

Short-term movement patterns and diet of small dasyurid marsupials in semiarid Australia

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Abstract. Since little information is available on the spatial ecology of small arid-zone marsupials, we used radio-tracking to investigate the small-scale activity patterns of three dasyurid species in semiarid Australia. *Sminthopsis crassicaudata*, *Planigale gilesi* and *S. macroura* were equipped with miniature radio-transmitters to monitor choice of resting sites and daily movements. Resting sites were located within an area of 1.27 ± 0.36 ha, 0.12 ± 0.02 ha and 3.60 ± 0.95 ha, respectively and individuals returned to previously used resting sites regularly. We also analysed scat samples of *S. crassicaudata* and *P. gilesi*, and identified Araneae, Hymenoptera and Orthoptera as the major prey taxa for both species. Our study presents the first radio-tracking-based information on movements for these species in semiarid habitat, which indicates that, over a period of several weeks, resting sites are situated within small and defined areas.

Additional keywords: arid zone, Dasyuridae, insectivorous diet, nesting range, *Planigale*, *Sminthopsis*.

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Introduction

The arid and semiarid zones of Australia provide habitat for a diverse mammalian fauna, and marsupials from the family Dasyuridae are the most successful group, with 45% of species occurring in these areas (Morton 1982; Geiser 2004). Dasyurids found here range in size from 4 g (narrow-nosed planigale, *Planigale tenuirostris*) to 190 g (crest-tailed mulgara, *Dasyercus cristicauda*) and although they generally show a high species diversity, this often corresponds with low population densities (Dickman 2003). They typically shelter in hollow logs or burrows, beneath rocks or shrubs, or in soil cracks. Dasyurids are carnivorous and/or insectivorous, depending on body size (Hume 2003). In the arid zone, they are opportunistic hunters and generalists in their prey choice, with invertebrates representing the major component of their diet (Morton 1978a; Morton *et al.* 1983; Read 1987a).

Small arid-zone dasyurids are understood to have large and shifting home ranges (Dickman 2003), which increase in size over time (Morton 1978b; Read 1984). Most of the information available is based on the capture–mark–recapture technique, which enables the investigation of long-term ecological aspects such as population fluctuations, response to fire or seasonal

changes in spatial organisation (e.g. Morton 1978b; Dickman *et al.* 1995; Bos and Carthew 2007). However, obtaining information on animals' daily movements on a smaller scale requires the use of radio-tracking. The development of miniature radio-transmitters has enabled detailed studies of the ecology of small species (9–30 g), including their short-term movements and thermal biology (e.g. Laidlaw *et al.* 1996; Bradshaw and Bradshaw 2002; Pavey *et al.* 2003; Körtner and Geiser 2009; Körtner *et al.* 2010).

We investigated the choice of resting sites for three dasyurids: the fat-tailed dunnart (*Sminthopsis crassicaudata*), Giles' planigale (*P. gilesi*) and stripe-faced dunnart (*S. macroura*). Previous mark–recapture studies in inland Australia suggest unstable and shifting home ranges (Read 1984); however, no radio-tracking-based information on movements or choice of resting sites is available for any of the three species in arid or semiarid habitat. We used internal radio-transmitters to monitor resting sites over a period of 5–25 days. Additionally, prey composition was analysed for *S. crassicaudata* and *P. gilesi*. The aim of our study was to obtain novel field-based information on the spatial ecology and diet of three small dasyurid marsupials in semiarid habitat.

Methods

All data were collected during the austral winter (May–September) at three different study sites that receive, on average, <250 mm of rainfall per year. Daily minimum/maximum air temperatures were $\sim 5^{\circ}\text{C}/20^{\circ}\text{C}$. We monitored *S. crassicaudata* and *P. gilesi* in Kinchega National Park ($32^{\circ}30'\text{S}$, $142^{\circ}20'\text{E}$) in 2006 and 2007, and *S. macroura* in Fowlers Gap Research Station ($31^{\circ}5'\text{S}$, $141^{\circ}41'\text{E}$) in 2005; both sites are located in western New South Wales. Additional data were collected for *S. crassicaudata* on Old Andado Station, Simpson Desert, Northern Territory ($25^{\circ}22'\text{S}$, $135^{\circ}26'\text{E}$) in 2010.

We trapped animals using pitfall traps (60×15 cm PVC pipes) connected by drift fences (10×0.3 m), box traps ($32 \times 10 \times 8$ cm, Elliott Scientific Equipment, Upwey, Australia) baited with oats and peanut butter, or by hand. For transmitter attachment, animals were kept in a field laboratory ($T_a = 18\text{--}23^{\circ}\text{C}$) for 1–5 days in separate plastic cages ($38 \times 30 \times 20$ cm) containing a nesting box, logs and leaf litter, and were fed daily with insects, minced meat and pet food. The animals used were part of studies on torpor and behavioural thermoregulation (Warnecke *et al.* 2008; Warnecke and Geiser 2009; Körtner *et al.* unpubl. data). We implanted miniature FM radio-transmitters (Holohil, Canada, and Sirtrack, Havelock, New Zealand) into the abdominal cavity under sterile conditions in the field laboratory using isoflurane in oxygen as an inhalation anaesthetic (for details see Warnecke *et al.* 2008). Animals were kept until fully recovered (~ 48 h) and released at their point of capture. We released animals after sunset, which is the time when they normally become active; we then immediately left the area to minimise disturbance and started radio-tracking the following morning. We radio-tracked animals (TR-4 Telonics receivers or ICOMIC-R10 and Sirtrack Yagi antennas) early in the morning to their resting sites, the locations of which we recorded in UTM (Universal Transverse Mercator) using a hand-held GPS (Garmin GPS 12, Olathe, USA; accuracy 15 m). If an animal could not be located near any of its former resting sites, we performed intense searches on that day and the following day (walking 20-m transects in an area of ~ 16 ha around the last location fix). During the following three days, an area of ~ 4 ha was searched. After that, an area of ~ 0.25 ha around all former nesting spots was searched for up to two weeks, plus intermittent searches while radio-tracking other individuals. The small detection range of the transmitters (<20 m) did not permit radio-tracking of active animals without disturbance, so we recorded diurnal locations only. Therefore, and because of our small sample size, we use the term ‘nesting range’ instead of ‘home range’, as the latter usually includes the area traversed while foraging or finding mates (Burt 1943).

Locations in UTM coordinates were analysed using the Animal Movement ver. 2 extension for ArcView 3.2 (Hooge and Eichenlaub 1997). We calculated the nesting range as 100% minimum convex polygons (MCP). The minimum and maximum distance between sites used on consecutive days (excluding zero, when animals reused sites) was calculated, as well as the maximum distance between any locations recorded for an individual over the study period. Distances were divided by the number of location fixes to correct for the differences in

study duration. Further descriptive analyses focussed on the reuse of sites. Data are presented as mean \pm standard error; n = number of individuals, N = numbers of observations.

Prey items were identified for *S. crassicaudata* and *P. gilesi* in Kinchega National Park. We collected scats from traps and kept all pellets from each individual in a single vial containing 70% ethanol until analysis. To enable prey identification each pellet was briefly soaked in a 10% KOH solution, teased apart with jeweller’s forceps and covered with 70% ethanol. Each pellet was systematically searched for identifiable material under a low-power binocular dissecting microscope (X6.4–10; for more details see Burwell *et al.* 2005). Prey taxa were identified to Order for insects and to Class for other invertebrates. All pellets were examined separately but results were analysed per individual by pooling data. The percentage volume that each prey taxon contributed to the identifiable material within a pellet was estimated. Mammalian hair (identified by R. Carter, Victoria) was not included in the percentage volume.

Results

Resting sites and movements

The small detection range of the transmitters made it difficult to locate animals in the field, and we radio-tracked six *S. crassicaudata* (12.2 ± 1.1 g), three *P. gilesi* (8.0 ± 0.4 g) and two *S. macroura* (16.3 ± 0.9 g), all males, for a period of 5–25 days (Table 1).

Sminthopsis crassicaudata in Kinchega National Park rested in soil cracks in areas with practically bare clay soil. Defining the exact resting site was often difficult due to the large number of soil crack openings in this habitat (Fig. 1a). However, the diurnal behaviour of this species assisted in classifying resting sites as we were able to observe animals next to their soil crack opening during the day, possibly for behavioural thermoregulation purposes (Fig. 1b, for details see Warnecke *et al.* 2008; Warnecke and Geiser 2010). Soil cracks used were always narrow with an opening the size of the animal (Fig. 1b). Resting sites in the Simpson Desert were predominantly holes in clay soil, possibly old reptile burrows, located in swales between sand dunes. However, one individual was found under a sheet of corrugated iron and was later tracked to the hollow bottom rail of a derelict stockyard. The estimated nesting range was 1.27 ± 0.36 ha (including continuous data only, i.e. data with <48 h between location fixes), and the average maximum distance between any locations recorded over the study period was 285.3 ± 44.2 m. Animals used 3–10 different sites, and reused 20–50% of the sites (Table 1). The time between the reuse of resting sites ranged from 1 to 14 days. We did not record sharing of resting sites, with 44 m being the minimum observed distance between resting sites occupied by different individuals. Animals alternated between times of high site fidelity and absence (i.e. periods where they could not be detected despite intense tracking efforts). For example, one individual was first detected 45 m from its capture location and could then not be located until seven days later. Over the following eight days it used resting sites separated by a maximum distance of 72 m, reusing one site five times; it was then not detected again. Note the two values for range size presented for this individual in Table 1, one including only

Table 1. Movement and use of resting site by *S. crassicaudata*, *P. gilesi* and *S. macroura*

‘Location fixes’ includes all locations recorded for each individual with less than 48 h between location fixes. Estimates of the nesting range are based on 100% MCP. ‘Resting sites (reused)’ refers to specific resting sites, with the number of reused sites shown in parentheses. ‘Maximum distance moved’ refers to the maximum distance between any locations recorded for an individual over the study period. ‘Site distance’ refers to the minimum and maximum distance between two resting sites used by the same individual on two consecutive days. ‘Per fix’ describes distances divided by the number of location fixes to correct movements for study duration

Species (Individual)	Location fixes	Nesting range (ha)	Resting sites (reused)	Maximum distance moved (per fix) (m)	Site distance, minimum (per fix) (m)	Site distance, maximum (per fix) (m)	Year
<i>S. crassicaudata</i> (1)	15	0.39	6 (3)	96 (6.4)	21 (1.4)	85 (5.6)	2006
<i>S. crassicaudata</i> (2) ^A	8 (9)	0.16 (2.26)	5 (1)	407 (50.9)	45 (5.6)	75 (9.4)	2006
<i>S. crassicaudata</i> (3)	20	1.87	10 (4)	292 (14.6)	7 (0.4)	129 (6.4)	2007
<i>S. crassicaudata</i> (4)	18	2.29	10 (5)	278 (15.4)	25 (1.4)	118 (6.6)	2007
<i>S. crassicaudata</i> (5)	8	1.94	5 (1)	371 (46.4)	17 (2.1)	320 (40.0)	2010
<i>S. crassicaudata</i> (6)	6	0.96	3 (1)	268 (44.7)	31 (5.2)	225 (37.5)	2010
<i>P. gilesi</i> (1)	13	0.13	9 (2)	79 (6.0)	9 (0.7)	28 (2.1)	2006
<i>P. gilesi</i> (2)	3	0.15	3 (0)	126 (42.1)	n.a.	n.a.	2006
<i>P. gilesi</i> (3)	3	0.07	1 (1)	108 (36.0)	n.a.	n.a.	2006
<i>S. macroura</i> (1)	13	2.65	10 (2)	323 (24.9)	42 (3.2)	158 (12.1)	2005
<i>S. macroura</i> (2) ^A	5 (6)	4.55 (7.68)	6 (0)	566 (113.2)	164 (32.8)	361 (72.2)	2005

^ANote that two individuals were not detected for one week within the trapping period and the values in parentheses show the overall location fixes and the range based on all locations.



Fig. 1. (a) A typical resting site of *S. crassicaudata*. The arrow shows the soil crack opening from which the *S. crassicaudata* emerged during the day. (b) An individual next to its soil crack opening (arrow) (see text for details).

continuously recorded locations (<48 h between location fixes), and the other based on all locations.

Planigale gilesi rested in an extensive system of cracks formed in dry clay soil under lignum bushes (*Muehlenbeckia florulenta*) (Fig. 2a). Resting sites were located in soil cracks with narrow openings, again confirmed via their diurnal behaviour as described above (Warnecke and Geiser 2009; Warnecke et al. 2010). Planigales rested at much deeper sites than *S. crassicaudata*, based on the weak transmitter signal, which was often reduced to less than 3 m. The calculated nesting range was 0.07–0.15 ha and the maximum distance between any locations recorded over the study period was 78–126 m. Resting sites were reused 2–4 times up to nine days apart (Table 1) and one planigale alternated between two sites for six days (separated by 16 m).

Sminthopsis macroura rested in areas without cracking soil, either directly under small bushes (Fig. 2b) or inside hollow logs. The estimated nesting range was 2.65/4.55 ha, and the maximum distance between any locations recorded over the study period was 323/566 m (Table 1). Within 13 days one animal reused three of nine detected resting sites. A pattern similar to that for *S. crassicaudata* was observed for one individual: it moved to a resting site 70 m from its capture location for a day, then could not be detected for seven days, before returning to the study area, where it was located 187 m away from its last resting site. It then stayed in an area with a maximum distance between resting sites of 360 m for the following five days before the signal was lost and not found again. For this individual, two nesting range values were calculated, as described above (Table 1).

Diet

We recorded *S. crassicaudata* (n=8; N=24 pellets overall, 3.0 ± 0.5 pellets per individual) feeding on eight invertebrate taxa and *P. gilesi* (n=8; N=22 pellets overall, 2.7 ± 0.8 pellets per

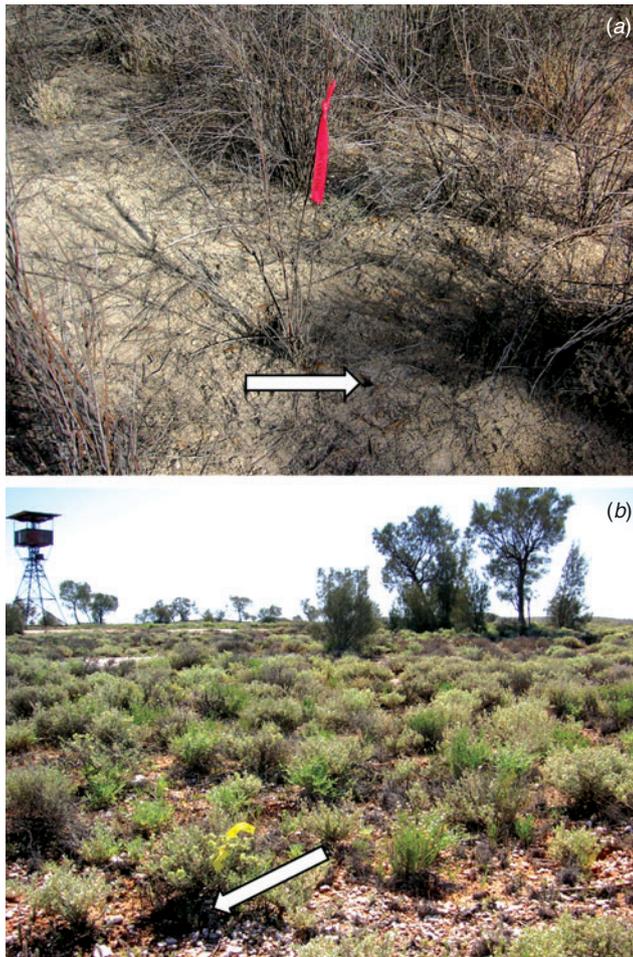


Fig. 2. Resting sites of (a) *P. gilesi* in cracking clay soil (transmitter signal was strongest at the soil crack opening, see arrow), and (b) *S. macroura* underneath a small bush (arrow).

individual) on five invertebrate taxa. Spiders (Araneae) were the main prey of both species, comprising 53% and 32% of the volume of invertebrates consumed by *S. crassicaudata* and *P. gilesi*, respectively. Hymenoptera (mainly ants) and Orthoptera (mainly crickets) were also heavily preyed upon by both species. Beetles (Coleoptera) were an important prey taxon (24%) for *S. crassicaudata*, but not for *P. gilesi* (<1%). Cockroaches (Blattodea) made up <1% of *S. crassicaudata* prey. Slaters (Isopoda) were eaten by one *P. gilesi*; seven pellets were analysed for this individual, six of which contained isopod remains. Three pellets of *P. gilesi* and one of *S. crassicaudata* contained mammalian hair, all of which was grooming hair.

Discussion

Our study provides the first information on small-scale movement patterns of *S. crassicaudata*, *P. gilesi* and *S. macroura* based on radio-tracking in semi-arid habitat. The use and reuse of resting sites within a relatively small area suggests that, over short periods, all three species have small and finite nesting ranges. However, due to the difficulties associated with radio-tracking

these small, cryptic animals, our results are based on small sample sizes and should therefore be interpreted with caution.

Generally, small desert dasyurids are understood to have large and unstable home ranges (Dickman *et al.* 2001). Published information on movement patterns for our three study species in semi-arid habitat is limited and entirely derived from sporadic recapture records. These studies monitored recaptures among trapping grids over months, reporting movements of 5 km within 8 months for *S. crassicaudata* and 1.3 km within a month for *P. gilesi*, and concluded that home ranges were unstable and continually shifting (Morton 1978b; Read 1984). Here, we provide additional information recorded over a short time period that can be collected only by using radio-tracking. Our observations of *S. crassicaudata* and *P. gilesi* suggest that small dasyurids may have a comprehensive spatial awareness of their surroundings, including locations of resting sites for reuse. Animals remained still when released and seemed to orientate themselves for a short time, before quickly running into a soil crack, which did not appear to be randomly chosen as it was not the closest accessible opening. Similarly, a previous radio-tracking study reported the reuse of resting sites by the lesser hairy-footed dunnart (*S. youngsoni*) (Haythornthwaite and Dickman 2006). Based on our findings we hypothesise that within their greater home range, animals have small, finite nesting ranges containing several resting sites. The nesting ranges are perhaps used over a period of days and weeks, and are possibly reused after a certain time of absence. Individuals from both dunnart species were not detected in the study area for a period of about one week, which may indicate that they had left the area, then returned to use a distinctive nesting range for about one week before departing again. Morton (1978b) similarly described *S. crassicaudata* in mesic habitat to leave the study area for some time before returning. Thus, it appears that while resting sites are chosen in a small area, animals nevertheless undertake long-distance movements, possibly to forage, find mates, and shift between different nesting ranges.

Interspecific competition can be avoided through microhabitat separation; for example, vegetation cover and soil crack depth were previously identified as important factors for *S. crassicaudata* and *P. gilesi* (Morton *et al.* 1983; Read 1987b). Our results imply that both species use predominantly soil cracks and reptile burrows with narrow openings (Fig. 1b), but dunnarts selected sites with less vegetation cover than planigales (compare Figs 1a and 2a). In support of a previous microhabitat exclusion hypothesis (Read 1984) the transmitter signal strength also suggests differences in depth of resting site, with dunnarts located closer to the surface than the smaller planigales, which can penetrate deeper into the narrow soil cracks. This could potentially be an avoidance response by *P. gilesi* to the larger *S. crassicaudata* (Moss and Croft 1988).

Small dasyurids in semi-arid Australia feed mainly upon insects, and both *S. crassicaudata* and *P. gilesi* are generalists in their prey choice (Morton 1982; Morton *et al.* 1983; Read 1987a). We found greater variety of prey taxa for *S. crassicaudata* than for *P. gilesi*, and spiders represented the main prey of both species, which supports previous reports (Morton *et al.* 1983; Read 1987a). In contrast to these studies we found beetles to be only a minor component of planigale diet, and we are the first to describe cockroaches as dunnart prey. Given the fast rate of food

passage in small dasyurids of 0.5–4.5 h (Read 1986; Hume 2003), collecting scats from trapped animals restricts interpretation because the prey choice is limited if the animal has been in a trap for several hours before collection. This probably explains the consumption of slaters by only one planigale, as they were found in pitfall traps in large numbers; this is similar to findings for the fat-tailed false antechinus (*Pseudantechinus macdonnellensis*), where one scat consisted entirely of slater remains (Burwell *et al.* 2005). To avoid these ‘artificial prey choices’, scats should ideally be collected from free-roaming individuals that are located and identified by radio-tracking (Pavey *et al.* 2009).

We conclude that in semiarid habitat *S. crassicaudata*, *P. gilesi* and *S. macroura* choose resting sites within a relatively small nesting range, but there might be several spatially discrete nesting ranges contained within the animals’ larger home ranges. Over several days and weeks these nesting ranges are used with high site fidelity as animals frequently reuse specific resting sites within this area. How often animals return to previous nesting ranges, and what factors cause animals to shift locations, should be the subject of future research. Larger sample sizes are required to address these questions but the low population densities and complex movement patterns present a challenge for free-range studies. The development of smaller transmitters with a larger detection range would facilitate such work. In the interim, small studies such as ours are nevertheless essential for helping contribute to the greater understanding of the ecology of these and other cryptic marsupials.

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