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Home-range use by the brush-tailed phascogale (*Phascogale tapoatafa*) (Marsupialia) in high-quality, spatially limited habitat

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Abstract. Nine phascogales (7 females, 2 males) were radio-tracked between March and July 1999 to investigate the spatial organisation of this species in spatially limited habitat near Euroa, Victoria. In this area, approximately 3.6% of the original woodland vegetation remains after 150 years of agricultural clearing. Most wooded habitat is confined to narrow linear strips along roads and streams. However, these remnants are on fertile soils and, because they have not experienced intensive harvesting, the density of large old trees is over 10 times that found in nearby State Forests and Parks. Female phascogales were monitored for 13–38 days over periods of 5–15 weeks. The size of home ranges of females was 2.3–8.0 ha, and averaged 5.0 ha. This value is one-eighth the mean home-range size previously recorded for the species in contiguous forest in Victoria. All individuals used multiple nest trees, with nests generally located in trees >80 cm diameter at breast height. Although fragmented and spatially limited, the stands of large old trees on productive soils near Euroa provide a network of well connected, high-quality habitat for phascogales. The relatively dense population of phascogales in these remnants suggests that prior to agricultural clearing and timber harvesting, phascogales may have been much more common in Victoria than at present.

Introduction

The brush-tailed phascogale (*Phascogale tapoatafa*) is a small, arboreal carnivorous marsupial whose range includes dry, forested habitats in south-western, south-eastern and northern Australia (Cuttle 1983). Within Victoria, *Phascogale tapoatafa* (hereafter referred to as phascogales) formerly occupied forests and woodlands in a broad geographic band across central Victoria (Menkhorst 1995). These forested areas have undergone extensive agricultural clearing and fragmentation since European settlement, which has targeted the most productive soils and eliminated approximately half the former phascogale habitat (Woodgate and Black 1988; Menkhorst 1995; Robinson and Traill 1996). The remnant forests on poorer soils have suffered from mining, grazing, intensive logging and firewood collection, leading to forests currently dominated by small trees (Robinson and Traill 1996). Habitat loss and degradation are believed to have contributed to the phascogale's decline (Menkhorst 1995) and the species is now classified as Vulnerable in Victoria (NRE 1999).

Previous studies in Victoria have found that female phascogales forage over intrasexually exclusive home ranges averaging 41 ha in size (Traill and Coates 1993; Soderquist 1995). The average size of males' home ranges exceeds 100 ha, and males's home ranges overlap extensively with those of both females and other males. Population densities are typically low, with one female per 100 ha being common (Soderquist 1995). In many areas, populations are isolated by habitat fragmentation, making the species highly vulnerable to local extinction. The annual die-off of all males just after the mating season (Cuttle 1982) exacerbates this susceptibility (Traill and Coates 1993).

The use of space by animals can provide important conservation information about factors limiting a species. Female phascogales previously studied in contiguous forests in Victoria used home ranges that were twice the size predicted by allometric comparison with other carnivorous mammals (Lindstedt *et al.* 1986; Soderquist 1995). Use of such large ranges suggests that habitat quality was poor and that extensive foraging areas were required to sustain individuals during lactation. This interpretation is supported

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by the observation that most mortality of females occurs during the stressful lactational period (Soderquist 1993).

The requirement by phascogales for large areas suggests that populations would not be expected to survive in highly fragmented landscapes, such as in cleared farmland where remnant forest is restricted to linear roadside vegetation and small isolated fragments. However, if habitat quality or environmental productivity, which are major determinants of home-range size (Lindstedt *et al.* 1986), were greater than that in remnant contiguous forest, phascogales might successfully occupy smaller foraging areas.

Near Euroa in central Victoria (36°45′S, 145°30′E), a network of remnant roadside vegetation amongst cleared farmland was recently identified as sustaining a resident population of phascogales (R. van der Ree, unpublished). In this study, the spatial organisation of the phascogale population in the roadside network was investigated by radio-tracking. The objectives of the study were:

(1) to determine the size and shape of home ranges occupied by female phascogales using the spatially limited habitat;
(2) to determine the extent of female territoriality under a high-density population structure; and
(3) to ascertain the health, short-term survival and reproductive output of female phascogales in this roadside network.

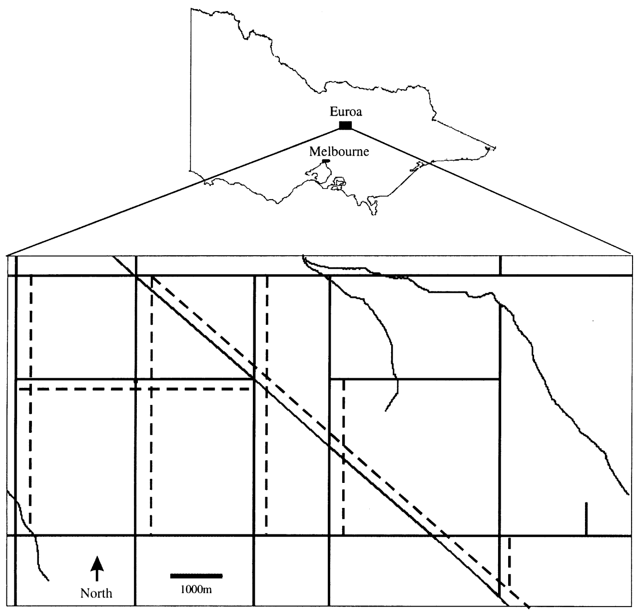

Fig. 1. The Euroa study area in north-eastern Victoria, with remnant woodland vegetation along roads and road reserves (solid straight lines) and along streamsides (solid wavy lines). The 27 km of linear habitat trapped for phascogales are indicated by dashed lines adjacent to linear habitats.

Study area

In the Northern Plains of Victoria, extensive clearing of temperate eucalypt woodlands for agriculture commenced in the late 1860s. It is estimated that in 1869, prior to large-scale clearing, 76% of the Northern Plains had woodland cover, with the remaining 24% being native grasslands (Woodgate and Black 1988). In 1993, there was less than 6% tree cover and almost all native grasslands had been eradicated (Bennett and Ford 1997). In addition to habitat loss, almost all remnant vegetation has been degraded to some extent by mining, timber harvesting, stock grazing, weed invasion, or soil degradation (Muir *et al.* 1995; Raven 1997; Bennett *et al.* 1998).

The Euroa floodplain lies in the south-east corner of the Northern Plains, and is bounded by the Goulburn River to the west and south, the Strathbogie Mountain Range to the east, and the Euroa–Violet Town Road to the north (*c.* 87 000 ha). Within this area, approximately 3.6% of the original woodland remains (van der Ree 2000). Of this woodland habitat, 83% occurs along roadsides, streams and drainage lines, forming an interconnected network of linear habitats that are typically 20–40 m in width. The remaining 17% of remnant woodland occurs in patches larger than 1 ha, mostly associated with wetlands. The natural vegetation is open grassy woodland and the dominant overstorey species is grey box (*Eucalyptus microcarpa*), with smaller proportions of red box (*E. polyanthemos*), yellow box (*E. melliodora*), red stringybark (*E. macrorhyncha*), yellow gum (*E. leucoxylon*), river red gum (*E. camaldulensis*) and Blakely's red gum (*E. blakelyi*). The midstorey is dominated by sparse shrubs, especially golden wattle (*Acacia pycnantha*) and lightwood (*A. implexa*), with a grassy and herbaceous understorey.

This study was undertaken in an area of 30 km^2 within the Euroa floodplain, approximately 10 km west of the town of Euroa (Fig.1). Here, remnant woodland along the roadsides and unused road reserves contains some of the best remaining examples of plains grassy woodland in the district. Assessment of 21.5 km of woodland along roadside and unused road reserves within the area trapped for phascogales (Fig. 1) indicated a high-quality habitat with a diverse age-structure of trees (van der Ree, unpublished data). The mean density of large trees [>70 cm diameter at breast height (DBH)] along 21.5 km of linear habitat was 22.0 ± 0.65 trees ha^{-1} (all variance is presented here as standard error of the mean unless otherwise noted). This value is much greater than the density of large trees estimated for nearby box–ironbark forests, which have a mean of 2 trees ha^{-1} of ≥60 cm DBH (NRE 1998). The mean number of hollow-bearing trees at Euroa, defined as the number of trees having holes visible from the ground without binoculars, was 20.7 ± 0.79 ha^{-1}.

Methods

Trapping and radio-tracking techniques

Phascogales were captured in large Elliott traps (48 cm by 15 cm by 16 cm) mounted on wooden brackets in trees at a height of 2–5 m. Traps were modified with a door-locking mechanism to prevent escape (Johnson 1996). They were baited with a mixture of peanut butter, rolled oats and honey, and a diluted honey and water mixture was sprayed liberally on the tree trunk from a height of 3 m above the trap to ground level. Traps were placed at intervals of approximately 200 m along 27 km of roadside and unused road reserve (Fig. 1). Trapping to capture animals for radio-telemetry was conducted between 30 March and 10 April 1999. In addition, trapping in the immediate vicinity of radio-collared animals was undertaken in late May–early June to monitor animal health, and in July and August to remove collars. Traps were checked at regular intervals during the night, at first light in the morning, and then again in the late afternoon. The condition of phascogales was gauged by the amount of somatic deposits along the caudal vertebrae, and the ages of the animals were determined using a combination of tooth wear and pouch development (Soderquist 1993; but see also Scarff *et al.* 1998).

All phascogales trapped were fitted with tuned-loop single-stage radio-transmitters with lightweight brass collars covered by heat-shrinkable plastic (Sirtrack, New Zealand), each weighing 4.0–4.5 g (<4.0% of body weight). Radio-tracking was undertaken on foot using a collapsible 3-element Yagi antenna (Titley Electronics, Ballina, New South Wales). Permanent reflective markers spaced 100 m apart were mounted on trees along linear habitats to identify locations. Once located, the position of a phascogale was determined by pacing to the nearest reflective marker. The accuracy of locations was high as the actual tree in which the animal was foraging or resting could usually be identified. Radio-tracking was undertaken for 4 days and 3 nights per fortnight between April and July. Up to four nocturnal 'fixes', spaced >2 h apart, were collected per animal on each night. Each phascogale was tracked to its nest tree during the day ('diurnal fixes').

Home-range analysis

There are numerous techniques for calculating and describing home-range characteristics (Kenward 1987; Harris *et al.* 1990; White and Garrott 1990). The spatial arrangement of habitat here (linear strips, with a clearly defined farmland matrix) precluded the use of commonly used techniques such as harmonic mean, convex polygons and kernel methods because 'ballooning isopleths' include areas of unused, cleared land within the home-range estimates (Andreassen *et al.* 1998). As a result, two estimates were used to describe spatial organisation: range length and a grid cell method (Kenward 1987; White and Garrott 1990). Both methods were calculated manually because of the linear nature and geometric arrangement of the habitat and the inability of computer packages to deal with such restrictions.

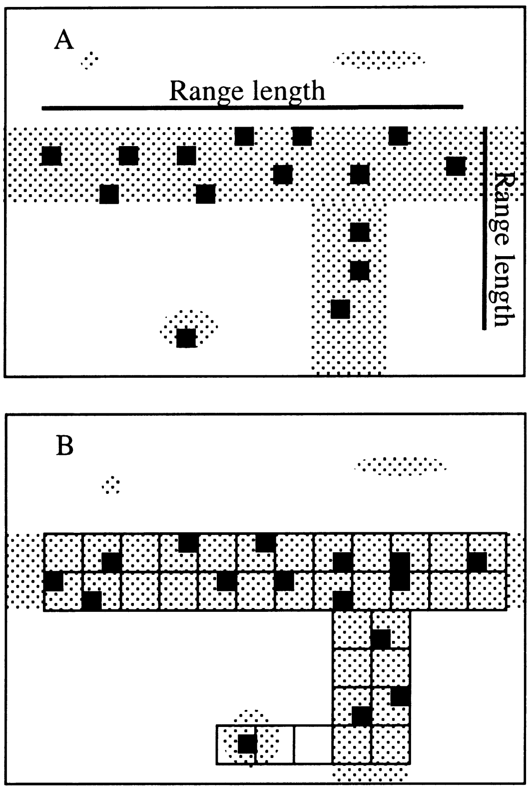

Fig. 2. Home range calculation techniques: (*A*) Range length is the sum of the two solid lines, and (*B*) home-range area is the sum of all grid cells. Solid squares denote hypothetical telemetry fixes, stippled areas are remnant woodland habitats and white represents cleared agricultural land.

Range length is a measure of the overall length of the home range (metres) and the grid cell method estimates home-range area (hectares). Range length is the distance over which the animal travelled during the study period (Fig. 2*a*). The grid cell method places animal locations into grid squares that overlay a habitat map of the area (Fig. 2*b*). The choice of grid cell size is arbitrary, and can have a major influence on over- or under-estimating home-range size (Macdonald *et al.* 1980). In this study, cell size was 20 m by 20 m, which corresponded with the level of accuracy of telemetry fixes (±10 m) as well as with the width of the narrowest linear habitats (20 m). In addition, various rules were applied to determine the treatment of unoccupied cells adjacent to, or between, occupied cells. Here, we assumed that any unoccupied cells between occupied cells must have been crossed, and that the entire width of the linear habitat (20 or 40 m) was utilised by the phascogale. When animals were located in woodland fragments within cleared agricultural land, we assumed they had travelled there via the shortest route from the nearest linear habitat. For both estimates, the influence of outlying fixes, or forays outside the normal home range, were reduced by manually deleting the 5% of fixes that were located at the ends of each range and contributed most to the estimate. The resulting measure was termed the '95% estimate', compared with that based on all radio-telemetry locations (100% estimate). Because short-term monitoring provides a conservative definition of home-range use, the total locations may be a more accurate description of long-term use.

The relationship between the size of home-range estimates and the number of fixes was determined by plotting cumulative home-range area against the number of consecutive independent fixes for all females tracked. This was not undertaken for the two males tracked because they disappeared from the study area and it is likely that their home ranges continued to increase in size.

Habitat assessment

Structural attributes of the vegetation were measured in linear habitats (21.5 km) and small woodland fragments occupied by phascogales. In linear habitats, all overstorey stems were identified to species and placed in one of the following size-class categories: <10 cm dbh, 11–30 cm, 31–70 cm, and >71 cm. All trees in fragments <1 ha in size were counted, and, in patches >1 ha, vegetation was sampled in 20 m by 50 m quadrats positioned randomly in each patch. The number of quadrats varied according to patch size: 1–2 ha, 2 quadrats; 2–4 ha, 3 quadrats; >4 ha, 4 quadrats. Data were converted to a value per hectare according to patch size. Isolated individual trees scattered within the cleared farmland were not assessed because they could not be converted to such a value.

Results

Trapping

The initial two weeks of trapping to fit radio-collars entailed 517 trap-nights and yielded 69 captures of five species of arboreal marsupial. Squirrel gliders (*Petaurus norfolcensis*) were the most commonly captured species (56 individuals), followed by phascogales (6), yellow-footed antechinuses (*Antechinus flavipes*) (3), common brushtail possums (*Trichosurus vulpecula*) (3) and common ringtail possums (*Pseudocheirus peregrinus*) (1). Additional trapping in local areas to check animal health and remove radio-collars yielded one new female and two male phascogales that were all fitted with radio-collars. Two sugar gliders (*Petaurus breviceps*) and 10 new squirrel gliders were also captured during this additional trapping.

Table 1. Radio-tracking details for seven female and two male phascogales in linear habitats near Euroa in 1999

The age of animals at commencement of the study is recorded as 1 (*c.* 9 months) or 2 (*c.* 21 months). A 'day' is midnight to midnight

Animal	Age	Tracking dates	Days tracked	Number of nest tree fixes	Number of nocturnal fixes	Total fixes
Female A	1	30.iii–11.vii	38	35	56	91
Female B	1	5.iv–24.vi	31	27	48	75
Female C	1	5.iv–11.vii	34	32	53	85
Female D	2	6.iv–11.vii	32	30	54	84
Female E	1	27.v–27.vi	13	13	16	29
Female F	2	30.iii–26.v	23	20	34	54
Female G	2	30.iii–25.v	20	17	31	48
Male H	1	26.v–21.vi	9	9	13	22
Male I	1	9.vi–10.vi	2	2	0	2

Home-range size and shape

Seven female phascogales were radio-tracked for 13–38 days from March to July (Table 1). The two males were radio-tracked for shorter periods before being lost due to their long-distance movements. Home ranges of all animals were spaced across the landscape throughout the network of linear habitat (Fig. 3). A total of 490 independent fixes was collected, and all locations were within remnant woodland habitat. However, cleared agricultural land was necessarily traversed by phascogales as they travelled between isolated woodland fragments within farmland. The longest distance of cleared ground traversed by individual females varied between 20 and 285 m.

Home-range area for female phascogales ranged between 2.25 and 7.96 ha (95% estimate) with a mean of 4.97 ± 0.79 ha (Table 2). The home-range area of males appeared to be much greater (>20 ha for Male H, 95% estimate), especially given that it is based on a limited sample. Excluding the most extreme 5% of locations, the range length for female phascogales averaged 1457 ± 251 m, and ranged between 665 and 2335 m (Table 2). The 95% range length for Male H was

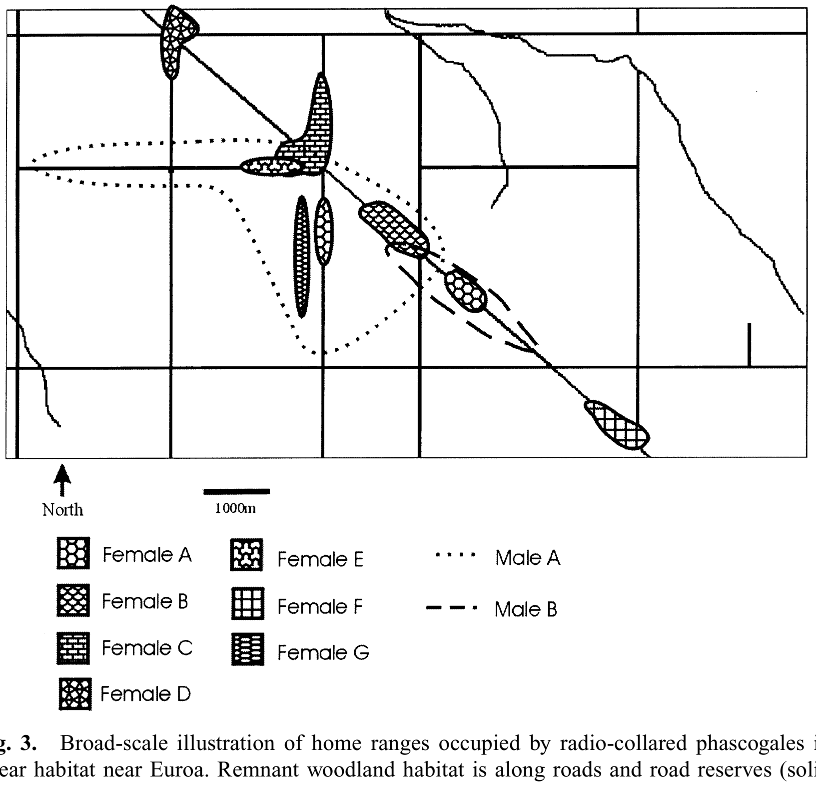

Fig. 3. Broad-scale illustration of home ranges occupied by radio-collared phascogales in linear habitat near Euroa. Remnant woodland habitat is along roads and road reserves (solid straight lines) and along streamsides (solid wavy lines).

Table 2. Summary of home-range estimates for phascogales radio-tracked near Euroa
Note that there are only two locations for Male I, and estimates must be interpreted cautiously

Animal	Home-range area (ha) 100%	Home-range area (ha) 95%	Home-range length (m) 100%	Home-range length (m) 95%
Female A	8.52	7.27	2670	2287
Female B	6.31	5.54	1185	1005
Female C	8.42	7.96	2455	2335
Female D	3.97	3.12	1425	1060
Female E	2.54	2.25	710	665
Female F	4.43	4.23	1115	1115
Female G	4.87	4.39	1735	1735
Male H	23.37	20.65	7810	7130
Male I	7.98	n.a.	1935	n.a.
Females: mean	5.58	4.97	1613	1457
s.e.	0.86	0.79	272	251

7130 m. Radio-tracking locations for each phascogale (except Male I, with just two locations) are shown in Fig. 4.

The influence of sampling effort on home-range estimates

As with many home-range calculations (White and Garrott 1990), an estimate derived using the grid cell method will often continue to increase incrementally as more locations are obtained. There was clearly a rapid increase in range size with the first 20 fixes for all individuals (Fig. 5). The rate of increase levelled off for 3 of 4 individuals at approximately 50–60 fixes, suggesting that sufficient locations were obtained for most phascogales to provide an accurate estimate of space use.

Nest-tree characteristics

In all, 83 nest trees used by phascogales were identified by radio-tracking (Table 3). For each individual, nests were typically distributed throughout all parts of its identified home range. Of the 185 locations of animals in nest trees, 96% ($n = 177$) could be identified to the individual tree, while the remaining eight locations were identified to a pair of trees very close together. Diameter measurements for these latter pairs of trees were excluded from further analyses. Most nests were located in living trees (94%), of which grey box was the most numerous ($n = 70$) followed by red box ($n = 4$), Blakely's red gum ($n = 2$) and river red gum ($n = 1$).

All radio-tracked individuals used multiple nest sites during the tracking period (Table 3). The mean number used by female phascogales was 11.4 ± 1.7. For females, the average ratio of number of days tracked per number of nest trees (Table 3) was 2.3 (1.5–2.9), further indicating frequent movement among multiple nest trees. Male H also utilised multiple nest trees, occupying seven during the nine days it was tracked. Trees selected were typically large, and for all individuals the mean size was >80 cm DBH (Table 3). Large-diameter trees were selected by phascogales as nest trees significantly more often than they occurred within linear remnants and woodland fragments ($\chi^2 = 452.14$, d.f. = 3, $P < 0.001$) (Fig. 6).

Health, reproduction and mortality

In early April, mean body weight of one-year-old female phascogales was 120 ± 0.6 g ($n = 3$). Second-year females averaged 152 ± 8.9 g ($n = 3$). No weight loss was recorded for animals recaptured in the following months. Upon initial capture, Male H weighed 240 g and Male I weighed 257 g. All phascogales were recorded as having a body condition that was average or above average.

Of the three second-year females trapped, two (G and D) had extended teats indicating that they had raised a litter the year before. One female (F) had teats that were not extended and a pouch that was poorly developed, suggesting that she had failed to give birth or sustain a litter in her first year. No female phascogales with pouch young were captured during this study. The pouch development (staining and swelling) of females trapped during the latter half of the study suggests that they had entered oestrus, but trapping in July to remove collars probably occurred just before young were born. For comparison, nine females trapped in the same area in 1997 were first observed to have pouch young in mid-August (R. van der Ree, unpublished). The crown–rump length of these young was approximately 1.5–2 cm, indicating an age of 30–40 days (Soderquist 1993), and a birth date in 1997 of mid-July. The mean litter size of these nine females was 7.4 young (range 5–8).

The radiosignals for both males disappeared from the study area during the breeding season. On the basis of their movements prior to disappearance, they probably travelled beyond tracking range. Female G was last detected on 25 May. Extensive trapping within and around her home range failed to capture her, suggesting either that she and her transmitter were lost to a predator, or that she dispersed from the study site (perhaps due to competition with Female A). Range area for Female A increased dramatically during April and May (70 fixes), after which she abandoned her previously established home range that she shared with Female G (possibly her mother). She was detected on 21 June in a new area approximately 1400 m away that did not overlap with the range of Female G. Within three weeks she had returned to her previous location (Fig. 4*a*).

When Females A and B were trapped to remove collars late in the breeding season, the plastic surrounding the collar had been chewed and the brass collar was severely crimped. It is likely that a male phascogale caused the damage while mating. This type of crimping has not been observed in previous studies employing brass collars on phascogales, perhaps due to the use of heavier-gauge brass (T. Soderquist, unpublished). Female E was found dead a short distance (<500 m) from her known home range with a severely

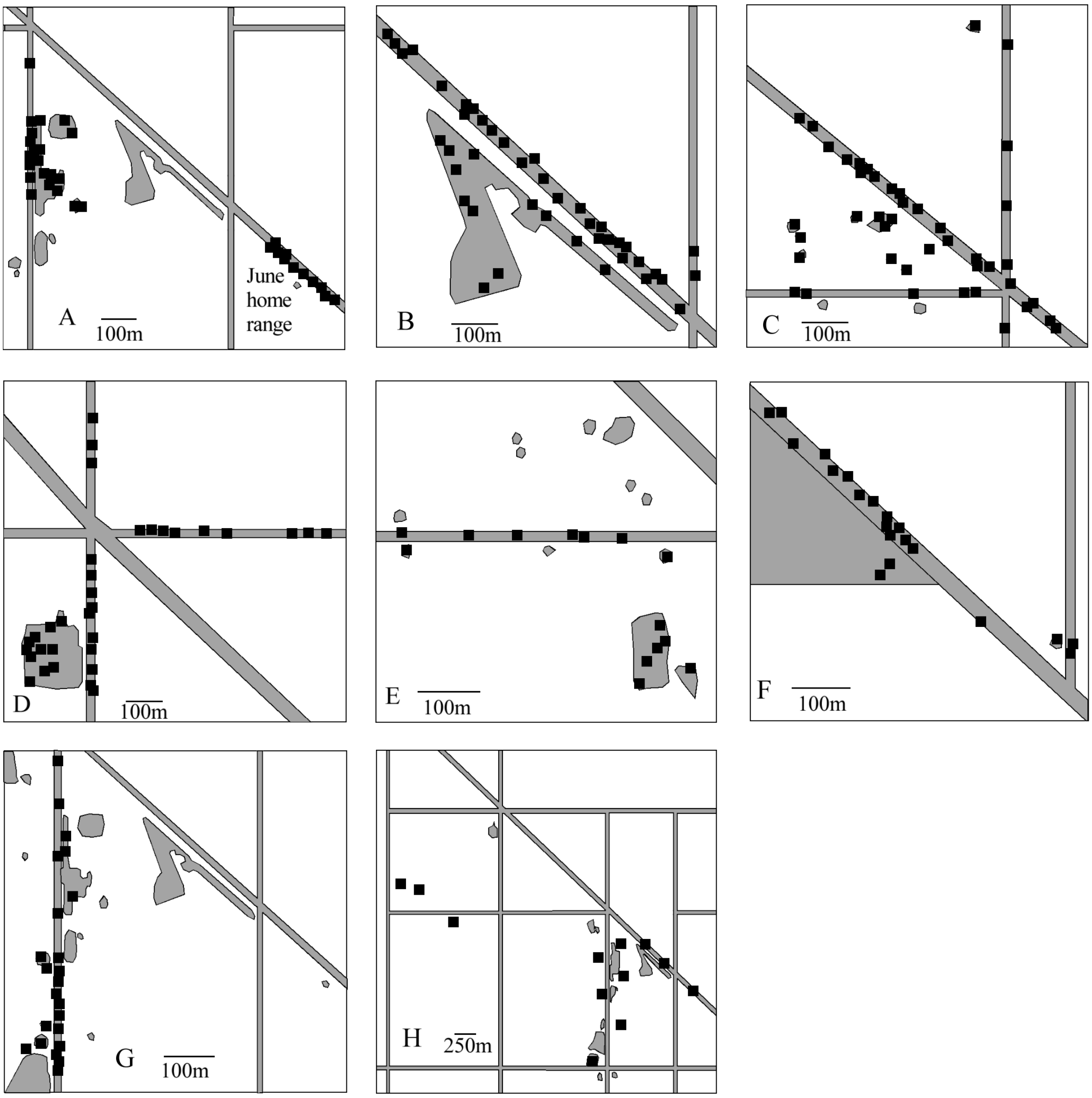

Fig. 4. Radio-tracking locations (solid black squares) for seven female phascogales (A–G) and one male phascogale (H). Remnant woodland habitat is denoted by grey and cleared agricultural land by white. Note that the map scale differs between the male and females. The home-range shift for Female A is shown.

chewed and bent collar, which had caused serious skin abrasions around the neck and shoulders. A necropsy revealed puncture wounds to the chest consistent with predation by a fox, cat or raptor. It is possible that the crimped collar inflicted injury that left the female vulnerable to predation.

Discussion

Previous research on the spatial organisation of brush-tailed phascogales indicated that home ranges of females are intrasexually exclusive (Soderquist 1995; Rhind 1998). Territoriality by female phascogales appears to be maintained in the Euroa study area despite a greater population density than recorded elsewhere in Victoria. The only extensive overlap of home ranges occurred between Females A and G. On the basis of previous studies, it is probable that Female A was a daughter of Female G, as one daughter often inherits a portion of the mother's home range (Soderquist 1995). The disappearance of Female G as lactation approached may have been due to breeding dispersal (Cockburn 1992; Soderquist and Lill 1995), which left the daughter to use the limited habitat available.

The average home range of female phascogales at the Euroa study site was an eighth the size of that used at other Victorian sites (Traill and Coates 1993; Soderquist 1995). Home ranges (95% grid cell method) at Euroa averaged

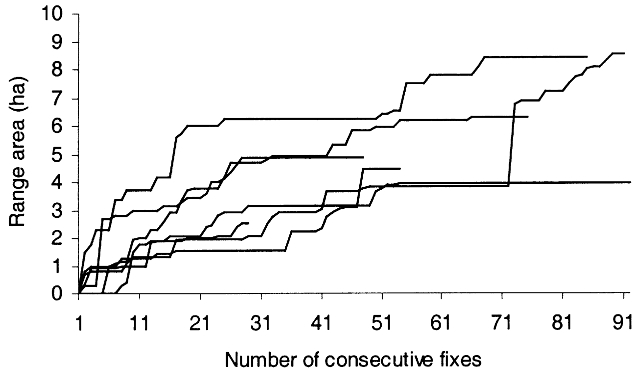

Fig. 5. Cumulative home-range area in relation to number of telemetry 'fixes' for seven female phascogales radio-tracked in linear habitats.

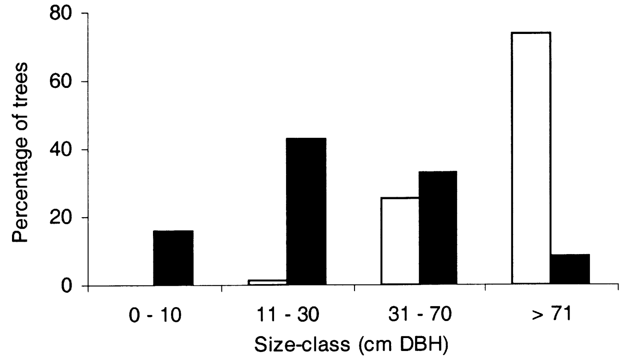

Fig. 6. The percentage of nest trees used by phascogales (white columns) and available trees (black columns) in each size-class category (dbh) within linear habitats and small woodland fragments utilised. Single isolated trees occurring in cleared paddocks were excluded from 'available' trees.

5.0 ha (range 2.3–8.0 ha). Females at three other Victorian sites where forest was less fragmented (but more degraded) used 24.5–78 ha, with a mean of 41 ha (100% minimum convex polygon method [MCP]) (Soderquist 1995). By comparison, the average home-range size (95% MCP) of females in south-western Australia is 10 ha in rich gully habitats and 17 ha in continuous forest (Rhind 1998). The contrasting methods used to calculate areas may exaggerate this size disparity (minimum convex polygons potentially incorporate more unused area than grid cells), but the trend toward small home ranges at Euroa is clear.

Two environmental factors probably contribute to the relatively small size of phascogale home ranges in the linear habitat near Euroa: high productivity and high density of large remnant trees. Soil nutrient levels and foliar nutrients are known to positively influence the occurrence and density of possums and gliders (Braithwaite *et al.* 1984; Kavanagh and Lambert 1990). Invertebrates are a primary food source for phascogales (Scarff *et al.* 1998) and the richness and abundance of canopy arthropods is also positively related to soil and foliar nutrient levels (Recher *et al.* 1996). In the Euroa study area, roadsides and unused road reserves occur on public land within productive farmland on alluvial soils of the plains. These areas were spared during the initial rush to clear land due to their public land status, rather than their low productivity. Unlike most of the extant forest and woodland in central Victoria, which remains because it occupies poor or rocky soils (ECC 1997), the linear habitats in this study area are remnants of formerly widespread tracts of high-quality habitat present prior to European settlement.

Table 3. Details of phascogale nest trees identified by radio-tracking near Euroa

Animal	Diurnal locations	Number of nest trees used	Nest tree diameter (cm DBH) Mean ± s.e.	Range
Female A	35	13	85.4 ± 5.8	42–111
Female B	27	14	83.0 ± 6.6	25–116
Female C	32	19	99.9 ± 6.7	59–171
Female D	30	11	89.1 ± 11.8	41–162
Female E	13	5	85.8 ± 8.9	69–110
Female F	20	7	80.1 ± 10.1	46–123
Female G	17	11	88.3 ± 12.3	38–156
Male H	9	7	93.2 ± 15.1	38–156
Male I	2	2	64.5	53–76
Total/mean	185	83[A]	88.9 ± 3.2	25–171

[A]Six trees were used by two individuals during the course of the study

Equally important to phascogales is the historical treatment of these areas. Roadside habitats at Euroa have not been harvested intensively, and hence retain a historically high number of large trees. The mean density of large trees (>70 cm DBH) in this habitat is 22 ha^{-1}, which is 10 times greater than that found in the intensively harvested box–ironbark forests (ECC 1997; NRE 1998) where previous work on spatial organisation of phascogales was undertaken (Traill and Coates 1993; Soderquist 1995). Large trees provide more hollows than do small trees (Bennett *et al.* 1994; Soderquist 1999) and so potentially more nest sites for phascogales. More importantly, large trees have a diversity of microhabitats seldom found in small trees, such as flaking bark and rotting wood, which may facilitate a greater diversity and abundance of invertebrates (e.g. Baehr 1990).

Large trees provide a greater surface area on which phascogales can forage compared with individual small trees. Because a phascogale must cross open ground between trees, the greater time spent productively foraging in a large tree reduces the animal's vulnerability to predation. The selective use of larger trees for foraging by phascogales has been repeatedly observed by researchers watching radio-collared animals (e.g. Traill and Coates 1993; Rhind 1998).

The importance of habitat quality to phascogales is reflected in their reproduction and survival. Lactational demands on female phascogales are extreme, with litter weights at weaning averaging 300% of the maternal weight (Soderquist 1993). Nutritional constraints during lactation can lead to slow juvenile growth rates, low body mass at weaning and high juvenile mortality (Rhind 1998). Female mortality is higher during lactation (Soderquist 1993), apparently due to more extensive foraging and perhaps debilitation.

At the Euroa study site, the reproductive rate of phascogales is higher than elsewhere in Victoria, with mean litter sizes of 7.4 young from nine females caught in 1997 *versus* 6.6 young elsewhere (Soderquist 1993). A major determinant of reproductive success in a range of species appears to be food availability and quality (Stearns 1992), which supports our view that habitat quality at Euroa is high. Conversely, mortality does not appear to be more severe than in other areas, although the radio-tracking did not extend into the lactational season. The one female known to be killed by a predator was previously injured, probably when her collar was crimped during mating.

Phascogales at Euroa can survive and breed in very small territories in areas of high-quality, well connected habitat. Habitat quality has also been shown to influence the size of home ranges of phascogales in Western Australia, where females residing in better-quality foraging areas encompassing gullies had significantly smaller home ranges and were in better condition than females outside gullies (Rhind 1998; Scarff *et al.* 1998). What must be understood, however, is that the high quality of habitat at Euroa was apparently the norm prior to European settlement of the area (Bennett *et al.* 1994; ECC 1997). The phascogale population, even though occupying severely fragmented and spatially limited habitat, enjoys a habitat that was common until the last century. The conservation potential of these Euroa remnants is great, and so too is their lesson for land management.

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