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Proc. R. Soc. B 2014 **281**, 20141304, published 22 October 2014

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Cite this article: Lovegrove BG, Lobban KD, Levesque DL. 2014 Mammal survival at the Cretaceous–Palaeogene boundary: metabolic homeostasis in prolonged tropical hibernation in tenrecs. *Proc. R. Soc. B* **281**: 20141304. <http://dx.doi.org/10.1098/rspb.2014.1304>

Received: 29 May 2014

Accepted: 22 September 2014

Subject Areas:

evolution, physiology, ecology

Keywords:

mammals, hibernation, Cretaceous–Palaeogene boundary, Madagascar, *Tenrec ecaudatus*

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Electronic supplementary material is available at <http://dx.doi.org/10.1098/rspb.2014.1304> or via <http://rspb.royalsocietypublishing.org>.

Mammal survival at the Cretaceous–Palaeogene boundary: metabolic homeostasis in prolonged tropical hibernation in tenrecs

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Free-ranging common tenrecs, *Tenrec ecaudatus*, from sub-tropical Madagascar, displayed long-term (nine months) hibernation which lacked any evidence of periodic interbout arousals (IBAs). IBAs are the dominant feature of the mammalian hibernation phenotype and are thought to periodically restore long-term ischaemia damage and/or metabolic imbalances (depletions and accumulations). However, the lack of IBAs in tenrecs suggests no such pathology at hibernation $T_{bs} > 22^{\circ}\text{C}$. The long period of tropical hibernation that we report might explain how the ancestral placental mammal survived the global devastation that drove the dinosaurs and many other vertebrates to extinction at the Cretaceous–Palaeogene boundary following a meteorite impact. The genetics and biochemistry of IBAs are of immense interest to biomedical researchers and space exploration scientists, in the latter case, those envisioning a hibernating state in astronauts for deep space travel. Unravelling the physiological thresholds and temperature dependence of IBAs will provide new impetus to these research quests.

1. Introduction

At the Cretaceous–Palaeogene (K–Pg) boundary about 65.5 million years ago (Ma) the ancestor of the placental mammals (Eutheria) survived the meteorite impact at Chicxulub, Mexico [1], which killed the non-avian dinosaurs and many other animals and plants [2–4]. A small (6–245 g), insectivorous ancestor inherited a tropical Earth, along with a few egg-laying mammals (Montremata), some marsupials (Metatheria) and a few lineages (e.g. Multituberculata) which went extinct during the Cenozoic [2]. Ecological release from the vice grip which the dinosaurs held over Mesozoic mammals drove remarkably rapid evolutionary processes within several hundred thousand years of the extinction event [2]. Four new placental lineages (Xenarthra, Afrotheria, Laurasiatheria and Euarchontoglires) [2] appeared very suddenly, harbouring forms that displayed spectacular new morphological and physiological characteristics [5–8]. The long *ca.* 160 Myr stint of the nocturnal, small, insectivorous mammal was over, and gave way to the age of the mammals, the Cenozoic. Yet, no placental mammal would exist today had this ancestor not survived the global short- and long-term effects of the Chicxulub impact [3,4] and an Indian Ocean meteorite impact 40 000 years later [9]. How did this placental ancestor, as well as the monotremes and the marsupials, survive when so many other vertebrate groups did not?

There is growing debate about whether the ballistic impact ejecta that re-entered the Earth's atmosphere following the Chicxulub impact could have generated an initial infrared heat pulse sufficient to ignite wildfires globally [10–15]. If global wildfires did occur, they would undoubtedly have been responsible for the extermination of all mammals that could not seek safe refuge from the short- and long-term effects of the fires. Indeed, it is the