# Torpor and thermal energetics in Australian arid zone bats


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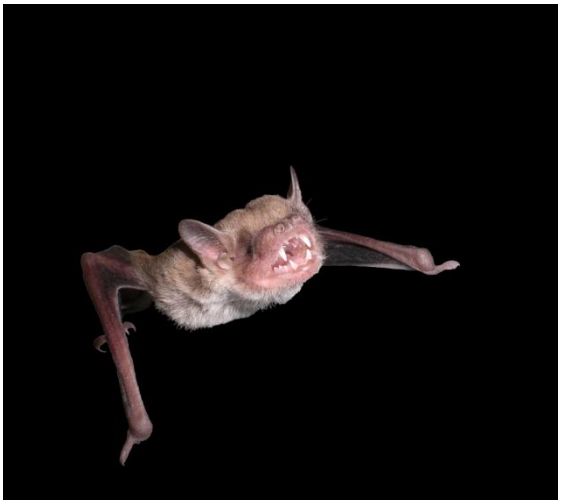

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# Declaration

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis and all sources used have been acknowledged in this thesis.

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Title page photographs: top left-to-right – the little broad-nosed bat (*Scotorepens greyii*) and the inland freetail bat (*Mormopterus* species 3); bottom left-to-right – the inland broad-nosed bat (*Scotorepens balstoni*) and the study site near Mt Wood Homestead, Sturt National Park, NSW, Australia.

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# List of abbreviations

| | |
|---|---|
| $T_a$ | ambient/air temperature |
| $T_{skin}$ | skin temperature |
| $T_b$ | body temperature |
| $T_{rectal}$ | rectal temperature |
| $T_{roost}$ | roost temperature |
| BM | body mass |
| TBD | torpor bout duration |
| MR | metabolic rate |
| BMR | basal metabolic rate |
| TMR | torpor metabolic rate |
| RMR | resting metabolic rate |
| TNZ | thermo-neutral zone |
| RER | respiratory exchange ratio |
| $C_{wet}$ | wet thermal conductance |
| $C_{dry}$ | dry thermal conductance |
| RH | relative humidity |
| EWL | evaporative water loss |
| EHL | evaporative heat loss |
| MHP | metabolic heat production |
| MWP | metabolic water production |
| PRWE | point of relative water economy |

# Thesis abstract

In spite of challenging and unpredictable environmental conditions, bats are among the most successful groups of Australian arid zone mammals. Yet knowledge about the thermal biology and energetics of desert bats is scarce. I used temperature-telemetry to obtain data on the thermal physiology, torpor patterns, thermoregulatory behaviour, foraging activity and roosting ecology of desert bats under natural conditions in relation to climate and season. The study species were the inland freetail bat (*Mormopterus* species 3, body mass, BM, 9 g, henceforth *Mormopterus*), the little broad-nosed bat (*Scotorepens greyii*, BM 6 g) and the inland broad-nosed bat (*Scotorepens balstoni*, BM 9 g). The study was conducted at Sturt National Park (New South Wales, Australia) over three summers (2010-13), two winters (2011-12) and one spring (2011). In addition, I used flow-through respirometry to collect data on the thermal, metabolic and hygric physiology of *Mormopterus* and *S. greyii* over air temperatures ($T_a$) from 5 to 42ºC during summer 2013.

In summer, all three species employed torpor regularly (~60-84% of all bat-days) and torpor patterns and activity were affected by $T_a$. Total time bats spent torpid per day was ~7.2 h and similar among species. The longest torpor bout duration (TBD) ranged from 22.7 to 39.3 h. Entirely passive rewarming from torpor was often observed in all species and occurred on 44.8% of all arousals in *S. greyii* and on 29.4% in *S. balstoni*, whereas *Mormopterus* rewarmed passively on 72.6% of all arousals. This is the first observation of entirely passive rewarming in bats. During the most extreme hot weather in January 2013, the maximum skin temperature ($T_{skin}$) recorded was 45.8°C ($T_a$ 47.9°C) in *Mormopterus* and 44.0°C ($T_a$ 46.1°C) in *S. greyii*, and these are the highest $T_{skin}$ values recorded in free-ranging bats. All three species of bats roosted in a similar roost type which was a dead, hollow tree trunk usually with multiple holes and cracks. However, *S. greyii* and *S. balstoni* roosted ~3.5 m above the ground in the dense tree stands, whereas *Mormopterus* roosted ~5.5 m above the ground usually in the sun-exposed roost trees located in open areas, which presumably, facilitated passive rewarming in this species.

In winter, *Mormopterus* remained torpid for up to 7.7 days and arousals were often followed by foraging activity. However, under similar thermal conditions, TBD in *Mormopterus* was ~40% longer in summer than in winter. This, in addition to the lower mean maximum rates of active rewarming from torpor in summer, suggests that seasonal changes in torpor patterns are governed not only by temperature effects, but also physiological acclimation. Even in spring torpor was common in pregnant *Mormopterus*, and torpor bouts up to ~6 h were observed on the daily basis. Often in addition to the long main torpor bouts in summer, winter and spring, *Mormopterus*

employed one or two short auxiliary bouts, which may represent a unique energy and water saving strategy used by this species throughout the year.

The mass-specific basal metabolic rate (BMR) was 1.03 ± 0.04 ml $O_2$ $g^{-1}$ $h^{-1}$ in *Mormopterus* and 1.15 ± 0.04 ml $O_2$ $g^{-1}$ $h^{-1}$ in *S. greyii*, and both were 10-57% lower than BMR in similarly-sized temperate, subtropical and tropical bats. Torpor significantly reduced metabolic rate (MR) and evaporative water loss (EWL) and their minimum values in *Mormopterus* were only 2.7% (torpor metabolic rate, TMR) and 10.7% (torpor EWL) of that of normothermic bats in the thermo-neutral zone (TNZ); in *S. greyii* these values were 3.5% (TMR) and 15.4% (torpor EWL). The steady-state minimum TMR was 0.028 ± 0.007 ml $O_2$ $g^{-1}$ $h^{-1}$ in *Mormopterus* and 0.040 ± 0.015 ml $O_2$ $g^{-1}$ $h^{-1}$ in *S. greyii* and $T_{skin}$ of both species fell to ~6ºC. These TMR and $T_{skin}$ values were similar to the values observed in other hibernators. Interestingly, even in the TNZ both species were able to reduce normothermic MR by up to 45% below BMR and $Q_{10}$ values, calculated for torpid and normothermic bats, were generally high (> 3), suggesting that metabolic inhibition was involved in down-regulating MR in these desert bats. Both species tolerated $T_a$s up to 42ºC (maximum $T_a$ tested) without visible signs of stress, which was achieved via increases in evaporative cooling and adjustments in thermal conductance. The point of relative water economy ($T_a$ at which metabolic water production (MWP) = EWL) was reached at higher $T_a$ in *Mormopterus* (12.7ºC) than in *S. greyii* (7.0ºC), but the water balance of both species was more favourable than in tropical cave-dwelling bats.

My study shows that torpor and passive rewarming combined with low BMR, low EWL, metabolic inhibition and high heat tolerance are crucial for these desert bats to successfully cope with the aridity of their environment. It demonstrates that heterothermy plays a key role in biology of desert bats and likely explains to some extent why these small bats are so successful in Central Australia.