LETTER

Lack of chronological support for stepwise prehuman extinctions of Australian megafauna

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The most enduring and high-profile scientific debate in Australian prehistory is that surrounding the loss of more than 50 species of endemic, large-bodied vertebrates (megafauna) and the timing of these extinctions (1). Wroe et al. (2) present a personal perspective on some of the available literature to reject the scenario of rapid, continent-wide losses, and downplay any role for human agency. They contend that different species of megafauna went extinct progressively during the Middle and Late Pleistocene, with many "disappearing" long before human hunters arrived, leaving climate change as the alternative explanation. However, these conclusions rely on a biased selection of data and disregard several underlying geochronological constraints.

The arguments of Wroe et al. for an extended overlap between late-persisting megafauna and humans after 40,000 y ago rest largely on secondary dating of sediments and charcoal from Cuddie Springs. However, they ignore recent direct dating of primary material (megafaunal remains) from this contentious site, which show the fossils to be more than 50,000 y old (3). Claims for late survival of megafauna at other sites, including Nombe and Seton Rockshelters, are also based on contested radiocarbon dates (1).

Wroe et al. summarize (in their table S1) the youngest ages for 88 megafaunal taxa in late Quaternary Australia and New Guinea and infer a pattern of stepwise cumulative extinctions, with 22 species surviving to cooccur with humans. They speculate that the other taxa were driven extinct before human arrival, raising the idea that climate progressively worsened over multiple glacial–interglacial cycles (we will address the latter claim elsewhere). The hypothesis of prehuman extinctions is statistically unsupported. Importantly, for instance, more than 60% of the prehuman taxa are known from only one or two dated records, so little can be inferred about their temporal duration. Sites where intensive sampling has been possible (Naracoorte and Tight Entrance Caves) reveal a pattern of repeated local losses in response to climatic fluctuations, but with the subsequent reappearance of most species (4).

A staggered extinction event could only be demonstrated if the complex sampling issues with incomplete fossil records and chronological uncertainties were adequately taken into account, but Wroe et al. largely ignore these critical prerequisites. Instead, they imply that resampling analyses of a few dates from a single hydraulically sorted site in southeastern Queensland is a valid basis for dismissing taphonomic or sampling biases across the continent; clearly, robust statistical models are required to integrate these factors rigorously (5). To date, there has been no convincing demonstration that most apparently prehuman Pleistocene extinctions in Australia are not simply an artifact of incomplete fossil survival and sampling bias.

Determining the causes of past extinction events requires careful weighing of different forms of evidence (1), development of new datasets (3, 4), or improved quantitative integration of existing knowledge (5) and application of hypothesis-driven approaches that are ecologically framed (see ref. 40 provide in ref. 2). Wroe et al. do not meet these criteria and exclude (or misinterpret) most of the key evidence and ecological arguments against a climate-driven explanation for Pleistocene megafaunal extinction.

1 Johnson CN (2006) *Australia's Mammal Extinctions: A 50,000 Year History* (Cambridge Univ Press, Melbourne, Australia).
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 Grün R, et al. (2010) ESR and U-series analyses of faunal material from Cuddie Springs, NSW, Australia: implications for the timing of the extinction of the Australian megafauna. *Quat Sci Rev* 29(5-6): 596–610.
4 Prideaux GJ, et al. (2007) Mammalian responses to Pleistocene climate change in southeastern Australia. *Geology* 35(1):33–36.
5 Bradshaw CJA, et al. (2012) Robust estimates of extinction time in the geological record. *Quat Sci Rev* 33:14–19.

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