*Physiological response of two species of tropical hot-roosting microbats (*Hipposideros ater *and* Rhinolophus megaphyllus*) to different ambient temperatures in high humidity.*

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The thermoregulatory patterns of two species of tropical Microchiropteran, *Hipposideros ater* and *Rhinolophus megaphyllus*, were studied at different ambient temperatures in high humidity. These species select hot and humid roosts with minimal ventilation that traps heat and moisture. The hot and humid environment which results presents a heat-loss challenge to small mammals as they have high mass-specific metabolic rates.

Microbats spend more than half their lives subjected to the conditions of their roost environment, which influences social behavior, energy requirements and physical development (Kunz 1982). Warm to high temperatures occur within caves in domes or horizontal passages where solar, metabolic and organically produced heat accumulates (Kunz 1982; Bonaccorso et al. 1992). Hot-roosts are generally set high in the karst and are characterised by a single, reduced entrance which minimises ventilation, with temperatures that often exceed external ambient temperatures and may remain stable throughout the seasons (Churchill 1991; Rodriguez-Duran 1995). A stable micro-habitat allows for less energy to be spent regulating a constant body temperature (Tracy 1977; Ruczynski 2006). Some cave-roosting microbats actively select conditions of extreme temperature and humidity and demonstrate little tolerance outside of these parameters (Maloney et al 1999; Churchill 1991). The heat load under high temperature and high humidity conditions experienced in these roosts would be lethal to many similar sized small mammals due to the difficulties of shedding metabolic heat by either dry means or evaporative heat loss (Adolph 1947; Licht & Leitner 1967). The ability of these hot-roosting bats to tolerate these conditions may hold potential benefits for energetics, reproduction and development of neonates (Kunz 1982). The high temperatures allow microbats, which have very small body sizes close to the lower limits for endothermy to conserves energy that would otherwise be spent on thermogenesis without resorting to the reduction in body temperature associated with torpor (Kunz 1982; Willis et al. 2005 Ruczynski 2006). However the appropriate combinations of warmth, humidity, and constancy of conditions may be limited throughout a species range, potentially restricting their distribution (Maloney et al 1999; Trune & Slobodchikoff 1976; Churchill 1991).

Microclimate conditions at two known roosting sites were quantified between April – September (tropical late-wet to dry season). Roost sites selected by these species had an ambient temperature ranging from 28-31^{o}C and relative humidity 84-90% with minimal daily variation. Eleven individuals of *H. ater* and five individuals of *R. megaphyllus* (average mass 5.4 ± 0.28 g and 7.8 ± 0.25 g respectively) were captured using a harp-trap at the cave entrance and exposed to five different ambient temperatures at high (95%) humidity. Flow through respirometry and open-flow plethysmography techniques were used to quantify the effect of ambient temperature on metabolic rate, body temperature, dry heat loss, evaporative water loss, respiratory rate, respiratory evaporative heat loss and tidal volume. Ambient temperature had a significant effect on metabolic rate in each species. Basal metabolic rate was 0.052 ± 0.01 W in *H. ater* which is 37% of the metabolic rate predicted for a mammal of its body mass. *R. megaphyllus* had a basal metabolic rate of 0.07 0.01± W, 77% of that predicted for a mammal of its body mass. The basal rate of metabolism occurred within a thermoneutral zone of 32-35^{o}C ambient temperature for both species. The rate of dry heat loss in both species was significantly affected by ambient temperature. In *H.*

ater this was 0.035 ± 0.002 W at 32^{o}C (124% of that expected from body mass) and 0.054 ± 0.008 W at 35^{o}C in *R. megaphyllus* (95% respectively of that expected from body mass). Evaporative water loss as a method of dissipating body heat was restricted in the high humidity environment and was not influenced by ambient temperature. Entry into torpor was not identified in either species despite being exposed to ambient temperatures below typical roost conditions.

These species roost in conditions nearing the upper limit of small mammal thermal tolerance. An increase in temperature in their roosting environment by a few degrees could result in heat stress and expose individuals to maximum lethal temperatures, although this level was not reached in this experiment. The thermo-neutral zone measured in these species (32-35^{o}C) suggests that temperatures above 35^{o}C will cause an increase in metabolic rate and therefore metabolic heat production which becomes more difficult to shed at higher temperatures. Increased variability in external temperature is unlikely to affect the roosting site as conditions currently remain stable on a seasonal and daily basis. Between April to September temperature ranged from 28–30.8^{o}C with an average daily temperature range of 0.06 ± 0.04^{o}C. Relative humidity inside the roosting chamber ranged from 84-90% between April to September with a daily range of 0.8 ± 0.4%. This stability acts as a buffer for the roosting site, which is only likely to be influenced by an increase in the long-term average temperature causing an increase in ground temperature as well as increased solar heating. Parts of the cave which are currently cooler than the selected roosting site may become options for roosting if temperatures were to increase; however these areas also experience greater variability in temperature and humidity on a daily and seasonal basis which does not serve the same purpose for energy conservation as the stability available in their current roosting sites. Despite the wide distribution of these species, the appropriate combination of high heat and humidity is restricted to caves or mines with the appropriate physical formation which allows heat and moisture to become trapped. Identifying and protecting these sites throughout the species range is important to ensure appropriate roosting conditions are available. Existing sites should maintain a suitable roosting environment until the long term average increases. Determining intolerable roost temperature would require further investigation.

Further research opportunities to enhance the findings of this study include expanding the range of experimental temperatures which the bats are exposed to in order to determine thermal stress at low and high temperatures. Different levels of humidity could also be explored to determine the tolerance of the species to variability in roost conditions. Further testing the limits of thermal tolerance needs to be done with caution as the small bodied species are prone to dehydration and heat stress can come on rapidly.

Reference list

Kunz, T.H. 1982. 'Roosting Ecology' in Kunz, T.H. (ed.). Ecology of Bats, Plenum Publishing Corporation, New York, pp. 1-46.

Bonaccorso, F.J., Arends, A., Genoud, M., Cantoni, D. and Morton, T. 1992, Thermal Ecology of Moustached and Ghost-Faced Bats (Mormoopidae) in Venezuela. *J MAMMAL* 73(2):365-78.

Churchill, S.K. 1991. Distribution, Abundance and Roost Selection of the Orange Horseshoe-bat, *Rhinonycteris aurantius*, a Tropical Cave-dweller. *WILDLIFE RES* 18:343-53.

Rodriguez-Duran, A. 1995. Metabolic rates and thermal conductance in four species of neotropical bats roosting in hot caves. *COMP BIOCHEM PHYSIOL* 110A(4):347-55.

Ruczynski, I. 2006. Influence of temperature on maternity roost selection by noctule bats (*Nyctalus noctula*) and Leisler's bats (*N. leisleri*) in Bialowieza Primeval Forest, Poland. *CAN J ZOOLOG* 84(6):900-7.

Tracy, C.R. 1977. Minimum size of mammalian homeotherms: Role of the thermal environment. SCIENCE 198:1034-5

Maloney, S.K., Bronner, G.N. and Buffenstein, R. 1999. Thermoregulation in the Angolan Free-Tailed Bat *Mops condylurus*: a small mammal that uses hot roosts. *PHYSIOL BIOCHEM ZOOL* 72(4):385-96.

Adolph, E.F. 1947. Tolerance to heat and dehydration in several species of mammals. *AM J PHYS* 151:564-75.

Licht, P. and Leitner, P. 1967. Physiological responses to high environmental temperatures in three species of microchiropteran bats. *COMP BIOCHEM PHYSIOL* 22:371-87.

Trune, D.R. and Slobodchikoff, C.N. 1976. Social Effects of Roosting on the Metabolism of the Pallid Bat (*Antrozous pallidus*). *J MAMMAL* 57(4):656-63.