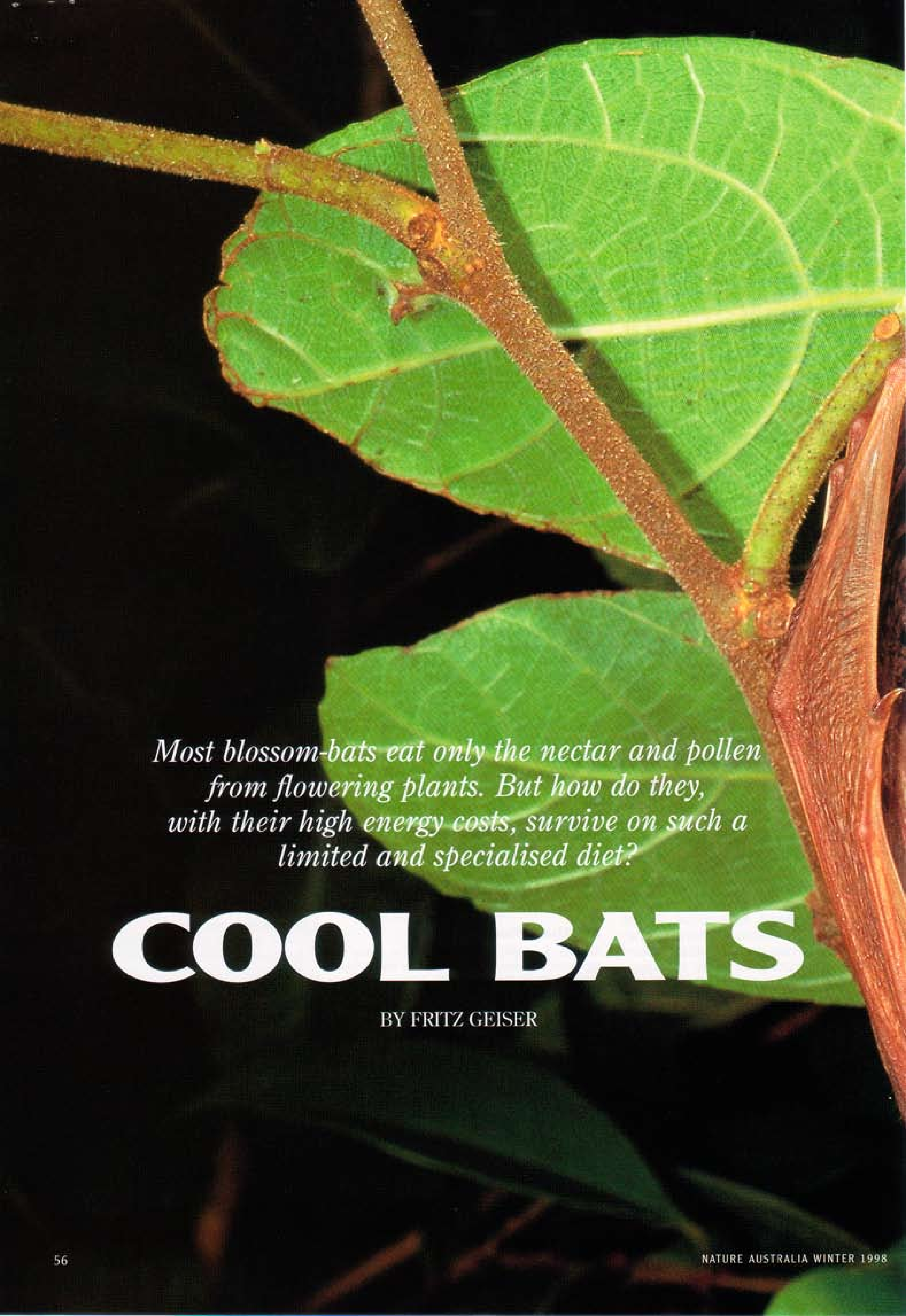

Most blossom-bats eat only the nectar and pollen from flowering plants. But how do they, with their high energy costs, survive on such a limited and specialised diet?

COOL BATS

BY FRITZ GEISER

The Common Blossom-bat is found on the east coast of Australia (north of Booti Booti, New South Wales) and New Guinea.

PAVEL GERMAN

THE COSTS OF LIVING FOR A SMALL blossom-bat are huge. If expressed as energy used per gram of body mass, these mouse-sized bats expend more than ten times that of a human, just to stay alive. During flight or other strenuous activity their energy expenditure (or metabolic rate) can increase another tenfold. To sustain such energy demands, many small mammals and birds must consume large amounts of food each day, often the same or even more than their body mass. Think about swaggering to a counter at your local fast food outlet and ordering several hundred hamburgers!

Most blossom-bats, as their name implies, eat only the nectar and pollen from flowering plants. But how do they, with their high energy costs, survive on such a limited and specialised diet? I discussed this with Brad Law, who had recently obtained a PhD on the biology and ecology of the Common Blossom-bat (*Syconycteris australis*). In particular, we wondered whether blossom-bats were homeothermic like humans (in other words, did they continuously regulate their body temperature at a constant high level, regardless of the environmental temperature?), or whether they employed some physiological or behavioural tricks to help them get by.

It is well known that, as an energy-saving strategy, many small mammals allow their body temperature and metabolic rate to fall to very low levels during parts of the day or night when at rest, particularly when food is scarce. Then, using internal heat production, they warm themselves up just before their next activity period. This physiological state of reduced body temperature and metabolic rate is called daily torpor, during which body temperature may fall to around 20° C and metabolic rate is reduced by about 60–80 per cent of resting levels. It differs from hibernation, which is a more extreme form of torpor and typically occurs during winter. Hibernating animals let their body temperatures fall to around 5° C and metabolic rates can be as low as one per cent that of active animals. This strategy allows the animal to go for months without eating, often surviving entirely on stored fat.

Many people believe that daily torpor and hibernation are processes that occur only in mammals from temperate regions and the Arctic, not Australia's warm eastern coast. Moreover, until recently, it was thought that, of the bats, only some insectivorous members of the suborder Microchiroptera were capable of entering torpor. All 'megabats' in the suborder Megachiroptera, including the blossom-bats, were believed to be strictly homeothermic.

BRAD AND I THEREFORE DECIDED TO study the use of energy by the Common Blossom-bat and determine whether or not the species could enter torpor. With the help of Gerhard Körtner, a postdoctoral fellow in my laboratory, the first bats for the project were netted during autumn near Iluka on the northern coast of New South Wales. They were immediately taken to the University of New England in Armidale and kept in a large holding room with branches for roosting and plenty of space for flight. We gave them an artificial 'nectar' diet of blended banana, apple juice, sugar, and Infasoy baby food (as their protein source). The bats loved these 'banana smoothies', with each of the five bats helping themselves to about 22 grams of the food. Given that each bat weighed around 18 grams, this meant they ate more than their body mass each day!

The Common Blossom-bat does not consume pollen directly from flowers but by grooming the fur and wings after a bout of nectar feeding.

Once the animals had acclimatised to their new home, we attempted to induce torpor by withholding food overnight and subjecting them to a range of constant temperatures. During this time we measured their rate of oxygen consumption to estimate their metabolic rate and daily energy needs. The bats remained active for most of the night and sustained high metabolic rates. However, even at temperatures as high as 26° C, as soon as lights came on in the morning the bats' metabolic rates began to fall, dropping to less than 30

PHOTOS: F. GEISER

At about the size of a mouse blossom-bats, like this Common Blossom-bat, are the smallest members of their family.

H. & J. BESTE/NATURE FOCUS

A Common Blossom-bat feeds at a banana flower. Its long snout and tongue help it reach the nectar.

per cent that of active animals within about half an hour. This rapid fall in metabolic rate seemed to indicate torpor, but to actually prove it we had to show that their body temperature had simultaneously declined.

Initially we attempted to measure the body temperature of torpid bats by using a fine rectal probe. The bats disliked this intrusion so much that they quickly changed their daily activity pattern and began to rest all night, expending so little energy that there was apparently no need for them to enter torpor the following morning. We therefore decided to implant tiny temperature-sensitive radio-transmitters, which allowed us to measure body temperature remotely without ever having to touch the animals. Sure enough, the bats *did* lower their body temperature, to about 18° C. However, if room temperature dropped below this, their internal heating mechanism would kick in to stabilise their body temperature at this minimum level.

We could now establish that torpor always commenced immediately after the lights went on in the morning (remember bats are nocturnal and for them daytime is rest time) and lasted several hours. During this time they reduced their metabolic rate to a minimum of about 15 per cent that of resting bats, meaning that up to 85 per cent of the energy they would have used to stay warm was saved. At the end of a torpor bout, typically a few hours before the lights went out, the temperature of the bats increased at the amazing rate of up to 1.5° C per minute. This means that they were able to warm themselves from a low of 18° C to their normal body temperature of 35° C within about 30 minutes.

They were able to warm themselves from a low of 18° C to their normal body temperature of 35° C within about 30 minutes.

Since the blossom-bats did so well in captivity, we decided to go one step further to determine if there were any seasonal changes in the way they used torpor. Many mammals from the northern hemisphere enter torpor more frequently, and allow their body temperature to fall to lower levels, during the winter. However, no-one had ever conducted a detailed study on seasonal changes of torpor patterns in mammals from the tropics or subtropics. Animals like blossom-bats are faced with entirely different changes in temperature and food availability during the year than are temperate animals. In comparison to temperate areas, the seasonal climatic changes in the sub-tropics are moderate and food is available all year round, although it may fluctuate.

To conduct the seasonal study, Dionne Coburn, an Honours student at the University of New England, and I netted blossom-bats near Iluka in both summer and winter. Bats from both groups were again returned to Armidale where they were held under conditions simulating the natural day length they experienced at the time of capture. Somewhat surprisingly, the bats caught in both winter and summer exhibited daily torpor. However, when we examined our data in more detail, we could establish that torpor patterns differed between summer and winter bats, but in a way that was exactly the opposite to what had been observed in species from cold climates.

In summer, bouts of torpor were longer, lasting an average of 7.3 hours, while in winter they were only 5.5 hours. Since body temperatures and metabolic rates during torpor were lower in summer than in winter, the overall daily energy expenditure of bats

AUSTRALIAN BLOSSOM-BATS

Classification
Order Chiroptera (bats), suborder Megachiroptera (megabats), family Pteropodidae (flying-foxes, fruit-bats, blossom-bats), subfamily Macroglossinae (blossom-bats), two Australian genera, each with one species: Common Blossom-bat (*Syconycteris australis*) and Northern Blossom-bat (*Macroglossus minimus*).

Identification
Very similar in appearance. Both lack an obvious tail (although *M. minimus* has a rudimentary palpable one), have a long brush-like tongue that is used to lap nectar, and have soft reddish fur on back, lighter underneath. Head–body length about 6 cm, body mass about 18 g for *S. australis*, 16 g for *M. minimus*. *M. minimus* has a flap-like interfemoral membrane ('pyjama') on each leg, absent in *S. australis*, but it lacks the obvious upper incisors present in *S. australis*.

Distribution
S. australis: east coast of Australia north of Booti-Booti, NSW, and New Guinea. *M. minimus*: northern, tropical Australia, South-East Asia and Melanesia. The two species overlap in north-eastern Qld.

Habitat
S. australis roosts solitarily in rainforests (especially littoral rainforest) and wet sclerophyll forests, but also in banana plantations. In NSW it requires heath for feeding, not too far from roosting sites. *M. minimus* roosts individually or in small groups in palms, bamboos, mangroves and rainforests and occasionally buildings.

Food
Nectar and pollen from a number of flowering native trees and bushes, especially *Banksia*, but also *Melaleuca*, *Eucalyptus* and some rainforest species. Where the species overlap they may also eat fruits and leaves. Both species are major pollinators of a variety of native species, and are probably significant seed dispersers for some plant species.

Breeding
For *S. australis* in northern Australia and New Guinea, breeding appears non-seasonal. In NSW, one young is born in Oct./Nov. and a second between Feb. and Apr. Young suckled for up to 3 months. *M. minimus* appears to have similar breeding patterns, becoming aseasonal in far northern part of range.

Status
S. australis common where limited habitat occurs, although it is formally listed as 'Vulnerable' in NSW, under the Threatened Species Conservation Act 1995; *M. minimus* common over a wide range.

The Northern Blossom-bat, although similar in appearance to the Common Blossom-bat, is distinguished by a flap-like membrane on each leg.

B. THOMSON/NATURE FOCUS

caught in summer was reduced by almost 20 per cent relative to winter-caught bats. Initially we were baffled by this rather unexpected finding. However, after reading how the nectar of *Banksia* flowers, one of the main food sources of the Common Blossom-bat, is produced in much greater volumes in winter than in summer, it became obvious that these 'cool' bats adjust their thermal biology and energetics to food availability. In summer, not only is overall nectar availability patchy and unpredictable, but the bats also have less time to forage because of the shorter nights and have to wait throughout long days before the next feeding period arrives. We believe that, at this time of the year, torpor is particularly important.

THE COMMON BLOSSOM-BAT IS NOT THE only small Australian megabat. A slightly smaller species is the Northern Blossom-bat (*Macroglossus minimus*), which weighs only about 16 grams. While the two blossom-bats look almost the same, and their general biology and habits appear to be quite similar, the Northern Blossom-bat is only found in tropical areas. Its range does not extend into the subtropical areas of northern New South Wales. How can this difference by explained? Is it possible that the Northern Blossom-bat is incapable of using torpor and is therefore restricted to the tropics where it is easier to keep its energy budget balanced?

To answer this question, Brad's expertise was again required. He netted some Northern Blossom-bats among flowering mangroves (*Sonneratia* sp.) near Cairns, in northern Queensland. The bats were flown, all-expenses-paid by Qantas, to Armidale where they were housed just like the Common Blossom-bats and subjected to the same experimental treatments, under the watchful eye of Wendy Bartels, a Masters student at the University of New England. Our prediction that Northern Blossom-bats may not enter torpor at all was quickly shattered, because they even entered torpor in the holding room when food was freely available. A detailed examination of the data, however, revealed that the minimum temperature the animals allowed their body to fall to was about 23° C, compared to 18° C for the Common Blossom-bat. The metabolic rates during torpor of the Northern Blossom-bat were also higher. So it appears that even this tropical species uses torpor, but perhaps as one would expect, torpor is not as pronounced and deep as that of their more southerly relatives and could well be a factor limiting this species to the tropics.

F. GEISER

Although blossom-bats, like this Common Blossom-bat, live in a warm climate, they enter a period of torpor to help them balance their energy budgets.

So, through the joint effort of a lot of people, we have revealed that yet another group of mammals, the megabats, previously thought to be homeothermic, also use torpor. What makes this even more surprising is that the entire group is restricted to warm climates, emphasising that even in mild climates torpor can be important for balancing the energy budgets of mammals. Since the majority of mammals are small and therefore could benefit by entering torpor, the question arises whether strict homeothermy still qualifies as a general mammalian characteristic as presented in most textbooks. It is possible that, as our understanding of the use of torpor improves, we will find out that homeothermy in mammals is the exception and not the rule. ■

Further Reading

Coburn, D.K. & Geiser, F., 1996. Daily torpor and energy savings in a subtropical blossom-bat, *Syconycteris australis* (Megachiroptera). Pp. 39–45 in *Adaptations to the cold. Tenth International Hibernation Symposium*, ed. by F. Geiser, A.J. Hulbert and S.C. Nicol. University of New England Press: Armidale.

Geiser, F., Coburn, D.K., Körtner, G. & Law, B.S., 1996. Thermoregulation, energy metabolism, and torpor in blossom-bats, *Syconycteris australis* (Megachiroptera). *J. Zool., Lond.* 239: 583–590.

Law, B.S., 1993. Roosting and foraging ecology of the Queensland blossom-bat (*Syconycteris australis*) in north-eastern New South Wales: flexibility in response to seasonal variation. *Wildl. Res.* 20: 419–431.

Law, B.S., 1994. Climatic limitation of the southern distribution of the common blossom-bat *Syconycteris australis* in New South Wales. *Aust. J. Ecol.* 19: 366–374.

McKean, J.L., McCoy, M. & Spencer, H.J., 1995. Northern blossom-bat, *Macroglossus minimus*. Pp. 421–422 in *The mammals of Australia*, ed. by R. Strahan. Australian Museum/Reed Books: Sydney.

Associate Professor Fritz Geiser lectures in the Department of Zoology at the University of New England in Armidale, New South Wales. His main interest lies in working out the functional adaptations that allow animals to survive the demanding and often unrelenting conditions in their natural habitat. His main focus is on hibernation and torpor and he has worked on this topic since 1979.