# Habitat use of a critically-endangered species in a predator-free but degraded reserve in Australia

Authors: Winnard, Amy L., Di Stefano, Julian, and Coulson, Graeme

**Original article**

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**Amy L. Winnard, Julian Di Stefano & Graeme Coulson**

The success of species reintroduction programmes depends on many factors, including habitat quality and predator occurrence at release locations. For the critically endangered eastern barred bandicoot *Perameles gunnii* in Australia, successful releases have been achieved only in the absence of predation by the introduced red fox *Vulpes vulpes*. However, few fox-free sites exist, but those that are fox free may have low habitat suitability, potentially leading to reintroduction failure. We studied a reintroduced population of eastern barred bandicoots at Mt Rothwell, a 420-ha fox-free reserve which appeared to have a degraded foraging range and a lack of nesting material due to overgrazing by marsupial herbivores. We quantified habitat use and measured several variables representing movement distances and nest use. Bandicoots foraged in open grassy areas and nested at sites containing high values of litter, lateral cover and concealment cover. Mean (± SE) home ranges (37.2 ha ± 11.8), daily movement distances (494.6 m ± 32.5) and distances between consecutive nests (122.6 m ± 29.0) were large for males. On average, the length of stay at each nest (2.8 days ± 0.4) was longer than previously recorded values for males, and 13.2% of the nests were used by at least two individuals, suggesting that nesting opportunities were limited. Despite behaviour indicating a low resource base, bandicoots appeared to be surviving and reproducing in our study area, indicating a capacity to live in structurally simple habitat in the absence of predators. Our results are consistent with predator exclusion being a critical factor for successful bandicoot reintroduction.

*Amy L. Winnard & Graeme Coulson, Zoology Department, The University of Melbourne, Vic 3010, Australia - e-mail addresses: amy.winnard@unimelb.edu.au (Amy L. Winnard); gcoulson@unimelb.edu.au (Graeme Coulson)*
*Julian Di Stefano, Department of Forest and Ecosystem Science, 4 Water Street, Creswick, Vic 3363, Australia - e-mail: juliands@unimelb.edu.au*

*Corresponding author: Amy L. Winnard*

Reintroduction programmes for threatened species play an important role in their conservation and aim to reestablish viable, free-ranging populations of endangered species within their historical range, through the release of wild or captive-bred individuals, following extirpation or extinction in the wild (IUCN 1998). They are necessary due to processes such as habitat destruction and predation by introduced species that have already led to the extinction of many species worldwide (Diamond 1989), and threaten many other species as well. Habitat loss due, for example, to deforestation and urbanisation, threatens more terrestrial species than any other process (Kingsford et al. 2009). Similarly, introduced predators can have large effects on native prey populations, and have been associated with species declines and extinctions (Salo et al. 2007, Hilton & Cuthbert 2010, Medina et al. 2011). In Australia, introduced red foxes *Vulpes vulpes* and cats *Felis catus* are thought to have contributed to extinctions of many species of small to medium sized mammals over the last 200 years (Dickman 1996).

The eastern barred bandicoot *Perameles gunnii*

is a small (< 1 kg) insectivorous marsupial that has declined to near extinction since European colonisation (Backhouse & Crosthwaite 1996). It is listed as critically endangered in Victoria, Australia (Victorian Department of Sustainability and Environment 2007), a status that is due to both habitat loss and predation by the introduced red fox (Winnard & Coulson 2008). As a consequence, the eastern barred bandicoot has been the subject of several reintroduction programmes, one of which was sited at Mt Rothwell, a 420-ha grassy woodland reserve surrounded by a predator-barrier fence (Winnard & Coulson 2008). At the time of initial release in 2004, the reserve was free of all introduced predators (red foxes and cats), and the bandicoot foraging areas contained > 74% grass cover (Ferguson 2006). Since then, the reserve has been overgrazed by macropods (i.e. eastern grey kangaroo *Macropus giganteus* and Tasmanian pademelon *Thylogale billardierii*). As bandicoots forage in grasslands (Heinsohn 1966), and typically use grass in the construction of nests (Ferguson 2006), overgrazing of these areas might represent a substantial reduction in habitat quality, leading to the ultimate failure of the reintroduction programme (Griffith et al. 1989).

The aim of our study was to quantify how a previously released population of eastern barred bandicoots behaved at Mt Rothwell, a predator free but apparently degraded reserve. We expected bandicoots to select open, grassy foraging locations and structurally complex nesting sites, as past work has demonstrated strong selection for foraging and nesting habitat with these characteristics (Heinsohn 1966, Quin 1985, Hocking 1990, Dufty 1991, 1994b, Mallick et al. 1997, Ferguson 2006). On the basis of theory predicting an inverse relationship between resource availability and movement distances (Harestad & Bunnell 1979, Pusenius & Viitala 1993, Mosnier et al. 2008, Hansen et al. 2009), we expected home-range size and daily movements to be relatively large. In addition, foraging in the absence of predators may be focused on maximising nutrient intake (Ripple & Beschta 2007), promoting relatively large, risk-free movements in search of higher quality forage (Yunger 2004), resulting in large home ranges. We also expected bandicoots to use the same nest for longer periods than seen elsewhere, and for the distance between consecutive nests to be large, reflecting a low availability of nesting resources.

## Methods

### Study site

Mt Rothwell is a 420-ha reserve situated 60 km southwest of Melbourne, Victoria, Australia, at the base of the You Yangs Ranges (37°54'S, 144°26'E). It is surrounded by a predator-barrier fence and contains a variety of mammals including the eastern barred bandicoot, southern brown bandicoot *Isoodon obesulus*, long-nosed potoroo *Potorous tridactylus*, rufous bettong *Aepyprymnus rufescens*, Tasmanian pademelon, eastern grey kangaroo, swamp wallaby *Wallabia bicolor,* common brushtail possum *Trichosurus vulpecula* and eastern quoll *Dasyurus viverrinus*. The main potential predators are diurnal raptors such as wedge-tailed eagles *Aquila audax*. The reserve is divided into two zones, i.e. Zone 1 (170 ha) and Zone 3 (250 ha), by a 400-m internal fence (Fig. 1). Bandicoots can move between the two zones via 30 PVC tubes, which had been placed at the base of the fence six months prior to our study. The habitat in Zone 1 is classified as grassy woodlands and has been heavily grazed by eastern grey kangaroos and Tasmanian pademelons, resulting in very little grass cover. The most common tree species in Zone 1 are yellow box *Eucalyptus melliodora* and red box *E. polyanthemos*, with hedge wattle *Acacia paradoxa* dominating the shrub layer and spear
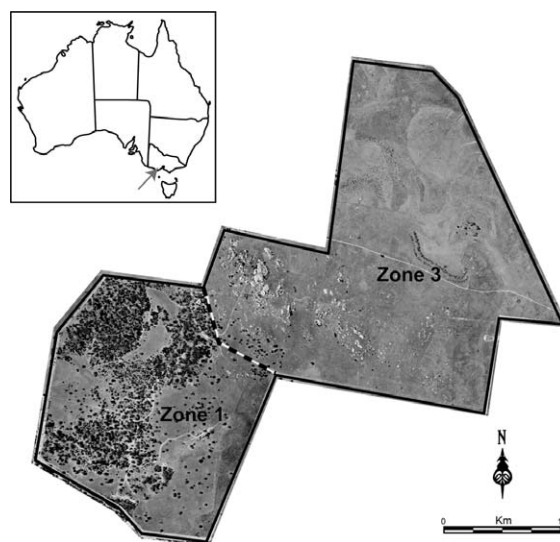


Figure 1. Mt Rothwell showing the areas of woodland (darker areas) and grassland (paler areas). The boundary line indicates the predator-barrier fence, whilst the dashed line between Zone 1 and 3 indicates the internal fence, which allows access by small mammals into each zone. Aerial photograph supplied by the Department of Sustainability and Environment.

grasses *Stipa* spp. the most common ground cover. Zone 3 is an open grassland with basaltic stony rises. Grazing pressure is less in this zone due to fewer herbivores being present, but grass cover and height is still low. This zone is dominated by spear grasses *Austrostipa* spp., and there is a patchy distribution of black wattle *A. mearnsii*, golden wattle *A. pycnantha* and hedge wattle.

### Trapping

We trapped for 14 days over a three-week period during autumn (April-May) 2009 using 50 x 18 x 20-cm (length x width x height) wire cage traps baited with peanut butter, honey and rolled oats. We placed 75 traps on two grids covering ~ 1 ha each in areas where we had observed an eastern barred bandicoot whilst spotlighting. We changed the location of both grids daily and checked traps at night between 22:00 and 24:00 and again in the morning from 07:00. Once an eastern barred bandicoot was caught, we attached a 4-g radio-transmitter to its tail with Fixomull stretch tape. Transmitters were single-stage tail-mount transmitters with a pulse rate of 40 minutes$^{-1}$ (Sirtrack Ltd, New Zealand), which took $\leq 2$ minutes to attach. This technique was chosen over others (e.g. collars) due to difficulties encountered in previous studies with short attachment periods and high injury rates (Murphy & Serena 1993).

We trapped nine adult eastern barred bandicoots (two females and seven males) in 1,050 trap nights. This low capture rate was due to a very high by-capture rate (48.4%, N = 508 non-target species), particularly of rufous bettongs, and trap interference from these other species. We caught another two male eastern barred bandicoots opportunistically by hand.

### Radio-tracking

From the time of capture, we tracked each bandicoot once during its active (night) and once during its inactive (day) period every 24 hours, using a Communications Specialists Inc. R-1000 telemetry receiver and a Yagi AY/C antenna. At night, we used a 50-W spotlight to locate tagged bandicoots. In > 75% of cases, we could approach on foot within $\leq 10$ m of a bandicoot before it fled. We then marked the location with a tent peg and recorded it using a handheld GPS unit (Garmin GPS60). We tracked each individual at different times every night so as to obtain an approximately even distribution of locations throughout this period. During the day, we marked nest sites with a tent peg, which we placed approx-

imately 20 cm from the nest so that we did not disturb the bandicoot; we then recorded the location as before. Radio-transmitters remained attached for 7-33 days, resulting in a range of 5-47 locations for males and 12-25 locations for females. In total, we obtained 140 nest locations, 102 foraging locations and 12 trap locations.

### Habitat assessment

We conducted a habitat assessment within circular plots, with a radius of 10 m, centred on each nesting and foraging location. We did not quantify habitat at occupied nest sites or at trapping locations. Within each plot, we made a visual estimate of the percentage (to the nearest 5%) cover of grass in two height categories (< 15 cm and > 15 cm; the approximate height of an eastern barred bandicoot), woody debris (twigs and sticks), litter (leaf and grass) and bare ground. We then measured the distance to the nearest cover (defined as any structure that could conceal an eastern barred bandicoot, such as trees, logs or hedge wattle). Using a Fujifilm FinePix S5500 digital camera, we took photographs of a 25 x 15-cm (approximate dimensions of an eastern barred bandicoot) cover board at each cardinal direction, 10 m from the centre of the plot, and a fifth photograph vertically from the centre of the plot to determine projective foliage cover (PFC). We analysed these images in Adobe Photoshop CS by counting the number of vegetation and cover board pixels (or sky pixels for PFC), then calculating the percentage lateral cover and PFC.

### Data analysis

We used a generalised linear mixed model (GLMM) with a logit-link to quantify the influence of habitat characteristics on bandicoot activity (foraging or nesting), specifying bandicoot identity as a random effect. We limited the final set of predictor variables to grass cover, lateral cover, litter cover and concealment cover as these variables represented habitat attributes expected *a priori* to be important for both foraging and nesting activities, and had low to moderate correlations (r between -0.18 and 0.63). For modelling purposes, we represented grass cover as the sum of the < 15 cm and > 15 cm grass values, as there was very little of the latter, and transformed the originally continuous concealment cover data to binary form (present, absent) as the raw data contained many zeros. Three of the other variables we measured (PFC, bare ground and debris cover) were highly correlated (r $\geq 0.70$) with one of the four

predictors in the final set. We ran the models in the R statistical environment (R Core Team 2013) using the lme4 package (Bates et al. 2013).

We used the four predictor variables to build a set of 34 competing models. These included all possible additive models, and all possible models including interactions between the categorical concealment cover variable and the three continuous variables. We ranked the models from best to worst using Akaike's information criterion (AIC) and calculated Akaike weights ($w_i$) to quantify the probability of each model being the best in the set (Burnham & Anderson 2002). We assessed the fit of the top-ranked models by calculating both marginal (fixed effects only) and conditional (full model) $r^2$ using the method of Nakagawa & Schielzeth (2013).

We calculated duration of nest use by dividing the total number of days that we tracked each bandicoot by the total number of nests that individual occupied. We calculated the percentage of nests reused over the study period for each bandicoot, including only nests that were reoccupied after a bandicoot had moved to another nest. We used Ranges 7 to calculate the distance between nests used on consecutive days.

We estimated home-range areas using minimum convex polygons (MCP) with 95% isopleths and harmonic means, and kernel contours (KL) with 95% isopleths. We used MCP only for comparison with other studies (Heinsohn 1966, Dufty 1994b, Jenkins 1998), acknowledging that this method is sensitive to the sample size of fixes and to outliers, and provides no indication of intensity of use within the range (Carter et al. 2012). For the kernel based analysis, we chose 0.75 as the smoothing factor multiplier for comparison with Ferguson (2006). In addition, we quantified the maximum distance travelled in each 24-hour period, representing the daily distance each bandicoot travelled between its nesting and foraging location. Finally, we calculated range span, the greatest distance between locations of an individual. We generated all home-range and movement data in Ranges 7.

## Results

### Habitat use
Foraging sites had a higher percentage of grass cover in both height categories ($< 15$ and $> 15$ cm) and were further from cover than were nest sites (Table 1). Nest sites had a higher percentage of lateral cover, litter, woody debris and PFC than foraging sites (see

Table 1. Means of eastern barred bandicoot foraging and nesting habitat variables ± standard error at Mt Rothwell, Australia.

| Habitat variable | Foraging | Nesting |
|---|---|---|
| % lateral cover | 41.6 ± 2.4 | 64.6 ± 1.5 |
| % < 15 cm grass | 25.4 ± 1.3 | 14.3 ± 1.2 |
| % > 15 cm grass | 5.5 ± 0.5 | 3.1 ± 0.3 |
| % litter | 10.6 ± 1.2 | 27.5 ± 1.2 |
| % woody debris | 10.3 ± 1.2 | 19.3 ± 0.9 |
| % projected foliage cover | 7.8 ± 1.9 | 28.7 ± 2.7 |
| Distance to cover (m) | 15.3 ± 1.6 | 5.4 ± 1.3 |

Table 1). At all locations where bandicoots were found, most grass cover was low to the ground and ranged from 0 to 63% cover, with a mean ± SE of 23% ± 1. Bare ground was common at all locations and ranged from 15 to 90% cover with a mean of 38% ± 1. Despite the lack of grass cover at Mt Rothwell, bandicoots were utilising areas with abundant lateral cover, ranging from 6 to 99% with a mean of 55% ± 2 for foraging and nesting sites combined.

The top-ranked AIC model suggested that the contrast between foraging and nesting activity was best represented by an interaction between concealment cover and both grass and litter cover, and the additive effect of lateral cover (Table 2). The total variance explained by this model (conditional $r^2$; see Table 2) was 0.87, indicating a good fit. Estimates and associated P-values are shown in Table 3. In general, bandicoots foraged at open, grassy locations and nested at locations with high values of litter and lateral cover, and where concealment cover was

Table 2. Ranking of the best models that explain the contrast between eastern barred bandicoot foraging and nesting sites at Mt Rothwell based on Akaike's information criterion (AIC) values. ΔAIC represents the difference between models, and Akaike weights ($w_i$) are interpreted as the probability that the associated model is the best in the set. Marginal and conditional $r^2$ relate to the variance explained by the fixed effects and the full model (fixed plus random effects), respectively. Models with interactions also contain the main effects of the interacting variables. CC, Lit, Gr and Lat stand for concealment cover, litter cover, grass cover and lateral cover, respectively.

| Model | ΔAIC | $w_i$ | $r^2$ Marginal (conditional) |
|---|---|---|---|
| CC * Gr + CC * Lit + Lat | 0 | 0.40 | 0.82 (0.87) |
| CC * Gr + CC * Lit + CC * Lat | 0.7 | 0.28 | 0.78 (0.83) |
| CC * Gr + Lit + Lat | 2.1 | 0.14 | 0.70 (0.78) |
| CC * Lat + CC * Gr + Lit | 3.5 | 0.07 | 0.67 (0.75) |
| CC * Lit + CC * Gr | 6.1 | 0.02 | 0.77 (0.85) |
| CC + Lit + Lat | 6.2 | 0.02 | 0.67 (0.70) |
| CC + Lit + Lat + Gr | 6.6 | 0.02 | 0.66 (0.71) |

Table 3. Estimated effects for each habitat variable at Mt Rothwell associated with the top ranked model.

| Fixed effects | Estimate | SE | P |
|---|---|---|---|
| Intercept | 2.364 | 0.899 | < 0.01 |
| Concealment cover (present) | 4.599 | 3.053 | 0.13 |
| Litter | -0.068 | 0.021 | < 0.01 |
| Grass > 15 cm | 0.125 | 0.061 | 0.04 |
| Lateral cover | -0.030 | 0.011 | < 0.01 |
| Concealment cover * litter | -0.125 | 0.073 | 0.09 |
| Concealment cover * grass | -0.404 | 0.193 | 0.04 |

present (Fig. 2). However, grass and litter influenced bandicoot activity most strongly in the absence of concealment cover. When concealment cover was present, the probability of foraging was low (and that of nesting high) regardless of grass and litter abundance (see Fig. 2 A and B).

The low Akaike weight associated with the top-ranked model (0.40) indicated substantial model-selection uncertainty. The second best model (see Table 2) suggested the interaction between concealment cover and lateral cover (estimate ± SE: -0.05 ± 0.04, P = 0.22) might also have an important influence on bandicoot activity (Fig. 3). As was the case for grass and litter, lateral cover influenced bandicoot activity only in the absence of concealment cover, the presence of concealment cover being associated with low foraging/high nesting probabilities regardless of lateral cover.

## Nest use

We identified four different nest types in our study. The most common (53%) was constructed from leaf litter, level with the ground, highly cryptic and found in woodland areas, usually next to a tree or coarse woody debris. A second type constructed in the woodlands (11%) was a large mound next to coarse woody debris and made from leaf litter and soil; this was also cryptic but easily found when radio-tracking. In the open grasslands, 30% of nests were constructed by digging a shallow depression in the ground, filling it in with grass and piling a substantial amount of grass on top, although 6% of nests were covered with soil instead of grass. All grassland nests were level with the ground and cryptic, yet more easily located than leaf-litter nests due to the lack of grass at Mt Rothwell. Only 4% of nests were constructed under hedge wattle, and another 2% were under a pile of planks. These hedge-wattle and plank nests were located in the open grasslands, but it is not known what they were constructed of, as we could not find their exact location.

Of the 53 nests located, 49% were used on > 1 occasion. Some (13%) were known to have at least two different occupants at different times, and one had three known occupants. Overall, 64% of nests were located in woodlands and the remainder in grasslands. Woodland nests were used for 3.2 ± 0.4 (mean ± SE) days, whereas grassland nests were used for only 1.4 ± 0.2 days (t = 3.81, df = 42.7, P < 0.001). Males spent more consecutive days in a nest and reused more nests than the two females (Table 4).

## Home range

Mean home range (MCP and KL) of males was larger than the female home range (Table 5). Males
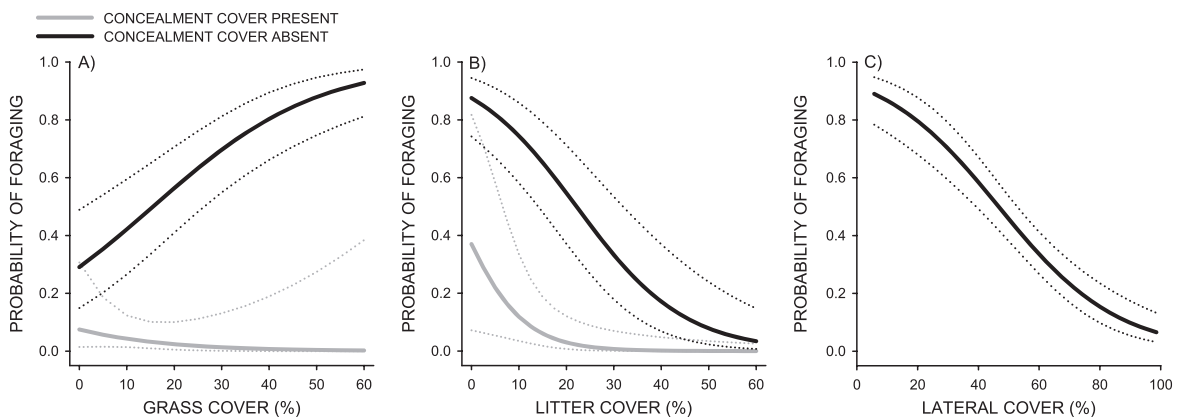


Figure 2. Graphical representation of the effects from the best model in Table 2. The first two graphs show how grass cover (A) and litter cover (B) influence the probability of eastern barred bandicoots foraging at Mt Rothwell when concealment cover is present (grey dashed line) and absent (black solid line). The third graph (C) shows how lateral cover influences the probability of foraging. The Y-axis represents a contrast between foraging and nesting, so smaller values indicate an increase in the probability of nesting. Dotted lines represent 95% confidence limits.

CONCEALMENT COVER PRESENT
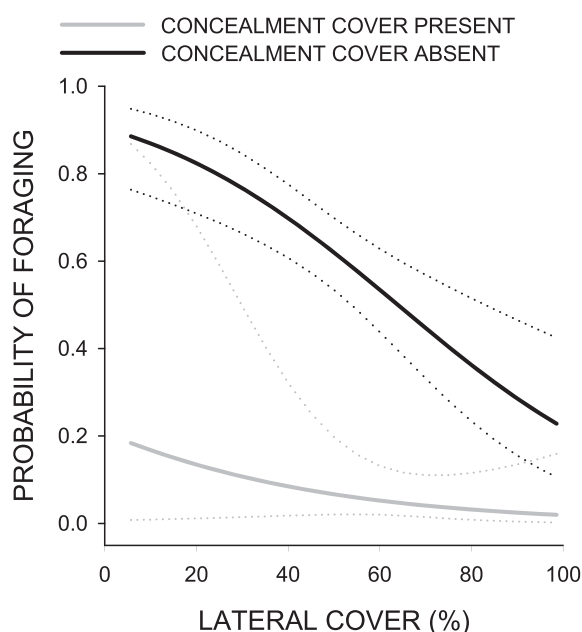CONCEALMENT COVER ABSENT

Figure 3. Graphical representation of the interaction between concealment cover and lateral cover at Mt Rothwell. The Y-axis represents a contrast between eastern barred bandicoot foraging and nesting, so smaller values indicate an increase in the probability of nesting. Dotted lines represent 95% confidence limits.

also travelled further from their nest to a forage site than the two females, and had range spans almost twice those of the two females (see Table 5). These differences observed between males and females should be interpreted with caution as female sample size was very small (N = 2).

## Discussion

Reintroduction is a valuable tool for the conservation of threatened species, and has been essential for reestablishing populations of the eastern barred

Table 4. Summary of nest use by male and female eastern barred bandicoots at Mt Rothwell. Means are ± standard error.

|  |  | Duration of nest use (days) | % nest reuse | Distance between consecutive nests (m) |
|---|---|---|---|---|
|  | Mean | 2.8 ± 0.4 | 17.9 ± 7.1 | 122.6 ± 29.0 |
| Male | Range | 1 - 4.3 | 0 - 50 | 0 - 1765.7 |
|  | N | 9 | 9 | 89 |
| Female | Mean | na | na | 125.2 ± 30.3 |
|  | Range | 1.5 - 2 | 0 - 28.6 | 0 - 403.1 |
|  | N | 2 | 2 | 15 |

bandicoot in southeastern Australia. The species has declined in the wild due to both habitat degradation and introduced predators (Backhouse et al. 1994, Winnard & Coulson 2008); thus, sites chosen for reintroductions must reduce these threatening processes sufficiently for reintroduced populations to persist (IUCN 1998, Seddon et al. 2012).

Mt Rothwell, the site of our study, differs from previous habitats in which eastern barred bandicoots have been studied (Jenkins 1998, Long et al. 2004) because overgrazing in recent years has left the area with sparse grass cover. Between 2005 (Ferguson 2006) and the time of our study in 2010, the grass cover at Mt Rothwell had declined by approximately 43%, apparently reducing the quality of foraging and nesting habitat resources. Studying the reintroduced population at this time provided the opportunity to quantify any behavioural responses to this state.

Previous studies found that bandicoots selected habitats with high ground cover and tall grass (i.e. grasslands) for foraging, and nested where structural complexity was greatest (i.e. woodlands), regardless of the presence of the main predator of eastern barred bandicoots, the introduced red fox (Heinsohn 1966, Quin 1985, Hocking 1990, Dufty 1991, 1994b,

Table 5. Home range, range span and maximum distance travelled in 24 hours by male and female eastern barred bandicoots at Mt Rothwell. Means are ± standard error. For male minimum convex polygons (MCP) and kernel contours (KL) home range and range span, one eastern barred bandicoot was omitted from calculations due to having a low number of locations (N = 5). His data were only used in the calculation of maximum distance travelled in 24 hours.

|  |  | Home range 95% MCP (ha) | Home range 95% KL (ha) | Distance b/w nest & forage site (m) | Range span (m) |
|---|---|---|---|---|---|
| Male | Mean | 24.2 ± 9.6 | 37.2 ± 11.8 | 494.6 ± 32.5 | 1045.2 ± 196.7 |
|  | Range | 1.6 - 85.5 | 3.5 - 106.8 | 49.3 - 1851.8 | 210.9 - 2117.6 |
|  | N | 8 | 8 | 185 | 8 |
| Female | Mean | na | na | 330.0 ± 44.0 | na |
|  | Range | 1.7 - 15.7 | 2.8 - 28.8 | 24.8 - 794.0 | 404.9 - 835.1 |
|  | N | 2 | 2 | 32 | 2 |

Mallick et al. 1997, Ferguson 2006). In general, our results are consistent with previous findings, reinforcing our understanding that eastern barred bandicoots require a mosaic of grassland and woodland habitat (see Law & Dickman 1998).

If habitat condition at Mt Rothwell were degraded, we expected bandicoots to use the same nest for relatively long periods and for the distance between consecutive nests to be extended. The distance between consecutive nests was larger in our study than reported at Mt Rothwell in 2005 by Ferguson (2006) for soft-released bandicoots 68.4 m ± 15.4 (± SE) and elsewhere by Jenkins (1998) 25 m ± 28 (± SD), suggesting that suitable nest sites or resources were indeed limited. Ferguson (2006) found that most nests were lined with grass, unlike our study where leaf litter was the most common nesting material. This change in nesting material shows a degree of behavioural flexibility and indicates that resources have declined. An important role of nests is to provide insulation and retard heat loss of the constructor or its offspring (Redman et al. 1999, Gedeon et al. 2010). A reduction in the preferred nesting material may reduce the capacity to do this, but additional research would be needed to determine whether nests of leaves provide poorer insulation. Nest type varied depending on their construction, with more cryptic nests found in areas that lacked structural complexity, as found in other studies (Heinsohn 1966, Dufty 1991, Murphy & Serena 1993).

Previous studies found that eastern barred bandicoots changed nest site every two days (Heinsohn 1966, Jenkins 1998, Ferguson 2006), which is slightly less than in our study. We found that 30% of nests were occupied for more than two consecutive days and for up to five days, but as radio-tracking did not occur on every day, the real figures may be higher. Again this is consistent with limited nest resources. Nest sharing (i.e. different bandicoots using the same nest on different days) has never been reported before for eastern barred bandicoots but has in another peramelid, the greater bilby *Macrotis lagotis* (Moseby & O'Donnell 2003). Eastern barred bandicoots are solitary, exhibit strict avoidance behaviour and aggressively defend foraging resources (Dufty 1994a) and nests (Heinsohn 1966, Jenkins 1998). Our finding suggests that nests were difficult to defend at Mt Rothwell, perhaps due to increased travel times from foraging areas. Limited nesting opportunities could force bandicoots to exploit undefended nests.

If habitat at Mt Rothwell were degraded, we also expected bandicoots to have larger home ranges and longer daily movements than typically observed. Male home range was larger than the ranges found in three other studies (Dufty 1994b, Jenkins 1998, Ferguson 2006) using MCP or kernel-based calculation techniques (Table 6) but similar to Heinsohn (1966), who calculated home ranges of Tasmanian bandicoots using trap data. Three males and one female in our study had home ranges larger than the maximum previously recorded for this species as well as the longest maximum distances travelled in 24 hours, which for one bandicoot was in excess of 1.5 km/night between foraging and nest sites. Longer distances have been recorded, but were dispersal movements over several weeks (Dufty 1991). These large home ranges and long movement distances indicate that resources were limited. A similar response has been found in North American porcu-

Table 6. Home ranges calculated in previous studies for male and female eastern barred bandicoots using Minimum Convex Polygons (MCP) or Kernel contours (KL).

| | | Heinsohn (1966) MCP ± SE (ha) | Dufty (1994b) MCP ± SE (ha) | Jenkins (1998) MCP ± SD (ha) | Ferguson (2006) KL ± SE (ha) |
|---|---|---|---|---|---|
| Location | | Tasmania | Hamilton, Victoria | Woodlands Historic Park, Victoria | Mt Rothwell, Victoria |
| Year(s) | | 1960 - 1962 | 1989 - 1990 | 1994 - 1996 | 2005 |
| Method | | Trapping | Trapping | Radio-tracking | Radio-tracking |
| Male | Mean | 26.3 ± 4.6 | 4.0 ± 0.6 | 4.9 ± 1.5 | 21.0 ± 7.4 |
| | Range | 18.7 - 39.7 | 0.8 - 9.0 | 1.9 - 6.4 | 6.2 - 32.5 |
| | N | 4 | 18 | 12 | 4 |
| Female | Mean | 3.2 ± 1.1 | 1.6 ± 0.4 | na | 8.1 ± 2.2 |
| | Range | 0.9 - 11.4 | 0.1 - 5.9 | | 0.1 - 20.2 |
| | N | 9 | 13 | | 8 |

pines *Erethizon dorsatum*, which can adjust to patchy distributions of preferred forage or roost trees and low availability of den sites by increasing home-range size in areas with low predation risk (Coltrane & Sinnott 2013). Furthermore, seven bandicoots foraged in the recently-accessible Zone 3 and nested in the Zone 1 Woodlands, suggesting that bandicoots were able to detect and respond to a previously unexploited area by expanding their home ranges. This behavioural response has also been seen in the southern brown bandicoot (Broughton & Dickman 1991).

In summary, the evidence for habitat degradation is mixed. Longer distances between consecutive nests, a change in nesting material, shared nest use, large male home ranges and long daily movement distances are all consistent with habitat degradation and show behavioural flexibility in this species. In contrast, the mean length of stay at a nest was longer than found in previous studies but not greatly different, and the habitat type chosen for foraging and nesting and an inverse relationship between cryptic nests and structural complexity are consistent with results of previous studies.

### Implications for future reintroductions

Despite some behavioural evidence for habitat degradation, eastern barred bandicoot abundance at Mt Rothwell appears to be relatively high, based on the number of sightings when spotlighting. These findings suggest a degree of behavioural flexibility in this species, and that introduced predator exclusion is a critical factor for successful reintroductions. This ability to cope with habitat alteration has also been seen in the greater bilby, in which successful reintroductions were more dependent on the strict control or removal of introduced predators, rather than habitat quality (Moseby & O'Donnell 2003). Quantifying the effects of habitat degradation on body condition and fecundity would increase our knowledge of how habitat quality affects individuals, but was not possible due to difficulties in trapping this species at Mt Rothwell.

Of the Victorian native grasslands and grassy woodlands in which this species formerly occurred, > 99% have disappeared (Backhouse et al. 1994). This makes the selection of release sites that are large ($\geq$ 400 ha), fox free and contain high quality habitat very difficult. Our findings suggest that habitats previously considered unsuitable due to a lack of structural complexity could support eastern barred bandicoots, provided they remain fox free. Despite this, it is clear that some minimum habitat state must be maintained at reintroduction sites, which for eastern barred bandicoots may involve the management of grazing species (Coulson 2001). More generally, threatened species reintroductions may be successful in the absence of high quality habitat if other major pressures are controlled. For species under threat from predation, understanding habitat-suitability thresholds at predator-free locations will be important for selecting appropriate reintroduction sites in the future.

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