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Summer and winter torpor use by a free-ranging marsupial

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ABSTRACT

Torpor is usually associated with low ambient temperatures (T<sub>a</sub>) in winter, but in some species it is also used in summer; often in response to limited food availability. Since the seasonal expression of torpor of both placental and marsupial hibernators in the wild is poorly documented by quantitative data, we investigated torpor and activity patterns of the eastern pygmy-possum Cercartetus nanus (17.4 g) over two seasons. We used radio telemetry to track animals during winter (n = 4) and summer (n = 5) in a warm-temperate habitat and found that torpor was used in both seasons. In winter all animals entered periods of short-term hibernation (from 5 to 20 days) containing individual torpor bouts of up to 5.9 days. In summer, torpor bouts were always <1 day in duration, only used by males and were not related to daily mean T<sub>a</sub>. Pygmy-possums entered torpor at night as T<sub>a</sub> cooled, and rewarmed during the afternoon as T<sub>a</sub> increased. Individuals interspersed torpor bouts with nocturnal activity and the percentage of the night animals were active was the same in summer and winter. Our study provides the first information on torpor patterns in free-ranging C. nanus, and shows that the use of torpor throughout the year is important for energy management in this species.

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readily enters prolonged torpor at any time of the year (Hickman and Hickman, 1960; Bartholomew and Hudson, 1962; Geiser, 1993), and adjusts torpor use in response to both Tb and energy availability (Westman and Geiser, 2004). In the wild, the movements, breeding patterns and diet of C. nanus are also adjusted in response to food availability (Arnould, 1986; Tulloch and Dickman, 2005, 2007; Ward, 1990), and although information on torpor is limited to only incidental accounts, individuals have been found torpid in all seasons (Bladon et al., 2002). The aim of our study was to investigate whether C. nanus hibernates in the wild, how torpor use is affected by season, and to compare our findings with available data on B. parvus and C. concinnus. Therefore, we monitored body temperature (Tb) in free-ranging individuals during both summer and winter using radio telemetry. Based on the expression of heterothermy in related species, we expected torpor to be used more in winter than in summer.

2. Material and methods

This study was carried out in Macpherson State Forest, a semi-open sclerophyll forest in eastern New South Wales, Australia (33°16′ S, 139°9′ E), which is characterised by warm summers and cool winters (see Fig. 1). Five C. nanus (2 females, 3 males; 17.0±2.6 g) were trapped in November–December 2008 (herein referred to as “summer”) and four (2 females, 2 males; 18.0±4.3 g) in May–June 2009 (“winter”). Captures were made using wooden nest boxes, arboreal PVC pipe traps (adapted from Winning and King, 2008), and 15×50 cm PVC pipe pitfall traps with drift fences. Individuals were transported to a field laboratory, kept under natural photoperiod for less than one week, and fed daily with pureed and fresh fruit and a nectar substitute consisting of high protein baby cereal, honey and a vitamin supplement. Water was provided ad libitum.

To measure Tb we used sterilised temperature-sensitive FM radio transmitters (0.5–1.1 g BD-2TH; Holohil Systems Ltd, Canada), which were coated in an inert wax and calibrated to the nearest 0.1 °C in a water bath from 2 to 42 °C at −7 °C increments using a mercury thermometer traceable to the national standard. Transmitters were implanted into the intraperitoneal cavity of C. nanus under inhalation anaesthesia of isoflurane in oxygen. All transmitters were <10% of an individual’s body mass, which is within the range permitting unhindered locomotion in small terrestrial mammals (Rojas et al., 2010). The incision was sutured closed using Coated Vicryl (muscle layer; 2.0 metric, Ethicon Inc.). After the procedure a local anaesthetic of iso-flurane in oxygen was administered to the surgical site. Animals were warmed immediately after surgery and once conscious fed a sweet algelics (Metacam, Boehringer Ingelheim, North Ryde, NSW, Australia). Animals were allowed to recover for ~48 h after surgery and the local anaesthetic and analgesic were administered daily. Before release at sunset at the point of capture a final application of the spray bandage was issued to ensure wound integrity. Animals were not recaptured after this release.

Individuals were located daily using radio receivers (Telonics TR-4 and Icom IC-R10) with Yagi antennas (AY/C, Titeley Scientific, Australia). The Tb of individual animals was measured remotely at 10 min intervals using mobile logger/receivers (see Körtner and Geiser, 1998 for details). Data were downloaded every 3–10 days. The short transmitter detection range of the logger/receivers (~20 m) required their frequent relocation and resulted in a loss of signal if an animal changed its nesting spot, so not all torpor entries were recorded. Manual Tb readings were taken using a receiver and a stopwatch several times each day. Activity periods were inferred from an absence of data recorded by the loggers.

The temperature characteristics of six out of the nine transmitters evidently drifted during the course of the study so no absolute Tb values are presented (but see below). However, the data clearly show times when animals were torpid and normothermic. Torpor bout duration was defined as the time period between the time an individual’s Tb began to cool at the onset of torpor before reaching low and stable torpid values, and the time when it rewarmed to normothermia (Willis et al., 2005a). Specifically, we defined entry into torpor as the time of the first Tb measurement after the initial steep Tb decrease below normothermia (see Fig. 2). The start of rewarming from torpor was the time of the first Tb value elevated above those of stable torpor at the beginning of the characteristic steep Tb increase, and the end of rewarming was the last point of this increase before stable normothermic Tb was reached (Fig. 2). We use the terms “short torpor” to describe a torpor bout <24 h in duration, “prolonged torpor” for torpor bouts >24 h in duration, and “hibernation” for a series of two or more prolonged torpor bouts, interrupted by rewarming to normothermia without activity.

Tb was measured to the nearest 0.5 °C using small data loggers (DS 1921G Thermochron iButtons; Dallas Semiconductor, USA; n = 12 in summer, 18 in winter) that were placed ~1 m above ground in the shade in various locations in the study site that were likely to be encountered by C. nanus, for example near food trees or nesting sites. The mean of all logger temperature readings was used in the analyses, and is referred to as “Tl”. To determine whether nest sites provided thermal buffering from daily Tb variation, additional loggers (n = 4 in both seasons) were placed inside (Ton) and outside (Tout) two occasionally used nest sites (a dead branch of a fallen tree and a small tree hollow). Additional climate data were obtained from the Australian Bureau of Meteorology (http://www.bom.gov.au).

Data analyses were conducted using R 1.8. Differences among means (means of means for each individual) were evaluated using one-way ANOVA (effect of time on torpor use), paired t-tests (Ton and Tout comparisons) and unpaired t-tests (Tl activity and body mass comparisons). The frequency of torpor bouts in each season and the influence of rain on torpor use were analysed using a chi-squared test. Linear regressions were used to examine the effect of body mass, Tb and activity duration on torpor bout length. The timing of torpor entry and rewarming was tested for non-random distribution using a Rayleigh’s test (significance of the mean angle using an r-value derived from a calculated z-value), after which a Watson-Williams test (WW; significance of a pairwise comparison using a calculated F-statistic) was used to compare times among these variables (Zar, 1999). Data are presented as mean ± 1 SD; n denotes the number of individuals, N the number of measurements.

To allow the visualisation of Tb data despite transmitter drift, we drift-corrected a 30-day Tb trace for each season. During normothermia the average Tb at the beginning of the study for a five-day period without drift was 37.5±0.3 °C (n = 2), and drifted normothermic Tb was adjusted to match. In winter, torpid Tb values were adjusted by assuming Tb − Tl = 1.9 °C during steady-state torpor (DT; Song et al., 1997). Daily Tb variation was then scaled to match the mean daily variation in Tmean. In summer, the minimum Tb during a torpor bout was assumed to be the same as daily minimum Tb, which is likely an overestimation of their depth because the torpor bouts were short (<5.5 h in duration), however Tmean was not available for the time period. Tb during entry into and rewarming from torpor was then scaled according to the corrected normothermic and torpid Tb values.

3. Results

3.1. Ambient conditions

The average daily minimum Tb during the winter tracking period (8.9±2.6 °C; 2.2–12.8 °C) was significantly lower than in summer (14.1±2.0 °C; range 9.0–18.6 °C; t56 = 9.18, p < 0.001; Fig. 1). Similarly, the average daily maximum Tb during winter (16.5±2.0 °C; 13.0–20.8 °C) was lower than in summer (26.2±4.7 °C; 17.5–36.1 °C; t56 = 11.94, p < 0.001; Fig. 1). The mean Tb of the second half of the
winter tracking period (10.4±1.6 °C) was cooler than the first
(13.0±1.1 °C; t30 =5.45, p <0.001), but this was not observed in
summer (t36 =0.56, p=0.582). In both seasons C. nanus
were usually
found nesting in the hollow stumps of dead trees or in dead branches
of living Angophora costata, Banksia serrata or Eucalyptus spp. In
winter Tm fluctuated signiﬁcantly less (daily amplitude=7.0±
2.5 °C) than Tout (9.8±4.5 °C; t30=6.74, p<0.001), and the same
pattern was observed in summer (Tm daily amplitude=11.3±4.5 °C,
Tout=14.7±5.4 °C; t30=9.21, p<0.001). One individual used a nest
site containing Tm/Tout data loggers on a single occasion but gave no
indication that it was disturbed by any ultrasonic noise that may have
been emitted by the devices (see Willis et al., 2009). In winter rain
was recorded on 74% of tracking-days (7.0±10.2 mm day−1) and
51% in summer (6.7±9.9 mm day−1). Sunrise and sunset during
winter were at 07:40 h±5 min and 17:44 h±2 min, respectively
day/night length 10.1/13.9 h), and during summer were 05:33 h±
6 min and 19:27 h±11 min (13.9/10.1 h).

3.2. Torpor expression

Individual C. nanus were radio-tracked for 28.5±5.4 days in
winter and 34.8±5.4 days in summer (Table 1). Torpor bouts were
easily identiﬁed despite the drifting transmitters (Fig. 2) and torpor
was used in both winter and summer (Fig. 3). In winter, animals were
found torpid on 63.2% of possum-days (n=4, N=72), but only on
10.3% in summer (n=3, N=18; Table 1, Fig. 4), and we found that
torpor was employed more often in winter compared to summer
(χ2 =89.42, p <0.001). We measured 13 complete torpor bouts in
winter, six in summer, and observed 47 individual bouts in total (the
time of torpor entry could not be determined for some bouts when an
animal had changed nest sites the night before). All individuals
entered torpor in winter (n=4, N=29), but in summer only the
males used torpor (n=3, N=18). During both seasons torpor
patterns were variable among individuals as different animals were
often either torpid or normothermic on the same day (16/27 days
when torpor was used in winter, 12/13 in summer; Figs. 4 and 5).
In winter both short torpor bouts (duration <24 h; N=11) and
prolonged torpor bouts (duration >24 h; N=18) were used (Figs. 3
and 5), whereas in summer C. nanus only entered short torpor bouts
(N=18; Figs. 3 and 5). In winter the length of an additional two
torpor bouts could not be classiﬁed as short or prolonged because
torpor entries were not recorded. The number of days torpor was
used did not differ between the ﬁrst and second halves of the study
periods in either winter (F2,5 =3.15, p=0.130; n=4) or summer
(F2,3 =5.96, p=0.090; n=3), suggesting no effect of date on torpor
use within a season. In winter, individuals were more likely to enter

| Table 1 | Torpor variables for pygmy-possums radio-tracked in winter and summer. |
| Season | Winter | Summer |
| ID | CnU | CnV | CnW | CnX | CnC | CnD | CnE | CnF | CnG |
| Sex | f | f | m | m | f | f | m | m | m |
| Mass (g) | 24.0 | 15.4 | 14.4 | 18.2 | 14.4 | 21.1 | 15.3 | 17.4 | 16.8 |
| Days tracked | 26 | 33 | 22 | 33 | 26 | 40 | 36 | 38 | 34 |
| Total torpor bouts | 6 | 11 | 6 | 6 | 0 | 6 | 6 | 6 | 6 |
| Short bouts | 2 | 6 | 1 | 1 | 0 | 0 | 6 | 6 | 6 |
| Prolonged bouts | 4 | 4 | 4 | 5 | 0 | 0 | 0 | 0 | 0 |
| Unclassiﬁed bouts | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Days torpor used (%) | 50.0 | 45.5 | 100.0 | 66.7 | 0 | 0 | 16.7 | 15.8 | 17.6 |

Fig. 1. Ambient temperature (Ta) at the study site during summer 2008 and winter
2009. The upper and lower solid lines indicate respectively average daily maximum
and minimum Ta, the dotted lines are daily average Ta.

Fig. 2. Drift-corrected body temperature (Tb; circles and solid line) of the one
individual during winter included in Fig. 3. Arrows point to the Tb values used for
classifying the beginning of entry into torpor (“Torpor entry start”), the start of
rewarming from torpor (“Rewarming start”), and the end of rewarming from torpor
(“Rewarming end”). The dotted line is ambient temperature (Ta) and the dark bars
indicate the scotophase.

Fig. 3. Drift-corrected body temperature (Tb; circles and solid line) for one individual
during winter included in Fig. 3. Arrows point to the Tb values used for
classifying the beginning of entry into torpor (“Torpor entry start”), the start of
rewarming from torpor (“Rewarming start”), and the end of rewarming from torpor
(“Rewarming end”). The dotted line is ambient temperature (Ta) and the dark bars
indicate the scotophase.
torpor on days without rain ($\chi^2 = 4.84, p = 0.028$), but rainfall had no effect on torpor use in summer ($\chi^2 = 1.61, p = 0.205$).

The average duration of short torpor bouts in winter of $7.3 \pm 3.7$ h (range 3.7–12.7 h; $n = 2, N = 6$) was longer than the duration of short bouts in summer ($3.8 \pm 1.4$ h; 2.3–5.5 h; $n = 3, N = 6$; $F_{3,3} = 9.74, p = 0.021$). The length of the prolonged bouts in winter was $101.1 \pm 37.2$ h (41.6–140.9 h; $n = 2, N = 7$). Body mass at the time of capture did not differ between seasons ($t_{3} = 0.43, p = 0.677$) and had no discernible effect on maximum torpor bout duration ($R^2 = 0.002, F_{1,5} = 0.011, p = 0.922$). In winter, all animals entered periods of short-term hibernation (between two and five successive prolonged torpor bouts) of up to three weeks, without leaving their nest sites (Figs. 3 and 5).

Short torpor bouts were always preceded by a period of activity, although no significant relationship was found between the length of the activity period and the duration of the ensuing torpor bout ($R^2 = 0.019, F_{1,7} = 0.14, p = 0.722$; $n = 5, N = 9$). Activity preceded a prolonged torpor bout on four occasions ($n = 3$), and each individual used a short torpor bout the day before a period of hibernation ($n = 4, N = 5$). Within a period of hibernation the duration of normothermic periods, after animals had periodically rewarmed from torpor, was $3.3 \pm 1.2$ h (range 1.7–5.8 h; $n = 4, N = 11$).

During winter, the mean $T_a$ of nights on which animals entered torpor ($5.9 \pm 0.7$ °C; $n = 4$) did not differ from those when they did not ($11.1 \pm 0.8$ °C; $n = 3$; $t_{2} = 2.17, p = 0.082$), and there was no difference in $T_a$ between nights animals entered short (10.2 ± 2.0 °C; $n = 4$) or prolonged torpor bouts ($10.1 \pm 1.2$ °C; $n = 4$; $t_{3} = 0.06, p = 0.957$). In summer the average $T_a$ of nights that C. nanus entered torpor ($16.1 \pm 0.6$ °C; $n = 3$) did not differ from those where they remained normothermic ($16.1 \pm 0.2$ °C; $n = 3$; $t_{2} = 0.03, p = 0.981$). Torpor bout duration and mean minimum daily $T_a$ were not correlated in summer ($R^2 = 0.067, F_{1,4} = 0.29, p = 0.620$; $n = 3, N = 6$) or winter ($R^2 = 0.02, p = 0.693$; $n = 4, N = 13$). In winter the mean $T_a$ of days that animals rewarmed from prolonged torpor ($13.7 \pm 1.0$ °C; $n = 4$) did not differ from those where they remained torpid ($12.9 \pm 0.9$ °C; $n = 4$; $t_{3} = 1.80, p = 0.170$), nor did it differ between rewarming from short ($14.1 \pm 1.1$ °C; $n = 4$), and prolonged torpor bouts ($13.7 \pm 1.0$ °C; $n = 4$; $t_{3} = 0.35, p = 0.747$).

### 3.3. Torpor timing

The time of torpor entry was non-randomly distributed for prolonged winter bouts (22:05 h ± 200 min; $z = 4.68, r = 0.68, p = 0.006$; $n = 4, N = 10$) and short winter bouts (02:40 h ± 176 min; $z = 3.89, r = 0.75, p = 0.015$; $n = 3, N = 7$), but not for short summer bouts, although it was close to significance ($06:29 h \pm 198 min; z = 2.84, r = 0.69, p = 0.052$; $n = 3, N = 6$; Fig. 6a). Entry times did not differ between summer and winter for short bouts ($F_{3,12} = 4.17, p < 0.05, WW$), but did differ between short and prolonged bouts in winter ($F_{3,15} = 7.88, p < 0.025, WW$).

The timing of initiation of active rewarming from torpor had a non-random distribution for short bouts in summer (10:14 h ± 124 min; $z = 8.20, r = 0.86, p < 0.001$; $n = 3, N = 11$) and prolonged bouts in winter (15:07 h ± 135 min; $z = 8.48, r = 0.84, p < 0.001$; $n = 3, N = 12$), but not for short winter bouts (10:51 h ± 274 min; $z = 1.91, r = 0.49, p = 0.149$; $n = 4, N = 8$; Fig. 6b). The timing did not differ between the summer and winter short bouts ($F_{1,17} = 0.13, p > 0.5, WW$), but occurred later for prolonged bouts than short bouts in winter ($F_{3,16} = 6.22, p < 0.025, WW$).

Animals took longer to rewarm from short torpor bouts in winter (1.3 ± 0.5 h; $n = 3, N = 7$) than summer (53.7 ± 10.3 min; $n = 3, N = 11$; $F_{3,11} = 4.03, p < 0.022$). There was no difference in rewarming duration between short and prolonged (1.9 ± 0.8 h; $n = 4, N = 12$) bouts during winter ($F_{3,7} = 1.36, p = 0.296$).

### 3.4. Activity

Animals were nocturnal and left their nest sites 14.4 ± 56 min after sunset in winter ($n = 4, N = 44$), and 7.1 ± 47 min in summer ($n = 5, N = 125$). They arrived back at their nest sites 2.9 ± 2.4 h before sunrise in winter ($n = 4, N = 32$), and 1.3 ± 1.2 h in summer ($n = 5, N = 158$). On days when torpor was not used, the percentage of the night animals were active did not differ between winter (79.3 ± 10.6%; $n = 3, N = 26$) and summer (82.5 ± 5.2%; $n = 4, N = 12$; $t_{5} = 0.52, p = 0.624$). Accordingly, the total time animals were active was longer in winter (11.0 ± 1.5 h) than in summer (8.3 ± 0.6 h; $t_{5} = 3.36, p = 0.020$).

### 4. Discussion

Our study provides the first quantitative information on torpor use by free-living C. nanus, and is one of the few documenting torpor patterns of any species in both summer and winter in the wild. We observed flexibility in torpor use, as different individuals were often...
torpid and normothermic on the same day (Figs. 3 and 4). Torpor was used more extensively in winter than in summer. In winter we observed periods of hibernation lasting in excess of 18 days, containing individual torpor bouts of up to 5.9 days.

Laboratory studies have suggested that C. nanus is an opportunistic hibernator. Torpor bouts of captive animals increased in duration and depth with decreasing Ta, with a torpid ΔT of −1–2 °C, and individuals entered bouts of prolonged torpor at any time of the year (Bartholomew and Hudson, 1962; Geiser 1993; Song et al. 1997). Indeed, when held under cold conditions with food withdrawal fat individuals hibernated for up to a year, the longest period of hibernation recorded for any mammal (Geiser, 2007). In free-ranging individuals we observed broad seasonal differences in torpor expression as expected: the shorter torpor bouts in summer and longer bouts in winter were consistent with this species’ response to Ta in captivity. Interestingly, we did not see a finer scale influence of Ta on torpor use. The nights that animals entered torpor were about the same Ta, as those where they remained normothermic, in both seasons. Further, in winter the Ta of days that C. nanus rewarmed from torpor did not differ from those days they remained in prolonged torpor. This differs from the closely related C. concinus, which entered torpor on nights that were colder than those when it did not employ torpor (Turner et al. 2012). Additionally, C. concinus rewarmed from prolonged torpor once nest site temperature reached a Ta threshold (Turner et al. 2012), similar to some bats (Nyctophilus spp.; Turbill and Geiser, 2008). This indicates that, unlike C. concinus, day-to-day Ta fluctuations were not an important factor influencing the torpor patterns of C. nanus.

Even though average Ta per se did not seem to influence torpor expression, entry into torpor always took place at night as Ta cooled, and reawakening from torpor occurred during the day as Ta increased towards the daily maximum. Individuals rewarmed from short torpor bouts late morning and prolonged torpor in the early afternoon. Allowing torpid Tb to increase with Ta is a strategy often used by heterotherms to reduce energy expenditure (Lovegrove et al., 1999; Schmid et al., 2000; Warnecke and Geiser, 2010), however since the animals in our study selected nest sites that were buffered from daily Ta variation, passive reawarming did not appear to be of particular importance. The amount of time required for animals to reawarm from torpor appeared to be more dependent on Ta (and probably Tb) than torpor bout length because it took longer to reawarm from short torpor bouts in winter than summer. This is most likely because individuals lowered their Tb and metabolic rate during torpor further in winter, when Ta was lower, compared to summer. This resulted in deeper torpor bouts and therefore an increased time required for reawarming to normothermia (Song et al., 1997). Additionally, the time it took to reawarm did not differ between short and prolonged torpor in winter. The similar reawarming times suggest that C. nanus is able to quickly achieve large energy savings by cooling Tb to just above Ta, which it can do during torpor bouts as short as 3 h (Song et al., 1997).

We assume that torpor and activity patterns in C. nanus were an indirect result of Ta influencing food availability, similar to other small hibernating species (e.g. Wojciechowski et al., 2007; Turbill and Geiser 2008). In most Australian habitats the seasonal change in weather and food availability is less severe than those occupied by seasonal hibernators on other continents, and can be highly variable within and among years. The primary food items of C. nanus are nectar and invertebrates (Turner, 1985; Arnould, 1986; Huang et al., 1986), which are available year-round, but usually decrease in abundance in winter because of the lower Ta (Smith, 1982; McFarland, 1985). The proportion of the night that individuals spent active was similar to C. concinus (Turner et al. 2012), and agrees with the relationship between body mass, prey item energy content and activity suggested by Jackson and Johnson (2002) for possums. Even though C. nanus can potentially find food during any season, negating the need for extensive autumnal fattening and extended seasonal hibernation, it can be inferred that lower winter Ta affected foraging success and as a result, torpor was triggered more often in winter (Matheson et al., 2010; Schubert et al., 2010). Conversely, summer torpor was infrequent because food resources were likely more abundant. This ability to opportunistically adjust torpor use in response to food availability is likely to be crucial for energy management.

Interestingly, in summer only the males entered torpor, whereas in winter both sexes did. Although our small sample size demands caution, we will discuss potential implications. We suggest that the
males in summer may have invested considerable time searching for females instead of food, resulting in decreased nightly energy acquisition and hence the need for torpor. This hypothesis seems plausible based on year-round male fertility (Ward, 1990), combined with a larger male home range size (Laidlaw and Wilson, 1996; Harris et al., 2007), which can be attributed to a larger effort made by males to find mates (Moraes and Chiarello, 2005). The lack of summer torpor in some female bats (Dietz and Kalko, 2006) and hedgehogs (Fowler, 1988) may be attributed to pregnancy and ensuring rapid foetal development (Racey, 1969), however pregnancy and torpor are not always mutually exclusive (Audet and Fenton, 1988; Kurta and Kunz, 1988; Körtner et al., 2008). More C. nanus births occur in summer than in winter, which appears to correlate with increased female body mass and therefore food availability (Turner, 1985; Turner et al., 2012). Individuals do not fatten on a day-to-day basis, animals may spend several weeks at a time either active, likely foraging, throughout the winter like C. nanus, or inactive between torpor bouts. As torpor use is adjusted on a day-to-day basis, the immediate trigger for torpor in B. parvus is probably more related to Tb-affected seasonal differences in food availability. This likely affected the nutritional status of individuals after a period of activity, resulting in individual flexibility in torpor employment independent of Tb. Hence, in addition to broad seasonal changes in torpor expression, C. nanus also has the ability to employ torpor opportunistically on a finer scale. This is a strategy likely beneficial for energy conservation, which would aid the survival of such a small and vulnerable species in an area where introduced predators and habitat destruction are threats.

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