Chapter 9

Final conclusions

In my PhD project I examined the ecology and thermal physiology of an Australian insectivorous microbat, *Nyctophilus bifax*, a species that is restricted to subtropical and tropical regions. Available data on this species was scarce and restricted to their general biology and roosting habits. Further, very little is known in general about the physiology of how subtropical and tropical insectivorous microbats deal with changes in weather and food abundance. Specifically, previously it was assumed that subtropical and tropical bats would not at all use torpor, an energy saving mechanism, in subtropical and tropical climates due to the high prevailing T_a and mild weather conditions. My study aimed to gather information on the ecology, thermal physiology and torpor use of *N. bifax* inhabiting a subtropical and a tropical region and to scrutinise whether these traditional views are correct.

Firstly (Chapter 2) I provided new information on the most successful methods of capturing *N. bifax* and also how to care for them while they are kept in captivity. Both harp traps and mist nets were tested as methods of capture and it was found that mist nets proved to be more successful in the habitats where my research was undertaken. *N. bifax*, similarly to their congeners, adapted readily to captivity and maintained a good body condition for periods of up to two weeks. The internal part of a camping tent provided ideal temporary housing for microbats, as the walls are made of soft fabric that does not injure the bats if they are to fly into it. Once mealworms had been introduced as a food source via hand feeding, *N. bifax* readily consumed mealworms on their own from a dish.

Insect samples were collected at a subtropical field site during different times of the year (winter, summer and spring) and also during winter at a tropical field site to determine the fluctuations in the food available for *N. bifax* in the habitats that they occupy. I provided evidence (Chapter 2) that insect abundance is similar during summer and spring, but significantly reduced during winter at the subtropical field site. Further, significantly more insects were available during winter at the tropical field site in comparison to during winter at the subtropical field site. However, insect abundance was lower at the tropical field site during winter in comparison to spring and summer at the subtropical field site. This suggests that *N. bifax* need to adjust their energy expenditure and savings throughout the year and in different parts of their range to compensate for the prevailing insect availability.

Further, I provided quantitative data (Chapters 3 – 6) that *N. bifax* uses torpor regularly throughout the year in a subtropical habitat. Specifically, I provided the first evidence of a subtropical insectivorous microbat expressing prolonged bouts of torpor up to 5.4 days during winter (Chapter 3). These long bouts of torpor usually coincided with periods of inclement and cool weather, and arousals from these bouts typically occurred on warmer days. While torpor bouts occurred on most days during summer and spring, these bouts were significantly shorter and shallower in comparison to torpor bouts during winter. Further, there were some seasonal differences in the physiology of torpor use between summer and winter (Chapter 5). During winter it appeared that torpor was used mostly during times of energetic stress, whereas during summer torpor may have served other purposes.

In many heterothermic endotherms torpor use is minimised when enough energy is available, perhaps because of the potential costs associated with torpor. However, Chapter 4 clearly shows that torpor during the active period at night was maximised in individuals in good body condition (i.e. high fat/energy reserves). A possible reason for this is that on cooler nights, when foraging was unlikely to return the energy required for foraging, individuals with already high energy reserves may decide to forgo foraging and remain torpid to conserve energy for a more profitable night. In contrast, those individuals with low energy reserves may need to forage regardless to try to maintain a balanced energy budget. Another potential reason for remaining torpid is to reduce the risk of exposure to potential predators such as owls. This is a highly likely explanation as it is known from other animals, in comparison to resting, that foraging increases the risk of predation.

In Chapter 6, I provided data showing that while torpor was used regularly during spring in a subtropical habitat by non-reproductive male *N. bifax*, torpor was very rarely used by pregnant female *N. bifax*. This is most likely due to the associated costs of using torpor while pregnant, such as delayed birth. While delays in birth are beneficial during periods of inclement weather, the weather during the current study was favourable and insect abundance was high. Therefore, there would be no need for females to delay birth and it would be better for them to take advantage of the favourable conditions for lactation, which in bats is energetically more expensive than pregnancy.

Similarly to the subtropical habitat *N. bifax* used torpor regularly during winter in a tropical habitat (Chapter 7). Winter in the tropical habitat was milder than in the subtropical habitat and insect abundance was also greater. This is reflected in torpor patterns as torpor bouts were shorter and shallower in the tropical habitat than in the subtropical habitat. However, torpor was still used on most days during winter in the tropical habitat and a torpor bout longer than a day was also recorded. Therefore, it seems that multiday bouts of torpor can also be used in tropical regions during extended periods of inclement weather or food shortages.

Finally, the thermal energetics of torpor use were examined in subtropical *N. bifax* throughout the year and also during winter in the tropical habitat (Chapter 8). The data show that basal metabolic rate did not vary throughout the year and was similar to their congeners from temperate regions. Also similarly to their temperate congeners, it was found that resting metabolic rate increased with decreasing ambient temperature and this relationship did not vary seasonally or between the subtropical and tropical populations. While much of the thermal energetics of *N. bifax* did not vary between the subtropical and tropical populations, the ambient temperature and body temperature at which individuals began to thermoregulate was significantly higher in the tropical population than in the subtropical population. This difference is most likely an adaptation to the local climate, such that individuals from the more northern tropical population will not experience ambient temperature as low as the more southern subtropical population.

In conclusion, contrary to previous assumptions, my work shows that torpor is used regularly throughout the year in a subtropical climate and also during winter in a tropical climate. Further, I found for the first time that a subtropical/tropical microbat is able to undertake prolonged torpor during adverse conditions. Additionally, while torpor is generally used for energy conservation, it may also be used for other reasons such as predator avoidance. From all of the data gained throughout my thesis project it can be concluded that *N. bifax*, although they employ torpor opportunistically and are restricted entirely to subtropical/tropical habitats, is a hibernating microbat because they can express multiday torpor bouts and reduce metabolic rates to extremely low values during torpor. My study has provided new knowledge on the ecology and thermal physiology of subtropical/tropical microbats and will contribute to the understanding that is required to conserve microbats and the habitats that they depend on. Specifically, as the use of torpor is integral to managing energy reserves in microbats, the knowledge gained throughout my thesis on how weather and roost choice affects torpor use will aid in determining what habitats are of importance to conserve for endangered microbats.