Ecology and thermal physiology of an insectivorous bat restricted to subtropical and tropical Australia

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(Photo by: Gerhard Körtner 2009)

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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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List of abbreviations

BCI	body condition index
BMR	basal metabolic rate
MR	metabolic rate
T_a	ambient temperature
T_b	body temperature
T_{skin}	skin temperature
TMR	torpor metabolic rate
TNZ	thermal neutral zone
RMR	resting metabolic rate
$\dot{V}O_2$	rate of oxygen consumption

Summary

Bats of the mammalian order Chiroptera make up about one-fifth of all mammal species and a large proportion of bat species inhabit subtropical and tropical regions. Most bats, particularly microchiropterans, weigh well under 25 g and therefore expend large amounts of energy for normothermic thermoregulation. Consequently, many microchiropterans are heterothermic endotherms and use torpor for energy conservation. However, despite the large number of species inhabiting subtropical and tropical regions knowledge about torpor use in free-ranging subtropical and tropical microbats is scarce. This is largely due to the view that low and stable ambient temperatures (T_a) are necessary for torpor use.

The aim of my project was to collect data on the skin temperature (T_{skin}) of free-ranging insectivorous northern long-eared bats (*Nyctophilus bifax*), which are restricted to the Australian tropics and subtropics. This was accomplished via temperature-telemetry. As weather, food availability and reproduction vary seasonally, I undertook seasonal studies on *N. bifax* at a subtropical field site, because detailed knowledge on how free-ranging subtropical insectivorous bats cope with such changes is essentially non-existent. Winter studies were undertaken on *N. bifax* in two different habitats, a subtropical region near the southern end of their range and a tropical region near the northern end of their range to determine whether they employ torpor and especially prolonged torpor, and also whether their thermal physiology varies within their range. Additionally, since few studies have examined the thermal energetics of torpor in species that inhabit only subtropical and tropical regions, I quantified the thermal energetics of *N. bifax* during summer, winter and spring from a subtropical habitat and also during winter from a tropical habitat.

Subtropical *N. bifax* used torpor regularly throughout the year during winter, summer and spring. During winter bats employed torpor on every day of the study period

and, in contrast to previously held views, exhibited prolonged multi-day torpor bouts of up to 5.4 days. Torpor was also used regularly during summer on 85% of study days, but no multi-day torpor bouts were recorded. Spring is a reproductive time of year for female *N. bifax* and all females captured during my study were pregnant. During this reproductive period in spring, non-reproductive males continued to employ torpor regularly (94% of observation days), whereas females entered torpor rarely (13% of days). Torpor was also found to be used regularly by *N. bifax* during winter in a tropical habitat. The longest bout of torpor recorded during winter in the tropical habitat was 33 h 20 min.

In all my field studies of free-ranging bats, torpor use was correlated with prevailing weather conditions and consequently was most likely affected by insect abundance. As predicted, insects were more abundant during summer in comparison to winter, which was reflected in the shorter and less frequent torpor bouts during summer. The T_{skin} of torpid bats in all my studies fluctuated with T_a and daily minimum T_{skin} was positively correlated with the corresponding T_a. These decreases in T_{skin} to T_a would provide significant energy savings to the bats. Further, the T_{skin} and torpor bout durations of subtropical torpid *N. bifax* were strongly influenced by their roost choice.

Many mammals avoid the use of torpor if they are not energetically constrained because of potential costs associated with reduced body temperatures (T_b) and slowed metabolic processes. This is known as the “cost-benefit hypothesis” of torpor use. However, against the predictions from this hypothesis, I found that during summer subtropical *N. bifax* with a high body condition index (BCI; i.e. good fat/energy reserves and therefore not energetically constrained) expressed longer and deeper torpor bouts and also employed torpor more often during the activity phase at night than bats with low BCI. Consequently, I provide the first data displaying increased torpor use in a free-ranging

subtropical mammal that is not energetically constrained, and therefore torpor likely is used for predator avoidance.

Thermal energetics of heterothermic endotherms often varies among species and even between populations of the same species. I found that the basal metabolic rate (BMR) of subtropical and tropical *N. bifax* was similar and was also comparable to other species of *Nyctophilus*. Similarly to their temperate congeners, *N. bifax* showed a negative relationship between T_a and resting metabolic rate (RMR) and this relationship was similar in both regions. One important difference that was identified between tropical and subtropical *N. bifax*, however, was the population-specific T_a threshold at which torpid individuals began to thermoregulate. Thus many aspects of the thermal physiology of torpor use in *N. bifax* do not seem to vary with their congeners and between different populations, with the notable exception of a population-specific T_a threshold that is most likely an adaptation to the local climate.

In conclusion, contrary to previous hypotheses, my thesis shows that torpor is used regularly by and appears highly critical to subtropical and tropical microbats. Moreover, while torpor is expressed more prevalently during winter when insect abundance is reduced and therefore energy is difficult to obtain, I have also shown for the first time that during summer torpor use is maximised and foraging minimised not because of low energy stores, but likely to avoid predation when bats are not required to feed to replenish energy levels. Lastly, the prolonged torpor bouts (> 24 hours) shown by subtropical and tropical *N. bifax* and the low metabolic rates displayed during torpor provide clear evidence that *N. bifax* is a hibernating microbat despite being restricted to subtropical and tropical regions.