

Reply to Evans and Bar-Oz et al.: Recovering ecological pattern and process in Ancient Egypt

Our recent paper used artistic depictions of animals and fossil evidence to examine the community-level effects of local extinction events over 6,000 y of Egyptian history (1). We found that local extinctions were non-random, that changes to community structure (quantified by the species predator/prey ratio) seemed to correspond to local aridification pulses, and that the decline in species richness throughout Egyptian history resulted in a drop in dynamic stability because of the elimination of smaller-bodied herbivores.

In response to our paper, Bar-Oz et al. (2) note complimentary faunal changes in the Levant, an area that did not experience such large climatic swings (pointing to human impacts as the primary driver of change). Evans (3) offers two critiques of our work: (i) that the time of extinction as recorded by historical artwork may not correspond to the actual time of disappearance (potentially compromising our results), and (ii) that community-level changes may correspond to cultural rather than ecological shifts.

With respect to Evan's (3) first critique, our paper includes an analysis of paleontological and archaeological data that confirm the broad temporal pattern of first and last appearances in the artistic record (1). Sensitivity analyses that incorporated error in the timing of extinctions (± 580 y), as well as flexible assumptions about species interactions and network structure, did not influence the qualitative predator/prey trajectory or the decline in stability over time. We explored the potential impact of species-specific biases in presence/absence, and found that

the effects are small, particularly for older time periods, when records of occurrence are more error-prone. Based on these tests, we conclude that the record of artistic depictions underpinning our analyses does not contain huge temporal biases [a conclusion that is supported by similar trends in the Levant (2)] and that the results we gleaned from analysis of that record are relatively insensitive to the smaller biases that might exist.

With respect to Evan's (3) second critique, it is unclear whether she is suggesting that the extinctions look more abrupt because of reduced sampling intensity as a result of cultural factors, or that extinction events didn't occur at all and that the animals may not be depicted for a period. The former point—that there may be missing ranges because of undersampling—might make the faunal events appear to align spuriously with climate events, when they were in fact more protracted. This was a primary motivation for our treatment of extinction as probabilistic, thereby introducing large amounts of temporal uncertainty regarding originations/extinctions. The second point suggests that the analyses might be affected by Lazarus taxa. In our analysis (1) we used only the first and last occurrences of animals in local, ecological contexts; they are assumed to be present during temporal ranges where they might not be depicted.

We appreciate the opportunity to highlight how our paper addresses the important concerns in Evans' critique (3); although the search for pattern and process in nature is always tempered by bias and uncertainty,

this does not mean that such pattern and process cannot be recovered.

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1 Yeakel JD, et al. (2014) Collapse of an ecological network in Ancient Egypt. *Proc Natl Acad Sci USA* 111(40): 14472–14477.

2 Bar-Oz G, Tsahar E, Izhaki I, Lev-Yadun S (2014) Mammalian extinction in ancient Egypt, similarities with the southern Levant. *Proc Natl Acad Sci USA* 112:E238.

3 Evans L (2014) Ancient Egypt's fluctuating fauna: Ecological events or cultural constructs? *Proc Natl Acad Sci USA* 112:E239.

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The authors declare no conflict of interest.

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