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Roosting behaviour of radio-tracked Tasmanian Masked Owls *Tyto novaehollandiae castanops*

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Abstract. Roost-sites and roosting behaviour are described for a juvenile female, an adult female and an adult male Tasmanian Masked Owl *Tyto novaehollandiae castanops* in a forest–farmland landscape. The two female Owls were radio-tracked, and frequently used roost-sites in the core area of use. Roost-sites were typically associated with small watercourses, on the edges of large contiguous forest patches within a complex mosaic of forest and pasture. The juvenile Owl used many different vegetation roost-sites after dispersing from her presumed natal territory. In contrast, the adult female used few roosts, including two vegetation roosts and one tree-hollow, and only one roost (a tree-hollow) was located for the adult male. The primary tree-hollow roost-sites of the male and female Owls were <400 m apart and were both <1200 m from a suspected nest-tree. This strongly suggests that the spatial proximity of nest- and roost-sites may be critical to facilitate territorial, foraging and reproductive behaviours of breeding pairs. Increased knowledge of spatial ecology and utilisation of tree-hollows by adult Tasmanian Masked Owls is crucial for their conservation.

Introduction

The Tasmanian Masked Owl *Tyto novaehollandiae castanops* is currently listed as Endangered under the Tasmanian *Threatened Species Protection Act 1995*. Major threats are considered to be habitat loss from urbanisation, agriculture, and forestry (Bell *et al.* 1997). Recent intensification of the agricultural industry in Tasmania, including the development of several new irrigation schemes in the last decade, has also resulted in the loss of forest remnants and paddock trees. In addition to the ongoing loss of important habitat for the Tasmanian Masked Owl, a substantial number of mortalities are attributed to anthropogenic activities such as use of rodenticides, collisions with cars, and electrocutions (Mooney 1993; Bell & Mooney 2002).

The Tasmanian Masked Owl is widely distributed throughout its range, and inhabits a variety of forest and habitat types including unmodified native forests, production forestry zones and agricultural and urban areas (Bell & Mooney 2002). However, little is known of finer-scale distribution patterns and habitat associations because of its cryptic nocturnal behaviour, large home-ranges (Young *et al.* 2020) and low abundance (Bell *et al.* 1997). Current efforts to manage important nesting and roosting habitat for this taxon are focused primarily on retaining mature forest patches that contain moderate numbers of large tree-hollows, but few data exist to enable specific management actions to be targeted in particular areas. The Tasmanian Masked Owl is strictly dependent on hollows for nesting, requiring large spacious hollows in mature eucalypts that are typically several centuries old (Mooney 1997), although various roost types are used, including tree-hollows, small caves in cliffs, dense foliage in riparian zones and, far less frequently, anthropogenic structures such as barns, buildings or sheds (Bell *et al*. 1997; Bell & Mooney 2002; Young *et al.* 2020). This implies that individual Owls can be relatively flexible when selecting a roost-site, but this may also reflect a lack of tree-hollows, which are typically preferred roosting sites, in particular landscapes (Young *et al.* 2020).

Although several ecological studies have been conducted in recent decades (e.g. Bell *et al.* 1997; Mooney 1997; Todd 2012; Young *et al.* 2020), knowledge of important roosting habitat and use of roost-sites in Tasmania is extremely limited and is based on observations at a relatively small number of roost-sites that are widely distributed throughout the state. Radio-telemetry provided us with a unique opportunity to investigate this important, little known, ecological aspect. Our study describes characteristics of roost-sites and roosting behaviour of two (one juvenile and one adult) radio-tracked female Tasmanian Masked Owls in a modified agricultural landscape. An additional roost-site used by an adult male (the mate of the radio-tracked adult female) is also described.

Study area

The study area is in the Huon Valley, ~20 km south-west of Hobart, Tasmania, in a rural landscape comprising a mosaic of modified forest, pasture and orchards. The topography is diverse and relief is moderate to steep, with altitude 15–90 m above sea level. The study area is located in a large river valley basin fringed by the peaks of the Wellington Range, and bordered to the north and east by the Mount Wellington Reserve. It is dissected by several watercourses of varying size. Mean annual rainfall is 750–1500 mm and the mean annual temperature range is 5–17°C.

Methods and analysis of data

The roost-sites described here are based on data from two radio-tracked female Owls that were sexed from morphometric measurements and weights. Tasmanian

Table 1. Parameters of roost-sites for a juvenile female, an adult female and an adult maleTasmanian Masked Owl, Huon Valley, Tasmania: tree species, type and height of roost above ground, characteristics of roost-tree and of forest patch where roost was located. Roost type: H = tree-hollow, V = vegetation roost; roost-tree: DBHob = diameter at breast height over bark; NA = not available. Tree species used as roosts: Scented Paperbark *Melaleuca squarrosa*, Stringybark *Eucalyptus obliqua*, Dogwood *Pomaderris apetala* and Silver Wattle *Acacia dealbata*.

Roost no.	*Tree species*	*Roost*		*Roost-tree*			*Forest patch*		
		Type	*Height (m)*	*DBHob (cm)*	*Height (m)*	*Distance to watercourse (m)*	*Distance to forest edge (m)*	*Size (ha)*	*Canopy cover (%)*
Juvenile female									
1	Scented Paperbark	V	4.6	4	6.4	202	27	30–50	10–50
2	Stringybark	H	8.4	106	29.8	500	13	10–20	10–50
3	Stringybark	V	NA	114	27.5	390	50	10–20	10–50
4	Dogwood	V	3.8	11	4.4	8	55	10–20	5-20
5	NA	V				5	52	10–20	50–70
6	NA	V				32	670	>100	10–50
7	NA	V				10	255	>100	10–50
8	Silver Wattle	V	13.6	39	17.7	14	100	10–20	5–20
9	NA	V				10	115	>100	10–50
10	NA	V				45	70	0–10	5–20
Adult female									
1	Stringybark	H	7.3	135	33.8	6	14	50–100	10–50
2	NA	V				10	21	10–20	10–50
3	Dogwood	V	4.6	12	5.1	1	110	50–100	10–50
Adult male									
1	Stringybark	H	14.1	155	24.1	31	47	>100	50–70

Masked Owls have extreme reverse sexual dimorphism (males are considerably smaller than females), allowing relatively reliable assignment of gender based on size (Higgins 1999). The age of the birds was estimated primarily from their behaviour. The juvenile was considered to be on the cusp of independence because of its incessant vocalising typical of food-begging by juveniles. The male was sexed from differences in size and vocalising behaviour compared with the female, and the proximity of his roost-site to that of his mate.

Information on the home-range and broad habitat utilisation of the same two radio-tracked female Tasmanian Masked Owls are described in Young *et al.* (2020). The present paper focuses primarily on descriptions of roost-sites, with particular emphasis on utilisation of tree-hollows and associated behaviours by the breeding pair.

Diurnal roost-sites were located to within 50–100 m during the day by radio-telemetry, or by direct observations, and were visited more closely when the Owls were absent. They were confirmed by evidence such as whitewash and regurgitated pellets typical of Masked Owls. The height and aspect of some roost-sites could not be determined because of inaccessible terrain or the potential to disturb the Owl. The spatial location and altitude of roost-sites were obtained using a hand-held Garmin GPS, and the dominant vegetation within a 30 m × 30 m quadrat of each roost-site was described to species level. The roost-tree was identified to species level, and the status of the tree was recorded as 'living' or 'dead'. Roost type was recorded as 'vegetation' or 'tree-hollow', and the heights of the roost and of the roost-tree were measured using a clinometer. Size of forest patch, percentage of canopy cover, and height of surrounding forest were estimated from photographic interpretation forest mapping layers (Forestry Tasmania 2006).

Diameter at breast height over bark (DBHob) of roost-trees was calculated from measurements of circumference to the nearest centimetre. Distances to the nearest watercourse and to the forest edge were measured from aerial photographs of the study area. Watercourse class was classified according to the Forest Practices Code (Forest Practices Authority 2005). The dimensions of the roost-hollow used frequently by the adult female were measured to the nearest centimetre when she was absent and the tree could be climbed. Parameters of roost-sites were analysed with Oriana Version 2.2 (Kovach 2003), and associations between ambient moonlight and time of egress from roost, and between time of return to roost and sunrise were analysed with one way Analysis of Variance.

Results

Juvenile female

Ten roost-sites were recorded within the home-range for the juvenile female (Table 1). One was in a tree-hollow

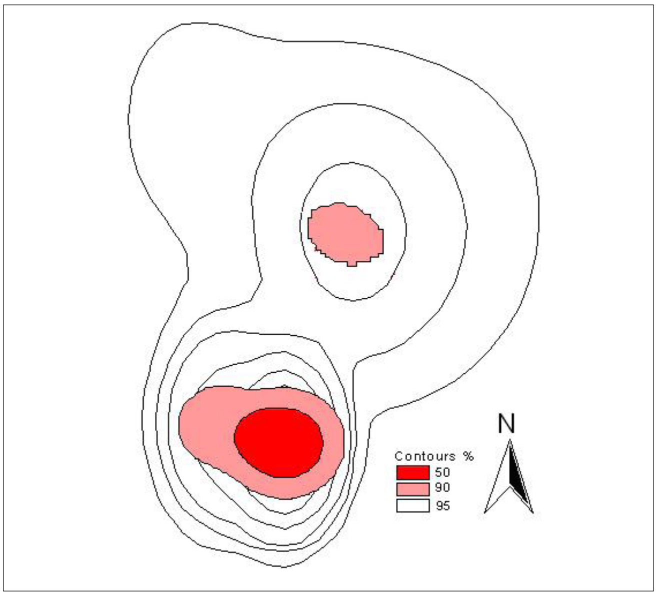

Figure 1. Kernel estimator probability contours of combined roost-sites and radio-tracked locations for a juvenile female Tasmanian Masked Owl. Note the primary core area (50% contours/darker red-shaded area) of usage at the southern end of the home-range (main roost-site and foraging locations).

(limb spout in a dead tree) and three were in living vegetation. The remainder were not visited because of inaccessible terrain so measurements were conducted remotely where possible. The frequently used vegetation roost-site and adjacent foraging area were in the core area of usage (Figure 1). Within the home-range, roost-sites of this juvenile were generally located towards the valley floor and mid slope in relatively small patches of forest. Only a single roost-site was located in the top third of the valley slope. Aspect of the slope of vegetation roost-sites tended to be easterly although this may reflect the location of the home-range in general. Half of the roost-sites were located in forest patches of 10–20 ha despite forest patches of this size accounting for only 7% of the Minimum Convex Polygon home-range area. Three roost-sites were in forest patches >100 ha in size, one was in a forest patch of 0–10 ha and one in a patch of 30–50 ha.

Seven of the ten roost-sites for this Owl were vegetation roost-sites in riparian forest <50 m from a Class 4 watercourse. The single tree-hollow roost was the furthest from a watercourse (500 m). Mean distance from a roost-site to the forest edge was 140.7 m ± 198.1 m standard deviation and to a watercourse was 121.6 ± 182.1 m. The maximum distance between roosts was ~7.5 km and the minimum ~250 m. Tree species used for roosting were Scented Paperbark *Melaleuca squarrosa*, Stringybark *Eucalyptus obliqua*, Dogwood *Pomaderris apetala* and Silver Wattle *Acacia dealbata*, all of which were common within the study area, indicating that locally abundant tree species were utilised.

The juvenile was observed roosting on numerous occasions in the foliage of small trees and always roosted in the top third of the tree, regardless of the tree's height. The most frequently used roost-site was at the southern end of the home-range and was near (200 m) a small river in a dense stand of Scented Paperbark, on the edge of a patch of mixed-age Stringybark forest. It was 800 m

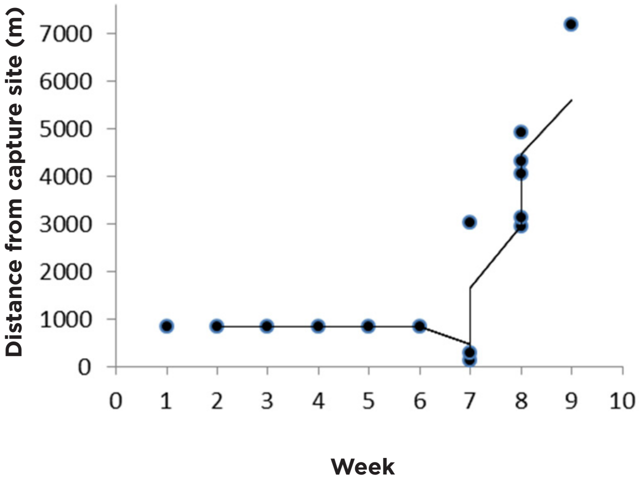

Figure 2. Distance of diurnal roost-sites from the trapping site (and possible post-fledging area) for a juvenile Tasmanian Masked Owl from Weeks 1–9. Note high fidelity at the main roost for the first 7 weeks of radio-tracking and subsequent dispersal behaviour at Week 7 following an interaction with another Masked Owl (possible parent or resident) at her main roost-site.

from her main foraging area, which might also have been the location of the parental nest-tree. After an interaction with another (unknown but possible parent or resident) Tasmanian Masked Owl at this roost-site (DY pers. obs.), the radio-tagged juvenile dispersed from this area on the following night and did not return. Following this interaction, her home-range size increased dramatically and nine different roost-sites were used in the following weeks. Each vegetation roost-site was used for only 1–3 days before the Owl moved to another roost-site (Figure 2).

Adult female

Three roost-sites were recorded for the adult female and all were located in the core of the home-range (Table 1, Figure 3). The main roost was in a tree-hollow (trunk-hollow) and the other two were in dense vegetation. Roost-sites were on the eastern flanks of the home-range and in the middle to lower third of the valley slope. The aspect of the slope at roost-sites was consistently to the west but this may reflect the general location of the home-range rather than a preference for this aspect. The main roost-site used was ~2.46 km from the most frequently used foraging area, indicating that large distances were travelled to forage.

Roost-sites were generally situated in riparian ecotones adjacent to Class 4 watercourses. However, the main tree-hollow roost-site was considerably different spatially and structurally from the vegetation roost-sites. It was situated on the edge of a patch of mature/old-growth Stringybark forest with low stem density and a sparse, open, mid-canopy structure. Vegetation was particularly sparse surrounding this roost-tree and was absent within 6 m of the entrance to the hollow. This roost-site was a trunk-hollow 7.3 m up in a living Stringybark (DBHob 135 cm). The entrance to the hollow was 42 cm high × 24 cm wide. The internal dimensions were 33 cm deep to the floor of the hollow from the entrance, and 80 cm wide inside from front to back.

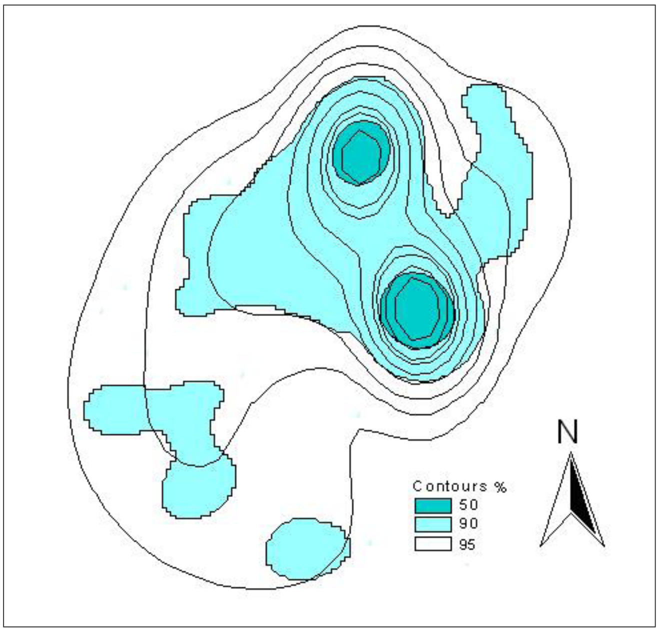

Figure 3. Kernel estimator probability contours of combined roost-sites and radio-tracked locations for an adult female Tasmanian Masked Owl. Note the two core areas of usage (50% contours/darker-blue-shaded areas) within the home-range (centre: primary core area = roost-sites; top: secondary core area = foraging sites).

The two vegetation roost-sites recorded were in dense riparian vegetation and were used only after vacating the hollow roost as a result of unintentional disturbance near the tree by the landowner in a tractor whilst slashing vegetation. The Owl subsequently returned to the main tree-hollow after 3 nights and resumed her normal roosting behaviour. DY notified the landowner of the roost-site location and she was not disturbed thereafter. The Owl continued to use only this main roost-site.

The main roost-tree was located 6 m from a Class 4 watercourse on the edge of a relatively large contiguous forest patch of 62 ha. One vegetation roost-site was located in a patch of 50–100 ha and one in a patch of 10–20 ha. Forest surrounding the three roost-sites was broadly mapped as mature-regrowth and old-growth, medium-density Stringybark forest (Forestry Tasmania 2006). Mean distance from roost-site to forest edge was 48.3 ± 53.5 m and to a watercourse was 5.6 ± 4.5 m. Tree species used for roosting were Stringybark and Dogwood, which were locally abundant.

The distance between the roost-sites of the adult female and the male (breeding pair) was only 377 m, and these roosts were ~865 m and 1150 m, respectively, from the nest-tree. The male's roost-hollow was further into the forest from the edge, had a higher overstorey stem density and a slightly smaller entrance-hole than the female's roost-hollow.

Male's roost-site

Only one roost-site (a trunk-hollow) was located for the male. This was used every day throughout the entire study period until breeding commenced, when an alternative roost was used but could not be located (Table 1). The male's roost-site was located on the eastern flank of the valley (near the female's roost-site) and towards the middle of the valley slope. The roost-tree was in a relatively large patch (>100 ha) of contiguous mature Stringybark forest and was adjacent to a minor drainage line. The tree-hollow used was 14.1 m above ground in an old-growth (DBHob 155 cm) living Stringybark. The roost-site was in a similar broad-scale spatial location to that of the adult female and was near the centre of a large mosaic comprised of forest, agricultural land and pasture.

Breeding

A spring–summer breeding attempt was recorded for this pair. The nest-tree was located by radio-tracking the female in early spring when she did not return to her main tree-hollow roost-site. The presumed nest-tree was a large, senescent, living Stringybark that contained a large oval-shaped hollow (considerably larger than the roost-hollow entrance) towards the top third of the tree. The tree was situated at the edge of a 30–50-ha patch of low-density Stringybark forest in the centre of the estimated home-range. It was adjacent to a small drainage line that did not hold permanent water and had been extensively cleared of vegetation in recent years. Vegetation surrounding the nest-tree, and the hollow, was extremely sparse and drier than round the roost-trees. Measurements of the nest-tree were not taken because access was denied by the landowner after notification of the nest on their property. It is estimated (DY) that the tree was at least 30+ m tall and was of a similar DBHob to the roost-trees (i.e. >100 cm). The nest-hollow was ~25 m above ground, based on other measurements taken in the field.

Behaviour

Typical loud screeches (similar to those of adult females: see Todd *et al.* 2017 for detailed descriptions of Tasmanian Masked Owl vocalisations) by the juvenile were heard at the roost-site at dusk and dawn. The juvenile was also particularly vocal (incessant begging calls) at the forest patch adjacent to the roost-site frequented during nocturnal hours. Reasons for the frequent use of this forest patch by the juvenile are unknown but it was most likely a post-fledging area. This patch of forest is likely to have contained the nest-tree because there were abundant large hollows there and other Masked Owls were observed in the vicinity.

Vocalising by the adult female (typical loud screech) was frequent during the study period, particularly before breeding, at the roost-site at dusk and dawn. Vocalisations by the male were also frequent (from near his roost-site) and could be heard when DY was at the female's roost-site. The adults made frequent calls (presumably contact calls) to each other every night at dusk and each call was replied to immediately by the other member of the pair. There was a distinct difference in the pitch of the calls between the female and male. Following the contact calls, the male usually flew to the vicinity of the female's roost-site and both birds then travelled down the small valley adjacent to the roost-sites, presumably to commence foraging. Very few calls were heard after the Owls left the roost area. The adults always returned to their roost-sites at dawn, closely retracing the route taken after leaving their roost-sites the previous night. This behaviour suggests that the Owls have detailed knowledge of the geography of their home-range.

Courtship behaviour by the male (circular flights above the canopy, chattering and calling behaviour) ~500 m from the roost-sites was seen or heard before nesting. When presumed nesting commenced in the following weeks, the female did not return to her main tree-hollow roost-site one morning and moved to a large tree-hollow (in the centre of the home-range) and did not call at dusk or leave this hollow to forage as far as we are aware. The male also moved from his main tree-hollow to another roost-site, which was not located. During nesting, vocalisations by both birds ceased and the behaviour of the male became extremely cryptic and he did not vocalise any more. The only evidence that this presumed nest-tree was occupied was the presence of whitewash and a few feathers from a Tasmanian Native-hen *Tribonyx mortierii* at the base of the tree. No regurgitated pellets were found. This presumed breeding attempt might have failed because after 5 weeks of using this hollow the female emerged to forage one night (indicated by radio-tracking) and resumed her normal roosting behaviour at her main roost-site. She did not return to the presumed nest-hollow whilst radio-tracked over the next 5 nights, suggesting that the nesting attempt failed (e.g. eggs did not hatch or female did not tend to the chicks).

Egress from roost

Throughout this study, both female Owls habitually left their diurnal roost-sites at the onset of complete darkness (20–40 minutes after sunset), and returned at first light (20–40 minutes before sunrise) regardless of day length. Intensity of ambient moonlight did not affect time of egress from roost by either Owl (juvenile : $H = 1.99$, $P > 0.05$; adult : $H = 2.54$, $P > 0.05$).

Discussion

Despite the small sample size, this study provides insights into the previously undescribed roost-site ecology of the Tasmanian Masked Owl. The results suggest that geomorphology, watercourses and size of forest patch may influence the broad-scale selection of roost-sites within the landscape. Structurally diverse, mature riparian forests with abundant tree-hollows appear to be important habitat factors in the selection of roost-sites at a finer scale. The two radio-tagged Owls (one juvenile female, one adult female) used a variety of fragmented habitats for roosting and had more than one roost-site within their home-ranges. However, both birds had one particular roost that was preferred as it was used most frequently. More importantly, both adults (one female and one male, a breeding pair) in this study used tree-hollows as their primary roost-sites, as has also been reported for Southern Masked Owls *T. n. novaehollandiae* in New South Wales and Victoria (e.g. Kavanagh & Murray 1996; McNabb *et al.* 2003; Bilney & L'Hotellier 2013). Moreover, these studies and several others support our results that a complex combination of abiotic and biotic factors influence roost-site selection by forest owls in general (e.g. Kavanagh & Murray 1996; Cooke *et al.* 2002; McNabb *et al.* 2003; Fitzsimons 2010; L'Hotellier & Bilney 2016).

Following an interaction with another female Tasmanian Masked Owl at her 'preferred' roost-site, the juvenile did not return to this roost-site and suddenly increased ranging behaviour and number of roost-sites following dispersal from her presumed natal territory/post-fledging area. This is likely the first documented evidence of dispersal behaviour by a juvenile Tasmanian Masked Owl. Kavanagh *et al.* (2009) recently reported an enormous dispersal distance (~80 km) for a radio-tracked male Southern Masked Owl in New South Wales that eventually settled in a home-range of 3000 ha. McNabb & McNabb (2011) reported similar findings for a subadult Powerful Owl *Ninox strenua* in Victoria that suddenly greatly increased home-range size and number of roost-sites following dispersal from the natal territory. These combined observations strongly suggest that these behaviours may be typical of dispersing juvenile forest owls. At the end of our study period, the juvenile had a higher number of roost-sites and the home-range was slightly larger than that of the adult female.

Thermoregulation, avoidance of sunlight, and reduced exposure to aggressive mobbing from other birds are increasingly reported as important factors underlying the selection of 'microhabitats' for roosting by forest owls (Barrows 1981; Cook *et al*. 2002; Hendrichsen *et al.* 2006). The present study supports these findings: roost-sites used by the Tasmanian Masked Owls were typically located in riparian habitats with a distinct microhabitat provided by the topography, canopy cover and proximity to a watercourse. These site attributes in particular have been demonstrated to reduce ambient temperatures and wind speeds, and to contribute to regulating other climatic variables (Barrows 1981). However, on mainland Australia, Southern Masked Owls are consistently reported to roost in tree-hollows in forested areas away from riparian zones (McNabb *et al*. 2003; Bilney & L'Hotellier 2013). In the present study, some tree-hollow roosts were considerably further away from the nearest watercourse than were vegetation roosts, which suggests that preferred tree-hollow roost-sites (and nest-sites) are influenced more by the spatial distribution and availability of suitable hollows than by the habitat surrounding the tree. However, in some cases owls are able to select both, and can acquire a tree-hollow within desirable habitat.

The two radio-tagged Owls in the present study typically moved from the vicinity of the diurnal roost-site within 1 hour of sunset and roost emergence. McNabb *et al*. (2003) reported a significant correlation between moonlight and roost egress, though no such association was found in our study. Indeed, on several occasions, the radio-tagged Owls left the diurnal roost-site on a bright night with a full moon shortly after sunset, but before complete darkness, and were observed gliding over DY en route to presumably forage. This suggests that factors other than moonlight intensity (such as wind, rain and appetite) may contribute and/or regulate roost egress.

Tree species used frequently for roosting by the radio-tagged Owls were all common in the study area, indicating that locally abundant species with suitable structural properties are utilised most often as roost-sites. At vegetation roost-sites in the present study, the perch heights compared with tree height were similar to those reported for Powerful Owls by Cooke *et al.* (2002): Powerful Owls also always roosted in the top third of the tree when using a small shrub/tree regardless of the tree height, suggesting that canopy cover and branch structure are important criteria for the position of roost-sites in canopies of small trees. Cooke *et al.* (2002) also reported a negative correlation between temperature and roost height, implying that thermoregulation is extremely important in roost-site selection. For example, with increasing temperature, Powerful Owls roosted lower in smaller trees. Further evidence of thermoregulatory properties of roost-sites is also provided by Barrows (1981), who reported that Spotted Owls *Strix occidentalis* selected roost-sites in habitats with a dense canopy cover on north-facing slopes that were 1–6°C cooler than more-open sites. He concluded that variations in roost-site habitat selection were indicative of a behavioural adaptation to heat stress in summer.

Conservation of Tasmanian Masked Owls

We found that diurnal roost-sites were in the primary core area of use by the radio-tracked Tasmanian Masked Owls and were generally situated within riparian forest ecotones. The tree-hollows used were in large trunk-hollows in old-growth trees. Roosting behaviour suggests that Tasmanian Masked Owls (especially adults) prefer tree-hollow roost-sites and only use less desirable alternatives (e.g. vegetation roosts) when needed. Likely reasons for the use of vegetation roost-sites may be that suitable tree-hollows are not locally available or that a hollow has not yet been acquired. The adult female and male (breeding pair) in this study both regularly used tree-hollow roost-sites in close proximity to each other, which strongly suggests that a suitable tree-hollow for each member of a breeding pair may be a prerequisite for the establishment and fidelity of a territory by a breeding pair. The spatial distribution and proximities of suitable roost-sites may be critical to facilitate behaviours such as communication, territorial defence and reproduction of breeding pairs. If the roost-hollows used by the male and female are interrelated within a territory, then disturbance or loss of a single tree-hollow roost-site could have significant consequences for the integrity of an entire territory and the breeding pair. Thus, additional data on the proximity and spatial configuration of tree-hollow roosts of breeding pairs is recommended to explore the interrelatedness of roost-sites and to improve conservation approaches for this taxon.

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