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Basking behaviour and torpor use in free-ranging *Planigale gilesi*

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Abstract. We investigated the importance of energy-conserving strategies for free-ranging *Planigale gilesi* in arid Australia. We monitored torpor use and basking behaviour using internal temperature-sensitive transmitters. Torpor was used every day; the maximum torpor bout duration was 18.2 h and the minimum body temperature was 10.5°C. Basking behaviour was observed during rewarming from torpor as well as during normothermia. The use of torpor and basking is likely to reduce the energy requirements of *P. gilesi*, thus helping it to survive in a harsh and unpredictable environment.

Additional keywords: arid zone, dasyurids, heterothermy, passive rewarming.

Introduction

Torpor and basking behaviour are important energy-conserving strategies for small mammals in Australia's arid zone (Geiser 2004). Torpid animals can reduce energy expenditure by up to 95% in comparison to active individuals (Geiser and Baudinette 1988) and basking during rewarming from torpor, usually the most energetically expensive phase of torpor, can reduce energy costs by up to 85% (Geiser and Drury 2003). Therefore, combining these physiological and behavioural strategies appears highly advantageous, especially for very small species that face relatively high costs of living due to their large surface area-to-volume ratio and high mass-specific metabolic rate (MR).

Planigales (*Planigale* species, Dasyuridae) include some of the smallest extant marsupials (3–15 g), thus their adaptations to environmental conditions are of special interest. In the laboratory, planigales enter torpor to reduce energy expenditure during times of inactivity (Dawson and Wolfers 1978; Morton and Lee 1978). However, no data on body temperature (T_b) fluctuations are available for any free-ranging planigale and there is no published information about torpor occurrence in planigales the wild.

Basking has been reported for several normothermic mammalian species in the wild (e.g. Brown and Downs 2007) but information on this behaviour in relation to torpor use is extremely scarce. Only free-ranging fat-tailed false antechinus (*Pseudantechinus macdonnellensis*), fat-tailed dunnarts (*Sminthopsis crassicaudata*) and stripe-faced dunnarts (*S. macroura*) have been observed basking during rewarming from torpor (Geiser *et al.* 2002; Warnecke *et al.* 2008; Körtner and Geiser 2009). Captive fat-tailed dunnarts selected radiant heat access while rewarming from torpor, thereby drastically reducing arousal costs (Warnecke and Geiser 2010). The Giles' planigale (*Planigale gilesi*) is known to bask in captivity (Andrew and Settle 1982), but no information about this behaviour in the wild and no measurements of T_b are available. Based on findings on closely related species we hypothesise that Giles' planigale, which inhabits soil cracks in arid floodplains (Read 1987), exhibits torpor and basking in the wild to reduce energy requirements.

Methods

Four planigales (8.0 ± 0.6 g) were caught in Kinchega National Park (32°30′S, 142°20′E) in western New South Wales during winter (May to July) 2006 using pitfall traps. Animals were kept at a field laboratory under natural light conditions at an ambient temperature (T_a) of 20 ± 2°C, with food (insects, lean mince and cat food) and water freely available. To locate these planigales in the wild and continuously measure their T_b, we intraperitoneally implanted wax-coated temperature-sensitive radio-transmitters (BD-2TH, 0.8 g, Holohil, Carp, Ontario) using general isoflurane/oxygen anaesthesia. Prior to implantation, transmitters were calibrated (to the nearest 0.1°C) in a water bath from 10 to 40°C using a precision mercury thermometer. After release, planigales were located early in the morning by radio-tracking and a mobile data logging station was positioned to record transmitter pulses every 10 min (Warnecke *et al.* 2008). Soil crack openings were observed with 10 × 40 binoculars from ~0900 hours on the day after the torpor site had been located. T_a was measured to the nearest 0.5°C every 30 min by placing iButtons (DS1921G, Dallas Semiconductor, Dallas, TX) on the soil surface in the shade ($T_{surface}$) and in a 25 cm deep soil crack (T_{soil}). *StatistiXL* ver. 1.7 (Perth) was used to perform *t*-tests. Data are presented as mean ± standard deviation for the number of observations (*N*).

Results and discussion

Ambient conditions differed greatly between $T_{surface}$ and T_{soil} during the study period. $T_{surface}$ ranged from –1.0 to 21.5°C (daily

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fluctuations 5.5–18°C) whereas conditions in the soil cracks were buffered with T_{soil} ranging from 11.0 to 15.5°C (daily fluctuations 0–3°C). Sunrise was at ~0730 hours and the sun reached the soil surface at ~0900 hours, at which point $T_{surface}$ measured 9.7 ± 2.7°C.

Of the four planigales released, one individual was monitored for 11 days within the 14-day study period; two animals were located fewer than four times but no sufficient T_b data were retrieved; and one individual could not be detected at all. This was likely owing to the very short signal detection range (often <5 m) when animals were resting in deep soil cracks. The mean normothermic T_b was 37.0 ± 1.6°C (range 30.1–38.9°C); T_b was affected by locomotion as T_b during rest (36.2 ± 3.2°C) was significantly lower than during activity (37.7 ± 0.9°C; $t_{13} = -2.5$; $P = 0.03$).

The observed planigale used torpor on all nights, which supports findings for other small dasyurids inhabiting arid Australia (Geiser 2003). Two complete torpor bouts were recorded from entry to arousal. Only the minimum T_b and the arousal phase were recorded for the other nine monitored nights because the planigale had moved out of the detection range of the logging station. During torpor, T_b was reduced to 12.2 ± 1.0°C ($N = 11$, each value averaged over 30 min; minimum single value $T_b = 10.5$°C) and closely followed T_{soil} (Fig. 1). At the time of daily minimum T_b, the daily minimum T_b (12.2 ± 1.0°C) and T_{soil} were essentially identical (12.0 ± 0.9°C; $t_{10} = 0.53$; $P = 0.61$). Soil cracks appear to present an energetically advantageous resting site in which to employ torpor as they allow for maximum energy savings during torpor (low MR because of low T_a) and ensure a long bout duration (because the stable T_a does not drop below the T_b set point) (Geiser 2003; Warnecke *et al*. 2008). Hence, soil cracks provide planigales with an ideal microhabitat, close to basking sites where passive rewarming can be employed.

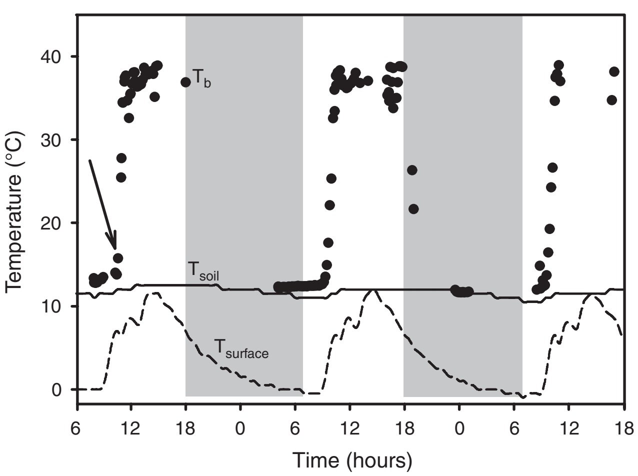

Fig. 1. Body temperature (T_b, circles) of a free-ranging *Planigale gilesi* on three consecutive days with ambient temperature measured on the surface ($T_{surface}$, dotted line) and in a 25 cm deep soil crack (T_{soil}, solid line). Basking behaviour was observed on the first day; it commenced at 1035 hours ($T_b = 15.7$°C, arrow) and ended at 1240 hours ($T_b = 36.4$°C). The grey vertical shading indicates the scotophase.

Basking behaviour was observed on three occasions, when the planigale emerged from its burrow entrance at 1026 hours ± 10 min with a T_b of 14.6 ± 1.0°C (range 13.8–15.7°C). The animal was observed positioning itself in the sun as its T_b increased (Fig. 1), and it continued basking for 40–125 min. The planigale's small body size made basking observations difficult so it is likely that basking behaviour occurred on more days. This ground-dwelling species prefers habitat with soil cracks of >1 m depth (Read 1987), and our extremely weak transmitter signal for resting animals supports the assumption that they rest deep under the surface. Hence, torpid planigales appear capable of coordinated locomotor activity to allow climbing ~1 m vertically with T_b < 14°C. This is remarkable and supports previous reports of good coordination for torpid planigales in captivity (Geiser and Baudinette 1988).

The torpid planigale emerged very slowly from the soil crack and positioned itself with a flattened body directly next to the soil crack opening (Fig. 2). This is similar to behaviour described for fat-tailed false antechinus (Geiser *et al*. 2002); the flattened body is likely to increase heat uptake due to the larger surface area exposed. Basking presents a risk–reward trade-off as it requires planigales to leave their sheltered resting sites in soil cracks and to place themselves in an exposed position on the surface during the day, which is likely to dramatically increase the risk of predation. Thus, it appears that this risk is outweighed by the energetic advantages achieved by basking (Pavey and Geiser 2008).

We observed long bouts of torpor combined with short activity periods, similar to findings for closely related species (Pavey and Geiser 2008; Warnecke *et al*. 2008; Körtner and Geiser 2009). Torpor entry occurred at 1850 and 1616 hours, the duration was 15.4 and 18.2 h, and the time of torpor arousal was 1014 and 1029 hours, respectively. We were able to collect data for one whole day (Fig. 1), when the animal left its resting site early at 1355 hours, returned at 1605 hours and entered a 15.4 h-long torpor bout at 1850 hours. Interestingly, the brief activity period was completed shortly after $T_{surface}$ had reached its

Fig. 2. A free-ranging *Planigale gilesi* displaying basking behaviour during arousal from torpor. The dark spot to the left of the animal shows the opening of the soil crack (photograph by J. Turner).

maximum daily reading of 12.0°C (Fig. 1). This suggests that planigales may be able to find enough food before sunset and thereby avoid surface exposure during the colder parts of the day, when heat loss increases.

Our study provides the first T_b measurements for a free-ranging planigale and demonstrates the animal's extensive use of torpor during winter. It also describes the first observations of basking in a torpid planigale, the smallest mammal for which this behaviour has been observed in the wild. As hypothesised, we found that planigales use the combination of torpor and basking to reduce energy requirements during winter, which facilitates decreased foraging requirements and short activity times. The pattern of torpor, maximum torpor bout duration, minimum T_b and observed basking behaviour were similar to findings for the sympatric fat-tailed dunnart (10 g), which reduced its estimated daily energy expenditure by 64% (Warnecke *et al*. 2008), and it is likely that planigales achieve similar energy savings.

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