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Hibernation in pygmy lorises (*Nycticebus pygmaeus*) – what does it mean?

Ulrike Streicher[1,3], **Julia Nowack**[2], **Gabrielle Stalder**[2], **Christian Walzer**[2], **Tilo Nadler**[3] and **Thomas Ruf**[2]

[1] Current address: Cascades Raptor Center, Eugene, USA
[2] University of Veterinary Medicine, Research Institute of Wildlife Ecology, Department of Integrative Biology and Evolution, Vienna, Austria, Savoyenstr. 1, 110 Vienna, Austria
[3] Endangered Primate Rescue Center, Cuc Phương National Park, Nho Quan District, Ninh Bình Province, Vietnam
Corresponding author: Ulrike Streicher <u.streicher1612@gmail.com>

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Summary

Torpor use in primates appeared to be restricted to African species and was only recently discovered in a species from Asia, the pygmy loris (*Nycticebus pygmaeus*). This finding has considerable implications for our perception of torpor in this mammal group and demonstrates that torpor is probably more widespread in mammals than commonly thought. This article summarizes the current knowledge on the use of torpor in the pygmy loris and places it into the context of ongoing research on this topic.

Hiện tượng ngủ đông ở loài culi nhỏ (*Nycticebus pygmaeus*) – Ý nghĩa là gì?

Tóm tắt

Hiện tượng ngủ đông ở các loài linh trưởng được cho rằng chỉ tồn tại ở một số loài linh trưởng ở Châu Phi. Gần đây hiện tượng này được khám phá ở một loài linh trưởng ở Châu Á, loài culi nhỏ (*Nycticebus pygmaeus*). Phát hiện mới này có thể thay đổi nhận thức của chúng ta về hiện tượng ngủ đông ở nhóm thú này và nó cũng minh chứng rằng hiện tượng ngủ đông có thể phổ biến ở nhiều loài thú khác hơn những gì chúng ta thường nghĩ. Bài báo này tóm tắt những kiến thức hiện tại về việc sử dụng phương pháp ngủ đông ở loài culi nhỏ và đặt ra những vấn đề cần tiếp tục nghiên cứu đối với hiện tượng này.

Introduction

Animals in highly seasonal habitats face severe seasonal fluctuations of climatic conditions and often of resource availability. Ambient temperatures can be substantially lower during the cold season than during the hot season, requiring higher energetic expenses for endogenous heat production to maintain a high body temperature. Whilst the conditions during the hot season often provide a surplus of food, animals have to deal with food scarcity or low-quality food resources during the cold season. To overcome these challenges, many small heterothermic mammals display states of energy conservation such as daily torpor that lasts less than 24 hours, or multiday torpor that lasts more than 24 hours, commonly called hibernation. Daily torpor and hibernation are both characterized by a reduced metabolic rate, decreased activity, and reduced body temperature (e.g. Bieber et al., 2014; Hoelzl et al, 2015; Ruf & Geiser, 2015).

Recently we have reported hibernation in the pygmy loris, which was the first description of hibernation in a primate outside of Madagascar (Ruf et al., 2015). The pygmy slow loris or pygmy loris (*Nycticebus pygmaeus*) is a small, solitary, nocturnal primate, distributed east of the Mekong in Vietnam, eastern Cambodia, Laos and the southernmost part of China.The species is listed as ‘Vulnerable’ on the IUCN Red list of Threatened Species, due to an estimated population decline of more than 30% over the last two decades caused by habitat loss and poaching (Streicher et al., 2008).

Evidence of torpor in the pygmy loris

Pygmy lorises are members of the same suborder as lemurs, and have a small body with a weight rarely exceeding 400 g, which accounts for a high rate of heat loss (Fig. 1). They live partly in habitats with distinct seasonal fluctuations in ambient temperatures and food availability. Both body size and the seasonality of their habitats have previously given cause to assume that lorises might use torpor, and anecdotal evidence suggested that pygmy lorises undergo bouts of torpor during the cold season (Ratajszczak, 1998; Streicher, 2004).

Fig.1. Pygmy loris (*Nycticebus pygmaeus*) at the Endangered Primate Rescue Center. Photo Ulrike Streicher.

Daily torpor can be employed fairly spontaneously and often without restriction to specific seasons (Geiser, 2013); in contrast hibernation requires preparation in the form of accumulation of substantial energy reserves, usually stored in the forms of adipose tissue (Carey et al., 2003; Geiser, 2013). Pygmy lorises showed pronounced seasonal body weight changes, weighing up to 50% more in winter than during the hot summer months (Streicher, 2005), and were regularly found rigid and unresponsive during the cold winter months (Streicher, 2004). Therefore, they were an obvious candidate for a study on thermoregulatory processes.

Five individuals, housed at the Endangered Primate Rescue Center in Cuc Phuong National Park of northern Vietnam (Fig. 2), were implanted with data loggers to record their core body temperature (Ruf et al., 2015). Torpor was defined as body temperature below 30ºC for at least one hour. For three individuals winter data was collected, and these three individuals all used torpor between late October and early April (Fig. 3) (Ruf et al., 2015). The recorded torpor bout durations varied substantially, from less than 12 hours to over 24 hours (Fig. 4). The longest torpor bout recorded was 62.6 hours. This might seem relatively short, but it is longer than the maximum bout duration in four other hibernating species (including one lemur, Table 1), and comparable to the median maximum torpor bout duration in mammals, which is only 4.8 days (Ruf & Geiser, 2015). The occurrence of multiday torpor bouts, the fact that minimum body temperatures closely resembled ambient temperatures, and the weight gain and accumulation of adipose tissue prior to the cold season all identify pygmy lorisesas seasonal hibernators (Ruf & Geiser, 2015).

Fig.2. Outdoor enclosures for lorises at the Endangered Primate Rescue Center. Photo Ulrike Streicher.

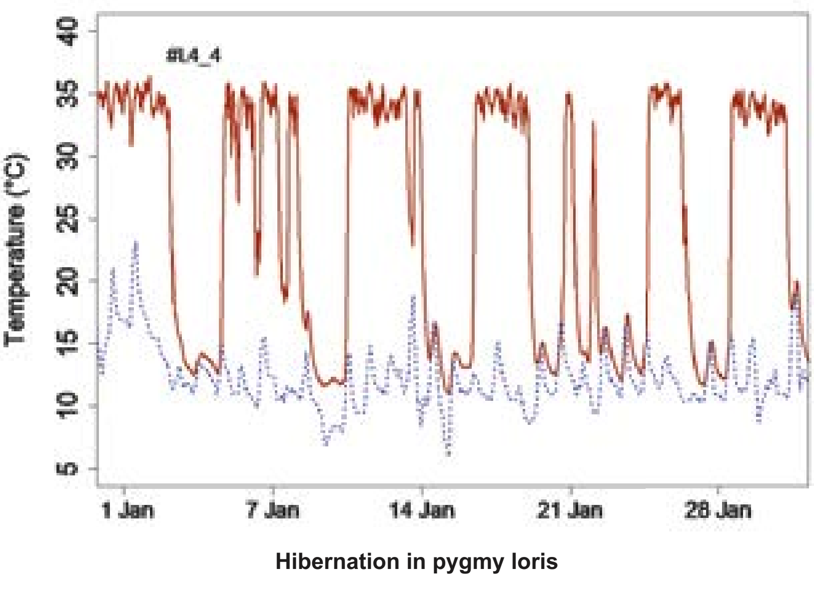

Fig.3. Core Tb (red line) in a pygmy slow lorises in midwinter, recorded over a four week period. The animal exhibited bouts of multiday torpor that is hibernation, interspersed with periods of euthermia and short torpor episodes. Blue line shows ambient air temperature.

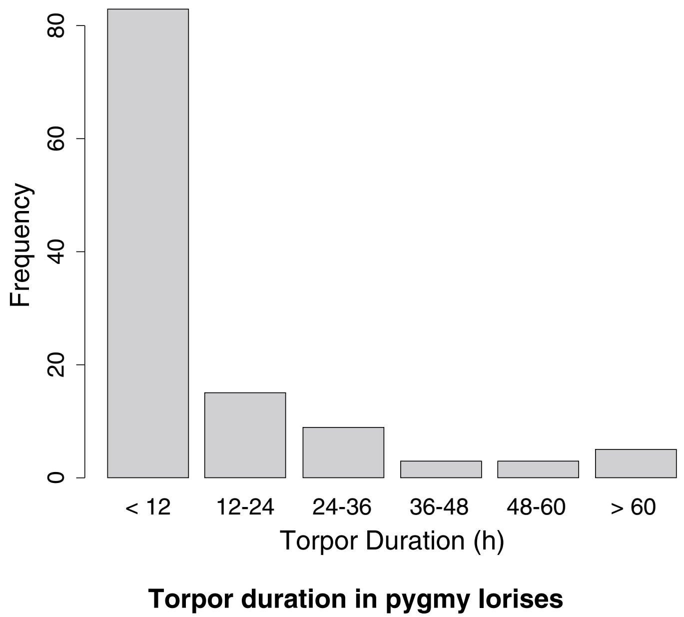

Fig.4. Animals (N = 3) exhibited both daily torpor (≤24h) or long phases of hibernation (or multi-day torpor) (≥24h).

Since study subjects were in captivity and not exposed to seasonal changes of food availability the occurrence of torpor was clearly not related to food availability. We assume torpor bout duration and frequency are even more pronounced in free-ranging individuals which experience seasonal food shortages. When provided with food *ad libitum* over winter, 'classical' hibernators such as the garden dormouse (*Eliomys quercinus*) exhibit short torpor bouts with a frequency distribution very similar to that of the pygmy loris shown in Fig. 3, with most torpor bouts lasting less than 24 hours (Daan, 1973). Torpor in the pygmy lorises was possibly triggered by ambient temperature and/or photo period, both well-known modulators of the timing of hibernationin the temperate zone (Körtner & Geiser, 2000; Malan, 1996). In contrast to many other hibernators, pygmy lorises do not retreat into burrows, but hibernate in relatively exposed locations (Streicher, 2004) and therefore are subjected exposed to highly varying ambient temperatures during torpor. The lorises predominantly entered torpor in the late night and early morning and remained torpid until the early afternoon (Ruf et al., 2015). They returned to euthermia when there was still sunlight available and well prior to the onset of their nocturnal activity, suggesting that they use sunbathing to reduce the energetic expenses required to return to euthermia after a torpor period, similar to many other tropical heterotherms (Schmid et al., 2000). Although torpor use allows for enormous energy savings, some species only use torpor opportunistically in response to acute energetic bottlenecks. There are costly trade-offs to energy savings during torpid periods such as slowed reactions (Nowack et al., 2016; Rojas et al., 2012), and reduced sensory abilities (Nowack et al., 2016) that potentially increase the risk of predation (but see Armitage, 2004; Bieber & Ruf, 2009; Turbill et al., 2011). Species using tree hollows or underground burrows are hidden and protected during torpor and often undergo hibernation for months (e.g. *Cheirogaleus sibreii*: Blanco et al. (2013); *Glis glis*: Hoelzl et al. (2015)), but pygmy lorises rest either in dense scrub or on exposed high terminal branches of trees (Streicher et al., 2003). An increased risk of predation might explain why torpor use was only observed on the coldest days during mid-winter (Ruf et al., 2015). In addition to expressing torpor and hibernation, pygmy lorises also slightly reduced their body temperature within euthermic levels on colder days, but not to levels below 30°C. Variability of body temperature likely allows lorises to remain alert and responsive to possible predators, while still permitting for energy savings (Glanville & Seebacher, 2010).

Table 1. Primate species for which heterothermy has been reported, including the maximum torpor bout duration (TBD) within the hibernation phase (in hours; not including uninterrupted hibernation when body temperature passively tracks ambient temperature. (T/H: T= daily heterotherm, H= hibernator, n.k.: not known).

Species	Common name	TBD (h)	T/H	Citation
LEMUROIDAE				
Cheirogaleus				
C. crossleyi	Furry-eared dwarf lemur	168	H	Blanco and Rahalinarivo (2010)
C. medius	Fat-tailed dwarf lemur	288	H	Dausmann et al. (2005)
C. major	Greater dwarf lemur	n.k.	H	Lahann (2007)
C. sibreei	Sibree's dwarf lemur		H	Blanco et al. (2013)
Microcebus				
M. berthae (published as M. myoxinus)	Madame Berthe's mouse lemur	19.2	T	Ortmann et al. (1997), Schmid et al. (2000)
M. griseorufus	Reddish-gray mouse lemur	61	H	Kobbe and Dausmann (2009), Kobbe et al. (2011)
M. lehilahytsara	Goodman's mouse lemur	n.k.	H	Blanco et al. (2016) Blanco et al. (2016)
M. imurinus	Grey mouse lemur	26 (captivity)	H	Schmid (2000),Schmid & Speakman (2000)
M. rufus	Brown mouse lemur	n.k.	H	Atsalis (1999), Randrianambinina et al. (2003)
M. ravelobensis	Gray brown mouse lemur	n.k.	T	Lovegrove et al. (2014)
Mirza				
M. coquereli	Coquerel's mouse lemur	n.k.	T	Dausmann (2008)
Allocebus				
A. trichotis	Hairy-eared dwarf lemur	n.k.	H	reviewed by Dausmann (2014)
LORISOIDAE				
GALAGIDAE				
Galagos				
G. moholi	African lesser bushbaby	10.1	T	Nowack et al. (2010), Nowack et al. (2013)
LORISIDAE				
Loris				
L. tardigradus tardigradus	Slender loris	n.k.	n.k.	Pers. obs. KAI Nekaris
Nycticebus				
N. javanicus	Javan slow loris	n.k.	n.k.	Pers. obs. KAI Nekaris
N. pygmaeus	Pygmy slow loris	62.6	H	Ruf et al. (2015)

Impact of the finding

Our study (Ruf et al, 2015) demonstrated that hibernation it is not restricted to primates of Madagascar. An earlier study already found daily torpor in a small primate from the African mainland, the lesser bushbaby (*Galago moholi*) (Nowack et al., 2013). However, in contrast to lorises, bushbabies only use torpor as an emergency strategy and may be unable to undergo prolonged phases of hibernation (Nowack et al., 2013). The hibernation found in an Asian primate and the daily torpor found in African bushbabies clearly indicate that these energy saving strategies are not a result of specific climatic conditions or evolutionary events unique to Madagascar, as was previously suggested (Dewar & Richard, 2007). On the contrary, torpor might have facilitated the colonization of Madagascar by lemurs and other terrestrial mammals (Kappeler, 2000; Martin, 1972; Nowack & Dausmann, 2015).

To date, torpor has been recorded in 12 lemur species of four genera of the same family in Madagascar (Table 1), one galago species in mainland Africa and one loris species in Vietnam. It is likely that further research will find hibernation and torpor in other primates living in seasonal habitats. There are also indications that the Javan slow loris (*Nycticebus javanicus*) and the slender loris, (*Loris tardigradus tardigradus*) might undergo states of decreased physiological activity such as torpor or even hibernation (Nekaris pers. com.). Tarsiers are another candidate for torpor (Lovegrove, 2012). Tarsiers are small (80–160 g), and exhibit the lowest euthermic body temperature (33.8°C) and basal metabolic rate (~65% of expected) of all primates (McNab, 1978). However, only a slight relaxation of euthermic body temperature regulation has been observed in this group with no evidence of pronounced torpor or hibernation (Lovegrove et al., 2014). Evidence of torpor in South American primates is entirely lacking (Alterman et al., 1995), but considering their small body sizes and variable climatic conditions further research might reveal torpor and hibernation among these primates as well.

Interestingly, torpor use in all primates seems to be restricted to the cold and dry season. It remains to be seen whether primates, as other hibernators (reviewed by Körtner & Geiser, 2000) have an endogeneous circannual clock that governs the timing of hibernation or if they entirely rely on external signals such as decreasing temperature and shortening photoperiod, and if primates are able to use torpor year-round in response to unexpected events.

Conclusion

We predict that, given the availability of increasingly smaller temperature recording devices with high storage capacity, torpor or hibernation will soon be detected in other primates. Many mammals and birds that are reluctant to exhibit torpor in captivity, even when kept in outdoor enclosures, readily undergo torpor in the wild (reviewed by Ruf & Geiser, 2015). Thus, it is likely that with an increasing number of studies on free-living animals the number of species known to use hibernation or daily torpor will further increase.

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