Reply to Brook et al: No empirical evidence for human overkill of megafauna in Sahul

We welcome comments by Brook et al. (1), supporters of human-driven models, on our review of the role of climate in Pleistocene faunal extinctions in Sahul (Pleistocene Australia–New Guinea) (2). In response, we begin on a point of agreement: the fossil fauna record on which our respective arguments are based is sparse, although our understanding of Pleistocene environmental conditions is improving (3–5). However, we also flag a basic point of difference. Unlike Brook et al., who focus on the ∼50 extinct Australian species (an artificial distinction because Australia was part of the larger landmass Sahul) and the 50 ka since human arrival, we consider the bigger picture, and the 88 large taxa that disappeared from Sahul from ∼450 ka.

We interpret the record as a result of climate-driven losses. Since Miocene times, the Earth has experienced cooling conditions that became more pronounced in the Pliocene, whereas climatic inconstancy was a distinct feature of the middle-late Pleistocene (5). This is not speculation, as Brook et al. state, but long-established fact. Glacial–interglacial cycles of the middle-late Pleistocene undeniably became more extreme, arguably since Marine Isotope Stage (MIS)16 (∼650 ka), but clearly since ∼450 ka (5). Of the 88 taxa now extinct in Sahul, 34 are unknown from deposits younger than ∼450–400 ka, an additional 16 disappear by ∼130 ka, and another 24 are absent from deposits <50 ka, leaving only 8–14 species clearly present when humans arrived. An increasing body of evidence suggests that the period leading up to the last glacial maximum (LGM; MIS4 and MIS3) was characterized by marked climatic variability (4, 5). The most parsimonious interpretation of these data is that the extinction process unfolded over multiple glacial cycles, with most now-extinct taxa gone before human arrival and subsequent extinctions occurring against a backdrop of significant climate change. Our climate-based argument is not dependent on each of the most recent glacial–interglacial cycles being more extreme or that the last was necessarily the most severe, although support grows for this contention (3, 6).

The human-driven scenario offered by Brook et al. invites the reader to first assume that all now-extinct megafauna were present at 50 ka, despite a complete lack of evidence for many since ∼400–450 ka and for most since ∼130 ka. Brook et al. assert that this can be explained as an as yet empirically undemonstrated statistical anomaly.

Reliance on a priori assumptions aside, a further fundamental shortcoming of their model is the failure to demonstrate any association/interaction of humans with megafauna. We recognize that Brook et al. believe that Cuddie Springs and other sites with late-surviving megafauna are controversial. However, Cuddie Springs represents the only Australian site with evidence of humans and megafauna in the same place at the same time. If rejected, then there is no direct evidence that people ever encountered any of the vertebrates they purportedly drove to extinction. Furthermore, the number of species accepted as overlapping with humans falls from 8–14 to 4. In the absence of empirical evidence for human–megafauna interaction, Brook et al. rely on tenuous proxy data and computer modeling to bolster their arguments (see references in ref. 2).

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1 Brook BW, et al. (2013) Lack of chronological support for stepwise prehuman extinctions of Australian megafauna. *Proc Natl Acad Sci USA* 110:E3368.

2 Wroe S, et al. (2013) Climate change frames debate over the extinction of megafauna in Sahul (Pleistocene Australia-New Guinea). *Proc Natl Acad Sci USA* 110(22):8777–8781.

3 Price GJ (2013) Quaternary. *Geology of Queensland*, ed Jell PA (Geological Survey of Queensland, Queensland, Australia), pp 653–685.

4 Cohen TJ, et al. (2012) Late Quaternary megalakes fed by the northern and southern river systems of central Australia: Varying moisture sources and increased continental aridity. *Palaeogeogr Palaeoclimatol Palaeoecol* 356-357:89–108.

5 Lisiecki LE, Raymo ME (2005) A Pliocene-Pleistocene stack of 57 globally distributed benthic delta O-18 records. *Paleoceanography* 20(1):PA1003.

6 Prescott GW, Williams DR, Balmford A, Green RE, Manica A (2012) Quantitative global analysis of the role of climate and people in explaining late Quaternary megafaunal extinctions. *Proc Natl Acad Sci USA* 109(12):4527–4531.

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