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Short-term movements and habitat use of the marsupial honey possum (*Tarsipes rostratus*)

S. D. Bradshaw* and F. J. Bradshaw

Department of Zoology and Centre for Native Animal Research, The University of Western Australia, Perth, WA 6009, Australia

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Abstract

Miniature radio-transmitters were used to follow movements over a 10-day period of the 10 g honey possum *Tarsipes rostratus*, and the areas covered were compared with home-range estimates calculated from long-term mark-and-recapture records using pitfall traps. The study was carried out in the Scott National Park, in the extreme south-west of Western Australia, and shows that honey possums may move far greater distances than is apparent from trapping records. The overall mean area used determined by radio-tracking was significantly larger at 0.54 ± 0.19 ha than the apparent home range of 0.03 0.01 ha determined by trapping. The area used by males was significantly greater than that of females when measured by radio-telemetry (0.79 ± 0.24 ha *vs* 0.14 ± 0.08 ha, $P = 0.058$), but did not differ significantly when estimated from trapping records (0.03 ± 0.01 ha *vs* 0.01 ± 0.01 ha). These data suggest that honey possums frequent plant assemblages at night where they are vulnerable to pitfall trapping, but that males, particularly, spend the day in other areas that may be as far as 200 m distant.

Key words: marsupial, home range, movements, radio-tracking, honey possum, *Tarsipes rostratus*

INTRODUCTION

The tiny (10 g) marsupial honey possum *Tarsipes rostratus* is unique in being the only non-flying mammal entirely dependent on flowers for its nutrition (Wooller, Russell & Renfree, 1984). It feeds on nectar and pollen collected from flowers of plants belonging to the families Proteaceae, Epacridaceae and Myrtaceae and particularly favours species of the genus *Banksia* (Russell & Renfree, 1989). Recent work, using isotopic turnover techniques, has made possible the measurement of the daily intake of both nectar and pollen of free-ranging individuals in the extreme south-west of Western Australia and these average *c*. 7 ml/day for nectar and 1 g/day for pollen (S. D. Bradshaw & Bradshaw, 1999).

Given that adult honey possums vary in body mass from 6 to 12 g, this represents an enormous intake in relation to their body size and must involve considerable energy expenditure in seeking out flowers with sufficient nectar and pollen. In common with other marsupials, honey possums are also nocturnal and dependent on nectar production by flowers that have already been visited throughout the day by numerous insects and a variety of species of honeyeaters of the avian family Meliphagidae (Goldstein & Bradshaw, 1998). The honey possum is not yet listed as threatened, as many species of Australian marsupials have been, but its range has contracted considerably in recent times and its preferred habitat of *Banksia* woodlands is also declining as a result of continued clearing and the impact of the plant pathogen, *Phytophthera cinnammoni* (Shearer & Hill, 1989).

In an early study of a population adjacent to the Fitzgerald River Reserve on the south coast of Western Australia, Wooller, Renfree *et al.* (1981) suggested that the honey possum is relatively sedentary, moving 20–30 m over a period of months. Garavanta, Wooller & Richardson (2000) confirmed these results in a more extensive study in the Fitzgerald River Reserve and reported home-range sizes of 0.13 ha for males and 0.07 ha for females. These home ranges are much smaller than those reported for other small marsupials such as *Antechinus stuartii* (Lazenby-Cohen & Cockburn, 1991), pygmy possums *Cercartetus nanus* (Ward, 1990*a*), feathertail gliders *Acrobates pygmaeus* (Ward, 1990*b*; Kirk, Smith & Agnew, 2000) and the dasyurids *Sminthopsis crassicaudata*, *Planigale gilesii* and *P. tenuirostris* occurring sympatrically in a semi-arid region of New South Wales (Read, 1984). This apparent sedentary nature of the honey possum is puzzling considering the recent observations of Bryant *et al.*, (2000) using microsatellites, which show the absence of any significant genetic differentiation between isolated northern

*All correspondence to: S. D. Bradshaw.
E-mail: Don.Bradshaw@uwa.edu.au

and southern populations that are separated by *c.* 700 km in Western Australia. These data suggest very strongly that the present populations have been contiguous in the recent past and that gene flow has been maintained, implying that individuals are far from sedentary and capable of moving considerable distances.

There is still considerable debate in the literature over the most appropriate method for the measurement of an animal's home range, originally defined by Burt (1943) as 'that area traversed by an individual in its normal activities of food gathering, mating and caring for young'. Burt's definition contains no temporal component and leaves open the question of over what time-span the home range should be estimated? Traditionally, mark-and-recapture trapping methods over a period of months or years have provided data with which home ranges may be estimated but, more recently, the development of small and reliable radio-transmitters has favoured the use of radio-tracking data, despite some inherent pitfalls with the technique (Harris *et al.*, 1990). An inherent limitation with telemetry, however, is the short battery life of the transmitters, which forcibly limits observations to periods of days or weeks rather than months or years, as is possible with trapping. Home ranges in the strict sense can only thus be measured by telemetry when the body size of the animal permits the use of larger transmitters with a battery life of at least several months.

The size and mass of available transmitters precluded their use for many years with animals as small as the honey possum, but the recent availability of minute transmitters weighing < 1 g has now made this a possibility, even though they have a limited battery life. We report here the first measurements of movements and areas exploited by both male and female honey possums determined by radio-telemetry and compare these estimates with home-range sizes derived from traditional pitfall trapping. A considerable disparity is evident between the two methods, which highlights a previously unsuspected aspect of the biology of this species.

METHODS

Individuals of *Tarsipes rostratus* were captured in Scott National Park (34°17′S, 115°13′E) in the extreme south-west corner of Western Australia. Trapping was focused on isolated groves of 6-m high holly banksia *Banksia ilicifolia*, which form virtual 'islands' of 10–20 ha surrounded by a low swampy heath in the Scott River site. In the early phase of the study, traplines were also placed in the heath areas surrounding these Banksia stands but honey possums have only ever been captured in the banksia groves where they feed. Many of these trees have succumbed to 'dieback' resulting from infection with *Phytophthora cinnammoni*, and the only other *Banksia* sp. on the site is *Banksia meisneri*, a small prostrate species gazetted until recently as 'rare' (Gibson & Keighery, 2001). Work over a number of years has shown that trapping success and density of individuals in the Scott National Park site are significantly correlated with the flowering phenology of *Banksia ilicifolia* which is clearly one of the preferred dietary items of honey possums in this particular habitat (S. D. Bradshaw & Bradshaw, 1999; F. J. Bradshaw & Bradshaw, 2001). The study site was partially burned in November 1993, and again in the same area in April 1999, providing an opportunity to compare movements and habitat use by animals in unburnt and regenerating parts of the study site.

Trapping

Honey possums were caught overnight in pit traps constructed from 40-cm lengths of 15-cm diameter PVC piping set into the ground with the rim flush with ground level. Trapping success rate averaged 3.81 ± 1% for a total of 14 505 trap nights between January 1987 and January 1998 at Scott River, which compares with a long-term average of 7.3% reported by Garavanta *et al.* (2000) for their Fitzgerald River site. Few individuals were recaptured over a time span > 12 months as the honey possum has a short life span, both in the field and in captivity (Russell & Renfree, 1989). Traps were set 5–10 m apart in 150–200 m lines and closed with metal lids when not in use. Traps were cleared at first light and animals were transported in calico bags to a nearby mobile field laboratory where they were individually marked, weighed and brushed for pollen. The honey possums were marked individually, following a binomial system, using an ear punch that removed very small crescents of tissue along the ear margin. Males and females without pouch young that were trapped during the period January 1998 to January 2001 and had a body mass > 10 g were then selected for fitting of radio-transmitters.

Radio-telemetry

Two models of radio-collars were used in this study. Initially, single stage collar-fitting transmitters (150–151 MHz range) manufactured by Sirtrak (New Zealand), weighing a total of 0.9 g, were used successfully to track a number of individuals of both sexes. A more powerful two-stage transmitter, weighing 1.3 g was tested on 3 individuals, all of which died after 6–7 days and thus use of these transmitters was abandoned. Subsequently, radio-collars manufactured by Titley Electronics (South Australia) and weighing 0.6–0.7 g have been found to be reliable and are supported well by honey possums weighing in excess of 10 g. The range of these transmitters varies from 200 m in open country to 20–30 m in dense bush, and they have a battery life of > 3 weeks. Two hand-held radio-receivers were employed interchangeably: Biotrak Model 3 (Sirtrak, NZ) and Australis 26 K Scanning Receiver (Titley Electronics) fitted with a Sirtrak 3-element Yegi antenna.

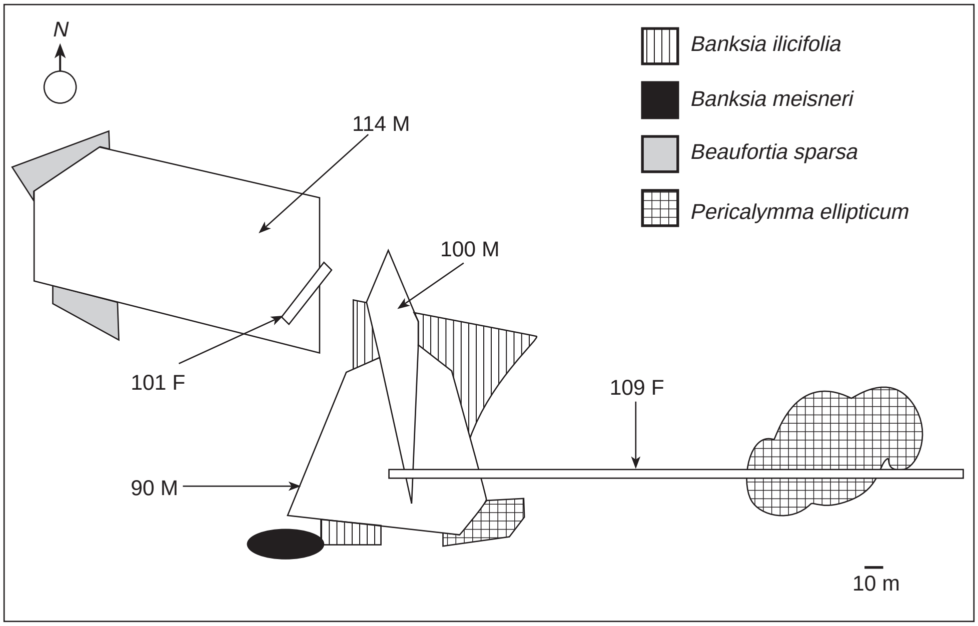

Fig. 1. Movements and utilization areas of three male and two female honey possums *Tarsipes rostratus* in the burnt northern part of the Scott National Park study site.

Collared individuals were released at the site of their capture in late morning or early afternoon and then located for the first time at 20:00–21:00 on the same day. Care was taken not to approach too closely to the radio-collared animals when they were active at night as they are readily disturbed and will run ahead of the observer for as long as followed. Ideally, the position of each animal was located rapidly by triangulation (Saltz, 1994) and the point marked with flagging tape giving the fix number, time and date. The location of each individual was then established the following morning between 08:00 and 10:00 and this new site was similarly marked. In this way data were accumulated on several individuals of both sexes giving their location at night, when feeding, as well as the site that they chose for their daytime refuge. Mapping of the data was made with a prismatic compass and tape where the animal had only moved over small distances between fixes, and using GPS (Magellan) where fixes were far enough apart (the accuracy of the GPS was about 20 m).

Estimation of area of use and home range

Radio-telemetry data were not considered adequate for the estimation of home-range sizes as they were gathered over short time spans ranging from 5 to 10 days. 'Utilization areas' (UAs) were thus calculated using both the minimum-area method and the harmonic mean method (Dixon & Chapman, 1980; Quin *et al.*, 1992), using the program Ranges V (Kenwood & Hodder, Institute of Terrestrial Ecology, Dorset, U.K.). Autocorrelation of the telemetry data was not a problem as successive fixes were always 10–12 h apart. Suitable radio-telemetry data were available from a total of 13 individuals (8 males, 5 females). Radio-telemetry studies were carried out between January 1998 and January 2001 and a minimum of 12 fixes were taken with each individual. Long-term trapping data, where individuals had been trapped on a minimum of 6 occasions, were available from 15 individuals that were recaptured from January 1987 to January 1998 (12 males, 3 females) and home ranges were estimated by calculating the area of the minimum convex polygon encompassing all the trap sites recorded for each individual (Jones, 1983).

RESULTS

Some idea of the variability between individual movements, and thus the size of UAs, can be seen from Fig. 1 where minimum convex polygons are plotted for three males and two females on a habitat map of the site. Female 101 F hardly moved over a period of 1 week and spent most of the time (day and night) in a large *Adenanthos meisnerii* bush that was flowering profusely at the time (January 1998). Her only recorded movement was 35.8 m when she moved and took up residence in another *A. meisnerii* bush where she remained until caught by hand in the early morning whilst in torpor. By contrast, female 109 F moved up to 250 m in 1 day, but always in a due line eastwards and was captured in a small shrub (*Pericalymma ellipticum*) in the centre of an 8 cm deep pond after having moved a total distance of 475 m from her point of capture. UAs for these two females are similar at 0.02 and 0.05 ha, respectively, but that for 109 F would have been much greater had she been located at any time at a point away from her due eastwards line of progress. Movements of the males (90 M, 100 M and 114 M) are much more extensive

Table 1. Estimated home-range size and utilization area (UA) of *Tarsipes rostratus* in the Scott National Park, Western Australia. Data in hectares (ha) as mean ± SE, number of individuals in parentheses

Parameter	Males	Females	Combined	Significance males *vs* females
Home range	0.03 ± 0.01 (12)	0.01 ± 0.01 (3)	0.03 ± 0.01 (15)	NS
UA	0.79 ± 0.24 (8)	0.14 ± 0.08 (5)	0.54 ± 0.17 (13)	$P = 0.\ 05$
Significance home range *vs* UA	$P = 0.001$	NS	$P = 0.005$	

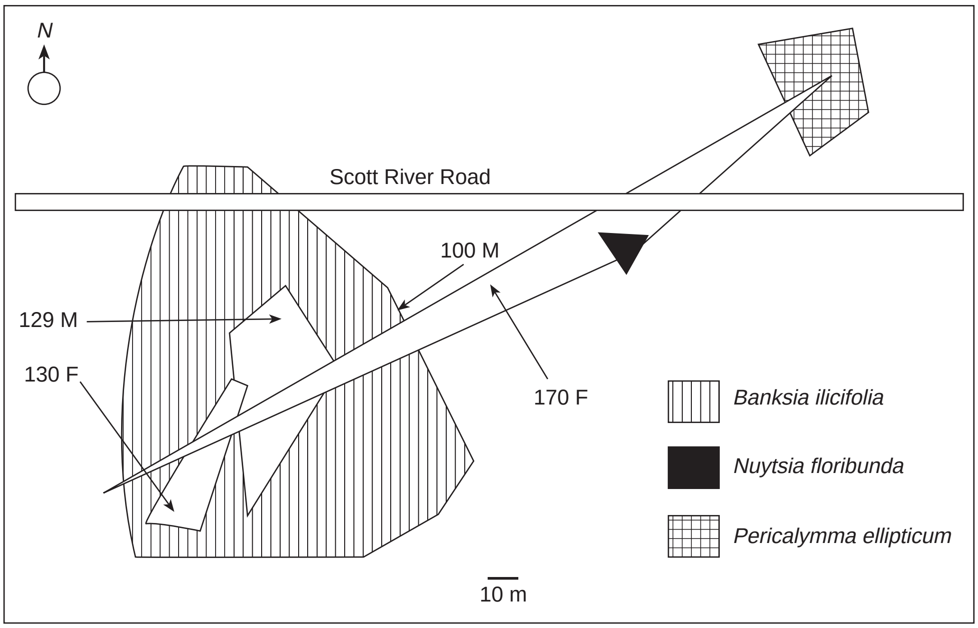

Fig. 2. Movements and utilization areas of one male and two female honey possums *Tarsipes rostratus* in the unburnt southern part of the Scott National Park study site.

with the largest area being covered by male 114 M with an estimated UA of 2.17 ha. This male was located each evening within 10 m of the site where he was first trapped, but each day he was found immobile in an extensive *Beaufortia sparsa* thicket over 250 m distant. To check that this 11.3 g male was indeed undertaking these regular movements each night, an early scan was made at dusk on 1 February 1999 and he was located half way between the *Beaufortia* thicket and the *Banksia ilicifolia* woodland where he had been initially trapped.

A comparison of home-range estimates from trapping records and UAs calculated from the radio-telemetry data is shown in Table 1. The mean UA for *Tarsipes rostratus* estimated by telemetry was *c*. 18 times larger than the home-range size calculated from mark-and-recapture records (0.54 ± 0.17 ha *vs* 0.03 ± 0.01 ha, $P = 0.005$) and this effect was due entirely to males. Home-range size did not differ between the sexes when estimated from trapping records ($t_{13} = 1.647$, NS) but the UA of males was significantly greater than that of females ($t_{11} = 2.03$, $P = 0.05$). The UA of males estimated from telemetry data was also significantly greater than the home range calculated from trapping results (0.79 ± 0.24 *vs* 0.03 ± 0.01 ha, $P = 0.001$), in contrast to the UAs estimated for females.

In view of the recent burning on two occasions of part of the study area (lying to the north of Scott River Road which bisects the study area) it was of interest to see whether home-range sizes and UAs vary in the two habitats, which differed markedly in the extent of plant cover (see Fig. 2). Analysis of variance, however, showed that estimated home-range sizes and UAs in burnt and unburnt areas did not differ significantly.

DISCUSSION

A variety of methods is now available for the estimation of home-range size in vertebrates, all of which have associated assumptions and limitations (Anderson, 1982; Worton, 1987). The minimum convex polygon (MCP) method has been used most extensively in the literature, because of its inherent simplicity and, although outlying fixes are known to bias the size and shape of the estimated home range, good agreement was found between the MCP method and the harmonic mean method of Dixon & Chapman (1980) by Quin *et al.* (1992) when studying sugar gliders *Petarurus breviceps*. These same authors also found good agreement between estimates of home range for this marsupial based on trapping data and on radio-telemetry. Garavanta *et al.* (2000) recently reported the first estimates of home-range size in the honey possum *Tarsipes rostratus*, based on long-term trapping results over 7 years. They found that males had a significantly larger home range than females (0.13 *vs* 0.07 ha) and speculated that this was because of males searching for mating opportunities and due to females behaviourally excluding males from rich nectar sources.

Our results, although from a more limited number of animals over a shorter time, provide an added perspective to the results of Garavanta *et al.* (2000). Home ranges of males and females, estimated from trapping records, were smaller (0.03 and 0.01 ha, respectively) and did not differ significantly between the two sexes. UAs of females determined by telemetry were not significantly greater than home ranges estimated in this study from trapping records, but UAs of males were vastly larger (0.79 *vs* 0.03 ha). These data suggest that trapping is a suitable method for estimating the home range of female honey possums, but that the method significantly underestimates the home range of males, as evidenced by their very large UAs. This suggests, in turn, that habitat-use patterns differ dramatically between the two sexes in this species, in contrast to the pattern often observed in other marsupial species (Cockburn, 1984; Laidlaw, Hutchings & Newell, 1996). Large displacements by small mammals, especially males, have also been reported in other studies using telemetry rather than repetitive trapping (Szacki, Babinska-Werka & Liro, 1993; Dickman, Predavec & Downey, 1995; Moro & Morris, 2000).

The pioneering study of McNab (1963) established body size as one of the prime determinants of home-range size and suggested that home range varies allometrically with body mass to the same power as the basal metabolic rate, i.e. 0.75. Subsequent studies (e.g. Mace & Harvey, 1983) have re-examined and refined McNab's conclusions and Harestad & Bunnell (1979) reported a relationship of $H = 0.008W^{1.08}$ for 54 eutherian mammals and one marsupial with a coefficient of determination (r^2) of 0.60, where H = home range in ha and W = body mass in g. Using this equation, the predicted home range of the honey possum is 0.096 ha, larger than that reported for females in this study, but considerably less than that of males.

Our radio-tracking data suggest strongly that male and female honey possums interact very differently with their immediate habitat. Females, which are considerably larger than males (10–12 g *vs* 6–8 g) are behaviourally dominant over males (Russell, 1986) and the fact that males have the largest testes in relation to body size and the largest sperm of any mammal (Harding, Carrick & Shorey, 1984; Renfree, Russell & Wooller, 1984; Russell & Renfree, 1989) points to this species having a significant history of sexual selection (Arnqvist, 1998). Recent unpublished studies with highly polymorphic microsatellite markers (Spencer & Bryant, 2000) have also found evidence of multiple paternity in litters of young pointing to active sexual selection in this species (Bentley, Spencer & Bradshaw, pers. obs.).

Dense stands of *Banksia ilicifolia* are obviously feeding areas of preference for both male and female honey possums in the Scott National Park and the distribution of our traps favours such areas. Two of the females studied showed evidence of significant displacements, in excess of 100 m, whereas the others were all extremely sedentary. One female (20 F) radio-tracked in January 2001, however, remained within a very small area over 7 days (UA = 0.07 ha) and then suddenly moved. A very faint signal was detected south of Scott River Road (see Fig. 2) on 29 January but this could not be located precisely, due to the extreme density of the vegetation. What is most significant, however, is that two males (37 M and 38 M) which, each evening had been located in the vicinity of this female, were suddenly located south of Scott River Road on the morning of 29 January. It thus seems that two factors are at work in determining movements of males: the availability of food and the presence of females. Surprisingly, home-range sizes and UAs did not differ significantly in burnt and unburnt areas of the study area, despite the large differences in plant cover between northern and southern sections of the study area.

Females clearly prefer to spend the daytime in bushes close to those on which they feed. Honey possums, however, do not build nests and, although in captivity they nestle together in groups (F. J. Bradshaw, Everett & Bradshaw, 2000), no evidence of such communal behaviour has been observed in the field. Why males prefer to leave the area where food is available and seek refuge elsewhere during the day is not clear and it may be, as Garavanta *et al.* (2000) suggest, that the females behaviourally exclude them. This seems to put them at some risk, however, as the areas where we have detected males in the day are often quite exposed and the animals typically curl up in the basal leaves of small shrubs and bushes. Also, the long distances that males, such as 114 M, travel each night to reach the feeding grounds from their daytime refuge must expose them to many nocturnal predators, such as foxes and owls.

The present study has highlighted the value of radio-tracking in revealing a previously unsuspected aspect of biology in the honey possum where there is an obvious disparity between the extent of use of the immediate habitat by males and females.

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