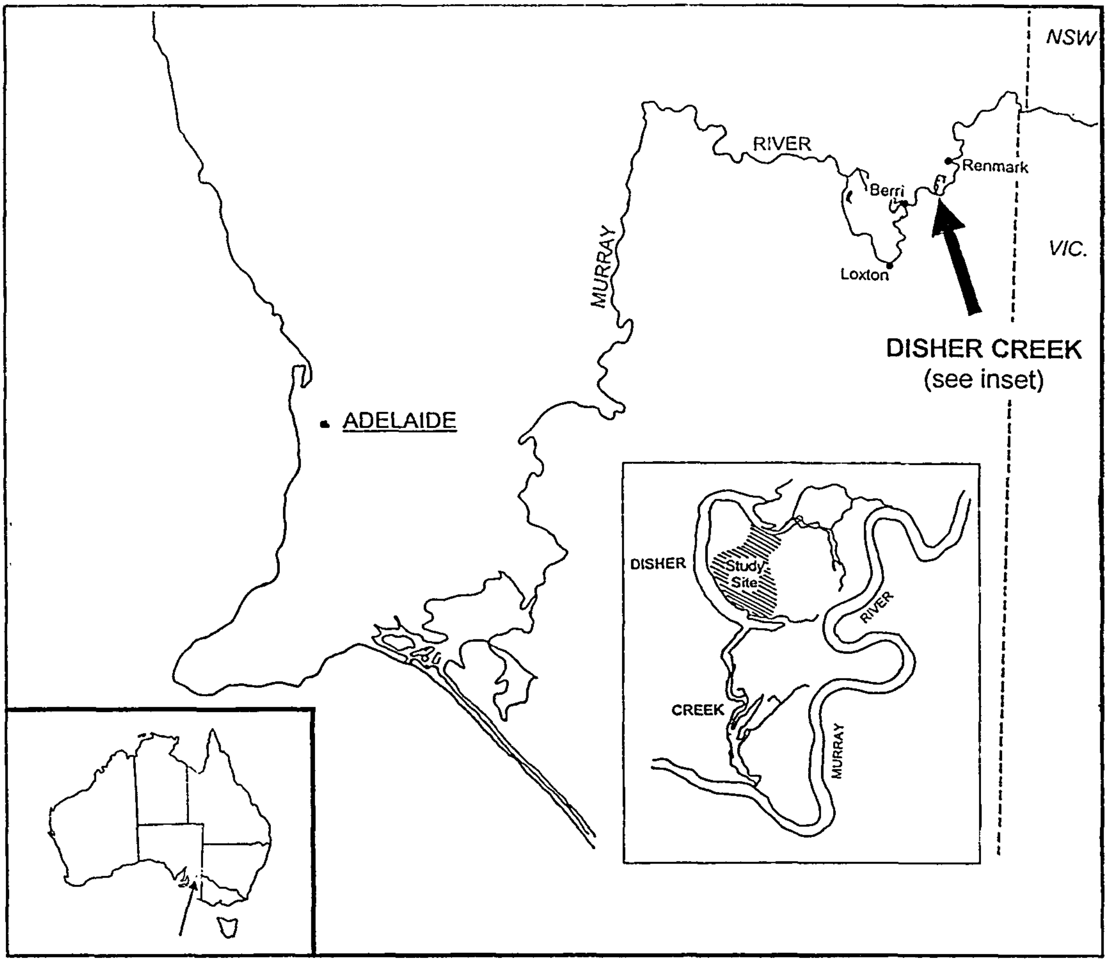

Figure 1. The location of Disher Creek and the study site.

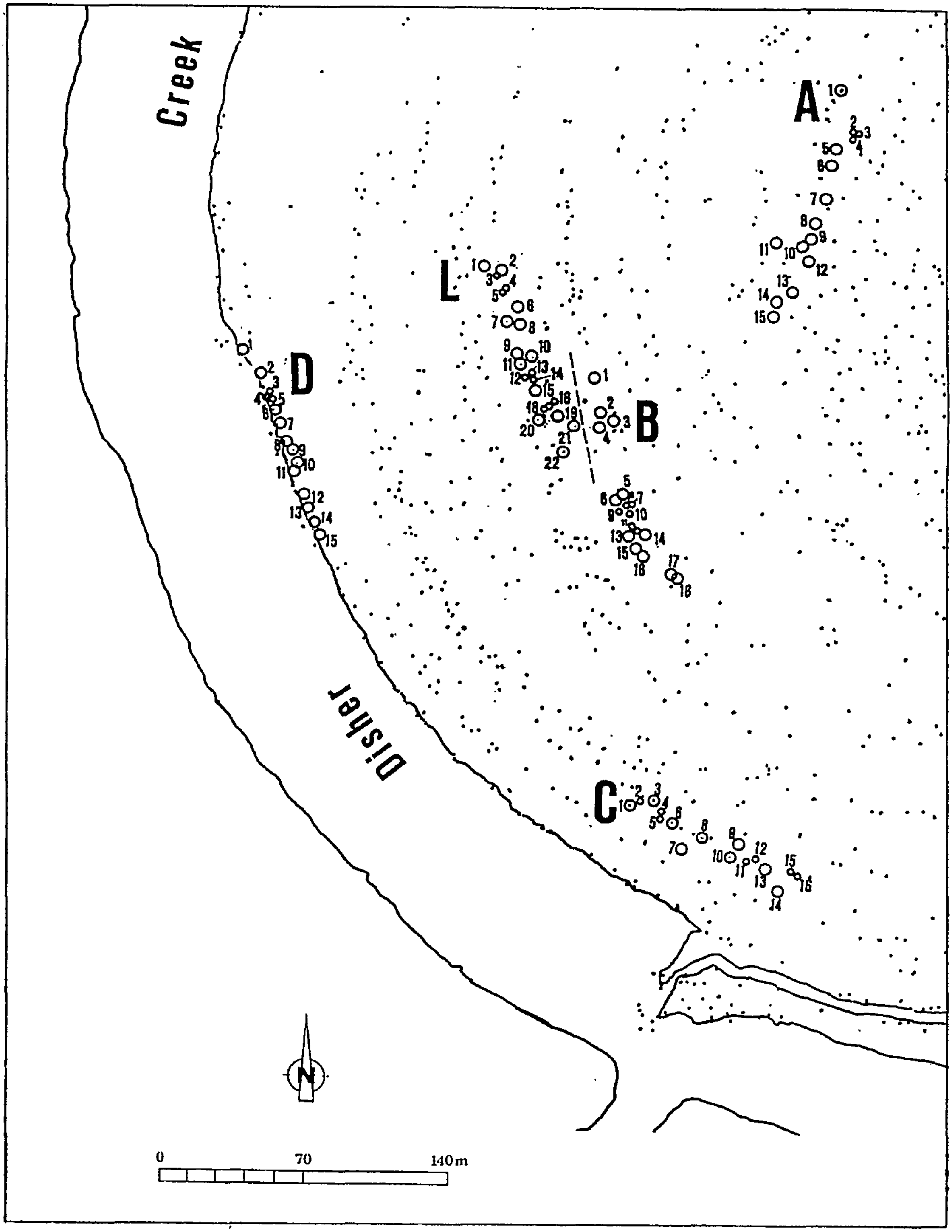

Figure 2. Location of the transects. A-D are river red gums and L is black box. Numbered circles represent individual trees surveyed. Dots are individual trees and were mapped from a 1:8000 aerial photograph dated 19/2/91.

observed at once. Incidental observations of the use of hollows of both marked and adjacent unmarked trees were recorded whilst traversing the site.

Stagwatching (Smith *et al.* 1989) was the technique used to survey the trees for arboreal mammals or bats. This technique involved sitting near the base of a tree at dusk with the tree silhouetted against the western horizon, so that emerging animals could be seen. During the period of fieldwork only eight nights were suitable for stagwatching and 22 trees (18 river red gums and four black box) were observed. Stagwatching began just prior to dusk (see Smith *et al.* 1989) and continued for up to 45 minutes, or until it was too dark to discern emerging animals. Since only one tree or several trees in a close group could be observed each night, a volunteer was used on several occasions to increase the sample size. Heavy cloud on the western horizon hindered observations on three nights. Incidental observations of bats heard calling from trees were also recorded.

RESULTS

The mean number of hollows per tree for river red gums and black box was 5.5 (±3.7) and 4.2 (±2.3) respectively (Table 1). All trees had at least one hollow (Figure 3), although river red gums had a larger range of hollows with one to 18 per tree, compared with one to 10 in black box. River red gums were also larger with an average DBH of 103.7 (±47.7) cm, while black box had an average DBH of 72.8 (±24.8) cm (Table 1). A significant positive relationship existed between the number of hollows per tree and the DBH for river red gum ($r = 0.65$, $p < 0.0001$, d.f. = 62) and black box trees ($r = 0.64$, $p < 0.001$, d.f. = 20) (Figure 4a,b), which would account for the river red gums having a higher mean number of hollows per tree, and a greater range of hollows.

Rates of occupancy of hollows by birds in each species of tree were similar (t-test; $t = 0.95$, $p < 0.005$, d.f. = 85), (Table 1). However, as indicated above the river red gums were on average larger than the black box trees and therefore potentially provide a larger range of hollow types. To eliminate this bias and to make a more accurate comparison of rates of occupancy, only trees between 50 cm and 100 cm DBH were compared. Again there was no significant difference between rates of occupancy for river red gums and back box trees of this size (t-test; $t = 0.33$, $p < 0.005$, d.f. = 85) (Table 1). On this basis the results of occupancy by birds of each tree species were combined. Sample sizes for occupancy of black box trees were too small to determine if individual birds had a preference for a particular tree species.

Of the 61 recorded nests, Red-rumped Parrots *Psephotus haematonotus*, Common Starlings *Sturnus vulgaris* and Tree Martins *Cecropsis nigricans* accounted for 85% (Table 2). The birds readily shared trees although Red-rumped Parrots did not share with conspecific parrots, and only three antagonistic interactions were observed. Other species incidentally recorded nesting at the study site, but not in the transects, were Peregrine Falcons *Falco peregrinus* (one pair), Australian Kestrels *Falco cenchroides* (two pairs) and Australian Shelducks *Tadorna tadornoides* (one pair). Three species of obligate hollow nesters which were commonly observed in the area were not recorded using the dead trees. Forty-nine percent of the trees and 13% of potential hollows were occupied, with a total of 61 nests in 42 trees. Figure 5 shows the number of nesting pairs per tree ranging from zero to four with the majority of occupied trees containing only one nesting pair.

Bats were observed leaving a roost site (in a river red gum) on only one occasion. Three bats were observed emerging from this roost over a period of

Table 1. The DBH, number of hollows and occupancy rate for river red gums and black box trees at Disher Creek.

Tree Species	n	DBH (cm)			No. of Hollows per Tree			Occupancy Rate*	
		mean	s.d.	range	mean	s.d	range	mean	s.d
river red gum	64	104	48	36–247	5.7	3.7	1–18	0.132	0.18
black box	22	73	25	39–130	4.2	2.3	1–10	0.097	0.14

*Proportion of hollows used by birds in each tree.

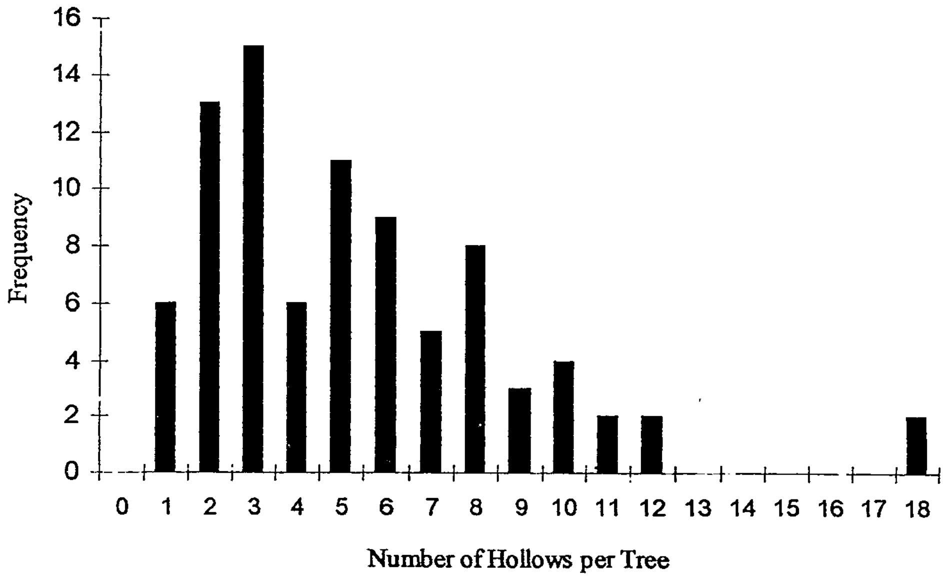

Figure 3. Frequency distribution of number of hollows per tree.

nine minutes. These bats were heard before they were seen to emerge, and bats were also incidentally heard in three other river red gums and two black box trees. No arboreal mammals were observed during stagwatching and no evidence (e.g. scats) of these mammals was observed at any other time.

DISCUSSION

Tree hollows were defined as any opening in the trunk or branch which could possibly be used by breeding birds or roosting mammals, and were counted from the ground. This method may result in some inaccurate assessments since some openings visible from the ground may not lead to hollows (see Calder *et al.* 1983) and/or entrances to some hollows may not be visible from the ground. Ambrose (1982) also observed that a lot of hollows remained totally unused and there are important selection criteria used by animals when choosing hollows (e.g. entrance dimensions, internal dimensions, interactions with conspecific animals; see Saunders *et al.* 1982). The number of suitable hollows may therefore be considerably less than the total count. This is recognised as a limitation of the study.

Newton John (1992) recorded 530 hollows in 158 live river red gum trees, with 44% of trees having hollows. All river red gums at the Disher Creek site contained hollows including those trees smaller than 50 cm DBH (Figure 4a). The average numbers of hollows per tree for both river red gum and black box trees at Outlet Creek were less than half the averages obtained in my study area (Oldroyd *et al.* 1994). Oldroyd *et al.* (1994) used similar techniques for assessing hollow numbers. It appears that more hollows are available at Disher Creek than other areas from which data are available. The obvious difference between Disher Creek and the other sites is that all the trees are dead. There is also a significant relationship between the number of hollows and the size of the tree for both river red gum and black box trees at Disher Creek. This is comparable to Oldroyd *et al.* (1994), and to Newton John's (1992) study where DBH provided a reasonable index of numbers of hollows. However, individual trees are unlikely to conform to predictions (Newton John 1992), and this is evident at Disher Creek where the loss of branches through branch shedding clearly reduced the number of hollows in trees. Also several trees consisted only of a completely hollowed trunk. Similarly Bennet *et al.* (1994) found that stem diameter and tree species were significant predictors of the total number of holes in a tree, but there was considerable variation in the number of holes between trees of similar diameter. They also found that, for a given increment in diameter, tree species had a different

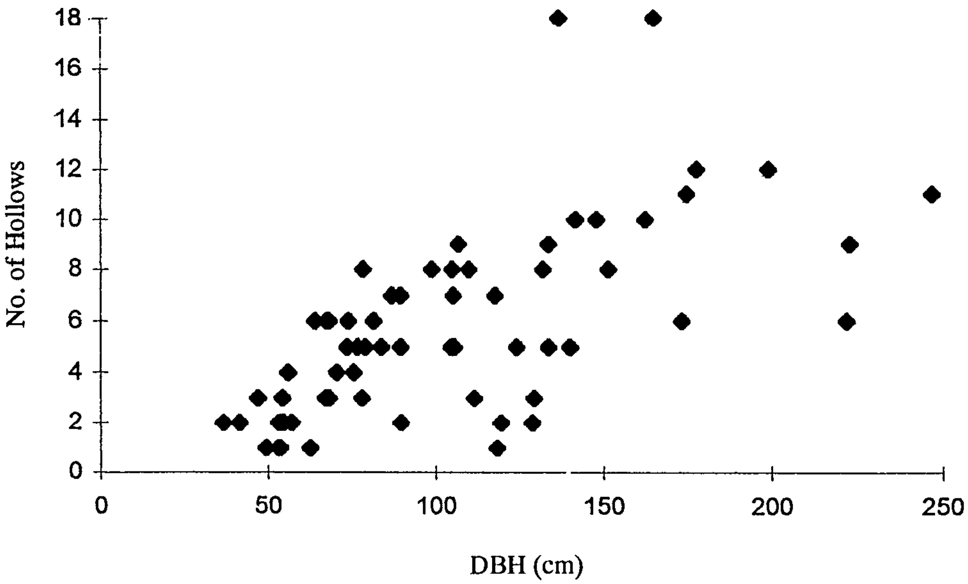

Figure 4a. Diameter at breast height (DBH) versus number of hollows for river red gums (*E. camaldulensis*) at Disher Creek. ($y = 0.52 + 0.05x$; $r = 0.65$)

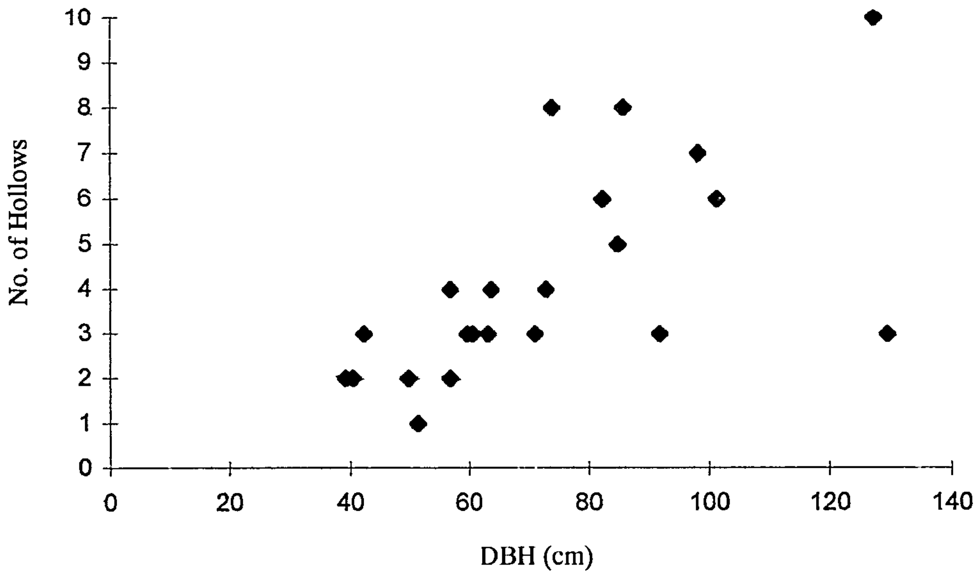

Figure 4b. Diameter at breast height (DBH) versus number of hollows for black box (*E. largiflorens*) at Disher Creek. ($y = -0.1 + 0.06x$; $r = 0.644$)

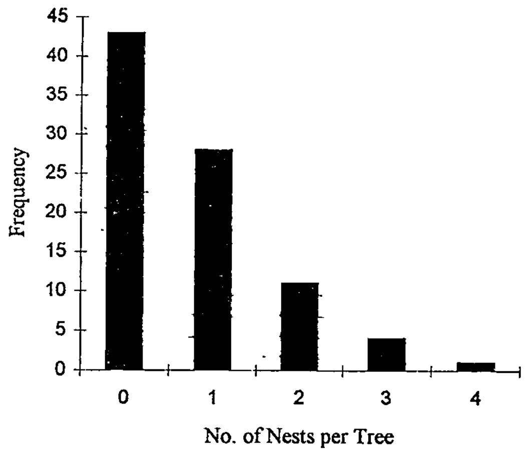

Figure 5. Frequency of the number of nests per dead tree at Disher Creek.

Table 2. The bird species recorderd nesting, and the number of nests and trees occupied by each species.

Species	Nests	Trees	%
Red-rumped Parrot	21	21	34
Tree Martin	18	17	30
Common Starling	13	13	21
Welcome Swallow	3	3	5
House Sparrow	3	3	5
Southern Whiteface	2	2	3
Brown Treecreeper	1	1	2
Totals	**61**	**42**	**100**

increase in the number of holes. For example, black box typically supported a larger number of holes for a given diameter, and had a greater rate of increase in the number of holes. By comparison river red gum had the fewest holes for a similar diameter, but achieved a greater diameter at maturity (Bennet *et al.* 1994). This is reflected at Disher Creek in the higher mean number of hollows per tree in river red gums and a greater range of hollow numbers compared to black box (Table 1).

The Use of Hollows by Birds

The use of the hollows at Disher Creek was dominated by three bird species, and four other species accounted for only 15% of all nests (Table 2). All of the species recorded nesting in hollows along transects are widespread and common species. The presence of Common Starlings is of concern and detracts from the value of the study site. Fortunately the number of hollows apparently available in this area would suggest that Common Starlings would not be competing with native species for nest sites. All species were also observed nearby in healthy vegetation and their breeding was not confined to the dead trees at the study site (pers. obs.).

Australian Kestrels, Australian Shelducks and Peregrine Falcons were also observed nesting at the study site. None of these birds are endangered, although the Peregrine Falcons are noteworthy as they are considered rare in South Australia (Garnett 1992). Evaporation basins often have a resident pair of Peregrines (Harper pers. comm.) and Pruett-Jones *et al.* (1981) recorded 18% of observed Peregrine Falcon nests in hollows. Of these 70% were in river red gums, as was the case with the nest at Disher Creek. These birds need consideration in the future management of this site. The presence of this species at the study site may have limited the number and types of birds nesting in the area.

The data on occupancy were collected over five weeks during one breeding season and may not represent total occupancy for a season. However, the observation effort was considered sufficient to record all hollow use at the time. Ninety percent of the birds observed using hollows were recorded within the first 50% of the total observation time, and all observed use of hollows was recorded within the first 67% of total observation time, which indicates that it is unlikely that nests were missed.

Forty-nine percent of the trees were occupied by birds but only 13% (61 of 458) of the available hollows were occupied. These results are difficult to interpret as there are no data in the literature for comparison, although the occupancy of hollows appears low. This may simply indicate that the number of hollows actually suitable were only a fraction of the total number counted. Alternatively, the degraded nature of the study site could account for this apparently low figure. I would suggest that a combination of these two factors is likely to have contributed to the results. Results from an isolated block of salmon gums in the Western Australian wheat-belt (Saunders *et al.* 1982) showed that 47% of hollows of a suitable size for cockatoos were occupied, however, all hollows smaller than 9 cm deep and 9 cm across the entrance were not considered. Saunders *et al.* (1982) concluded that this occupancy represents near capacity for the cockatoo species occurring in the area. Although a number of the remaining hollows were probably suitable, several factors, including conspecific interactions, made them unavailable, and must be taken into account when considering data on the occupancy of hollows at Disher Creek. Unlike the study site used by Saunders *et al.* (1982), Disher Creek is situated in a relatively large area of continuous woodland which should alleviate the pressures associated with small isolated remnants. Despite consideration of these factors, the overall occupancy rate of only 13% obtained in this study seems low and suggests that hollows were not a limiting resource for hollow nesting birds at Disher Creek in the spring of 1992.

The few antagonistic interactions observed support this, as only two interspecific interactions (between a Common Starling and a Red-rumped Parrot, and between a House Sparrow and a Tree Martin) and one intraspecific interaction (between two male Red-rumped Parrots) were observed. During his study Ambrose (1982) observed antagonistic behaviour within each fortnight of the year between all recorded species (nearly two-thirds of encounters involved at least one introduced individual), although disputes were particularly evident during the early parts of the breeding season when establishment of possession of hollows occurs. If hollows were limiting at Disher Creek then it would be expected that more antagonistic interactions would have been observed.

Other factors are therefore likely to be limiting the use of this site by hollow frequenting birds, with the lack of shelter and an adequate food source being two obvious constraints. The altered hydrological regime has influenced the plants that are able to survive, thereby altering the vegetation community considerably. Dead trees provide little shade or shelter and this is likely to have discouraged some birds from using the site for nesting. A whole array of potential food resources are also absent from dead trees. The ground layer is also considerably more open than in areas with healthy vegetation and the birds which feed within this stratum may be exposed to predation from birds such as the peregrines, as well as cats and foxes. Observations of three obligate hollow nesters provide an interesting case in point. Regent Parrots *Polytelis anthopeplus*, Crimson Rosellas *Platycercus elegans* and Galahs *Eolophus roseicapillus* were rarely recorded in the dead trees although they were common in the surrounding areas of healthy vegetation (pers. obs.). Only one flock of five Regent Parrots was observed to fly over the study site, although they were common nearby and were observed inspecting hollows there. A flock of at least 30 Regent Parrots was observed feeding on baldoo within nearby healthy black box trees at Disher Creek. Regent Parrots rarely nest away from water, and one third of nests are known to occur in dead trees (Beardsell 1983; Burbidge 1985). However, these parrots were not observed to use the area of dead trees at the study site in any way. The same situation existed with Galahs and Crimson Rosellas, which were common in the area, but were not recorded using the dead trees. The dead trees were obviously not attractive to these obligate hollow nesters, probably for the reasons outlined above, but it also suggests that within this area hollows are not a limiting resource.

The Use of Hollows by Mammals

The data obtained on bats is limited and therefore also difficult to interpret. Bats were recorded in both species of tree which is consistent with previous studies which have indicated that the species and age of a tree is unlikely to be significant to bats (Tidemann and Flavel 1987; Taylor and Savva 1988). Research has shown that bats show fidelity to a roost area rather than individual roosts or hollows. Most bats have several roosts within a small area (Fenton 1983; Taylor and Savva 1988; Lunney *et al.* 1988). This would indicate that the number of roosts (hollows) used over a period of time by bats may be higher than the presence of bats in six trees suggests. So the dead trees may provide an important resource for these animals. However, relative to the use of hollows by birds, bats increase the overall occupancy of trees and hollows minimally.

Not surprisingly, no arboreal mammals were recorded in the dead trees. The lack of resources, in particular a foraging substrate, is an obvious explanation for the absence of these animals.

Management Implications

Recher (1991) points out that forest management for wildlife affected by logging has maintained an emphasis on the retention of mature and senescent trees ('habitat trees') for fauna dependent on tree hollows for nesting or roosting. For similar reasons wildlife managers in North America place emphasis on retaining 'snags' (Davis *et al.* 1983), or stags as they are known in Australia. The impact of logging on fauna dependent on hollows is very real (Lindenmayer *et al.* 1990b, 1990c, 1991; Milledge *et al.* 1991). However, as Recher (1991) points out, there are many resources other than hollows which are required by birds. Nest sites, nesting materials, a variety of foraging substrates and suitable types of prey and food are all necessary resources and different birds have a wide range of requirements (Recher 1991). Disher Creek is devoid of many of the other resources required by birds and mammals for existence. This is reflected in both the low occupancy of hollows and in the absence of obligate hollow dependent fauna. Studies in North America have shown that other factors will influence populations dependent on hollows (e.g. Brawn and Balda 1988 – interspecific and intraspecific influences; Rendell and Robertson 1989 – intraspecific territoriality; Waters et al. 1990 – availability of food, winter mortality and territorial behaviour; see also Sedgwick and Knopf 1986). In Australia studies on cockatoos have shown the effects of conspecific interactions (e.g. Saunders *et al.* 1982). Although hollows are becoming a critically limiting resource in some areas, the assumption that animals are always limited by the availability of nest/roost sites may not be justified. Disher Creek appears to provide an example of this. I would suggest that the relatively continuous woodland associated with the upper reaches of the Murray River in South Australia still provides adequate hollows, and that the low occupancy rate of hollows at Disher Creek indicates that there is reduced demand for hollows in degraded sites such as this.

ACKNOWLEDGMENTS

This project was undertaken as a six month honours study. I am grateful to Janice White and Bob Baldock for supervising this project, and to Janice White and David Paton for their advice and comments on the manuscript. The comments of an anonymous referee are gratefully acknowledged. Roger Clay and Bob Huxtable are gratefully acknowledged for statistical guidance. Mike Harper, Tim Fraser and the staff at the South Australian NPWS Murraylands office in Berri are gratefully acknowledged for their logistical support during fieldwork, as are Marcel Cardillo and Mark Mobbs for help with data collection. The Department of Environment and Natural Resources, Kangaroo Island, is acknowledged for granting study leave to initiate the production of this manuscript.

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Jody Adam Gates: University of South Australia, School of Human and Environmental Science, Smith Road, Salisbury East, S.A. 5109

Present address: Department of Environment and Natural Resources, Flinders Chase National Park, PMB 246, Kingscote, S.A. 5223

Received: 10 November 1995