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## The past as a prologue to the frontiers of ecology: informative and engaging lessons from ancient mammals

Mammalian paleoecology: using the past to study the present, by Felisa A. Smith, 2021, Johns Hopkins University Press, 260 pp., ISBN 9781421441405 (hardcover).

Just as we as individuals are shaped by our past experiences, the nature and dynamics of extant biotas represent the legacies of ancient lineages that were molded by interactions with their contemporary but now long past environments. In Felisa Smith's hometown of Santa Fe, New Mexico, the engraving on the State's Archive building – *What's past is prologue* (from Shakespeare's *Tempest*) – seems a fitting and seminal inspiration to a distinguished career in applying lessons from the past to better understand the current and future.

*Mammalian Paleoecology* is written in a clear, engaging and highly informative style. As the title implies, the focal taxa are mammals – not only because so many of us find them inherently intriguing subjects, but because of the logistics of preservation and their tremendous diversity of body sizes, shapes, life history and ecological characteristics. As Smith cogently emphasizes, however, the descriptions of paleoecological methods and general lessons that are woven throughout the book are applicable to deciphering the ecological relations of other life forms (invertebrate and as well as other vertebrates).

For many of us studying the ecological and evolutionary dynamics of extant biotas, we realized early on that the reconstructions of the past provide invaluable lessons to unlocking the mysteries of the present and responses of native species to anticipated global dynamics long into the future. Yet, because many if not most of us lacked a formal education in paleoecology, our understanding of its methods and applications to our own studies was fragmentary if not woefully inaccurate. *Mammalian Paleoecology* serves to fill such gaps.

The book is strategically structured in three sections: the first describing the fundamental principles of the field along with the issues most relevant for interpreting the geological record. Chapter 1 introduces us to the author as well as the field of paleoecology and its relevance to disciplines including evolution and ecology, and conservation of contemporary biotas. Here she also begins to develop our appreciation for spatial scale and the antiquity of the Earth and its lineages, emphasizing the invaluable realism of the natural experiments provided by the fossil record. Chapter 2 takes us on an historical journey across space and time and through the foundational development of paleoecology. The essential material presented here includes the nature and types of fossils, a review of the

fossil record, in general, and the evolutionary history of mammals in particular. Chapter 3 introduces us to taphonomy – the study of biases incurred during the formation and preservation of fossils, including those occurring prior to and following final burial (biostratinomy and diagenesis, respectively). Here she also showcases some of the more spectacular fossil assemblages (fossil Lagerstätte), those preserving entire communities of plants and animals due to some rapid and catastrophic event. Chapter 4 describes methods involved in estimating relative and absolute ages of fossils, reviewing the geological time scale and applications of paleomagnetism for reconstructing locations. The chapter then details methods involved in radiometric dating (using isotopes of Carbon, Nitrogen, Potassium, Argon and Uranium) and amino acid geochronology.

The second section of *Mammalian Paleoecology* explains the techniques used to describe the morphological characteristics of long-dead mammals (their body sizes, shapes and, in particular, characteristics of their teeth) and how this in turn is used to decipher their life histories and general ecology (habitats, diets and nature of their interactions with other species). Chapter 5 argues cogently that, among all morphological traits of an organisms, body size represents one of the most informative indices of an organism's physiology, life history, behavior and ecological interactions. Here Smith goes on to explain how size can be estimated accurately from fossilized fragments of ancient organisms, turning to applications of the allometric formula to describe how various indices of life scale with body size. She then describes, given accurate estimates of the size and age of fossilized life forms, general trends in body size of mammals and other vertebrates over space and time. Chapter 6 focuses on perhaps the most informative fossilized fragments of ancient life – their teeth. The success of the class Mammalia is evidenced, not just in their numbers of species throughout their 220-million-year history, but in their diversity of niches and trophic strategies – this allowing them to invade and often dominate food webs across a broad diversity of terrestrial and aquatic ecosystems. Here Smith provides a compelling overview of this diversity in dental configurations and how evolution and natural selection have bioengineered teeth across an apparently unrivaled variety of niches on land and sea. She then demonstrates how paleoecologists

can take this one step further and use the dominant configurations of teeth from a fossil deposit to reconstruct past environments (grasslands, shrubs, forests, etc.).

Chapter 7 introduces us to stable isotopes and how the assemblage of those chemicals can serve as a signature of particular habitats and specific locations where an ancient organism was born and developed, thereby allowing reconstructions of both diet and migration histories of focal species. Chapter 8 introduces us to a very different set of fossils – trace fossils, which include evidence of past life other than the fossilized bodies of the organisms themselves. These include foot prints preserved in sedimentary rock formations, and burrows, nesting material (e.g., plants and animal remains collected by packrats) and fossilized feces known as coprolites. Packrat middens, in particular, have proven especially valuable in reconstructing past assemblages of vegetative communities and associated animals, which in turn has enabled reconstructions of their contemporary climatic conditions. Similarly, analytical methods for coprolites have advanced to the point of allowing accurate reconstructions of the diets of long dead animals with increasing precision of both the material consumed and the periods when coprolites were deposited. This chapter concludes with the compelling advances in genetics and applications of analyses of ancient DNA to resolve the evolutionary and biogeographic histories of both extinct and extant mammals.

The final chapter in this section (Chapter 9), is one of the most foundational and essential as it presents an overview of methods to reconstruct past climates. Here Smith walks us through the historical record of past climates, and then describes particular proxies of temperature and precipitation including ice cores, tree rings, pollen analysis and fossil foraminifera (single-celled planktonic protists whose shells or ‘tests’ record the chemistry of seawater during their formation).

The last section of the book reinforces the lessons from the first two by providing case studies where the historical and paleontological perspectives have enabled Smith and her colleagues to tackle some of the most complex environmental issues of today –

the impacts of climate change on biological diversity. In Chapter 10, Smith reviews the substantial and sometime extremely rapid shifts in paleoclimates and how mammals, in particular those of North America, responded to them either by shifting their ranges, adapting in place (often via body size and other morphological changes), or suffering population decline and eventual extinction. Chapter 11 is a sobering overview of the ongoing biodiversity crisis and places it in perspective by comparing the rate of loss of extant and recent species to the record of mass extinctions throughout the Phanerozoic Eon (the past 541 million years). Here she comes full circle by describing mass extinctions of the Pleistocene megafauna and how this has fundamentally altered one of the most defining traits of all mammals, their body size. These transformations in the body size profiles of mammals have, in turn, cascaded through both terrestrial and aquatic food webs to fundamentally alter the nature and dynamics of native ecosystems across the globe.

One final and more general note; this contribution by Felisa Smith provides valuable lessons in the history of science and, in particular, serves as an homage to the legacy of (in her words) “strong women” who inspired her and, albeit largely unheralded in their day, established the foundations of studies of ancient life. With *Mammalian Paleoecology*, along with her other valuable contributions to the field, Felisa Smith joins this lineage of visionary scientists applying lessons from the past to advance the frontiers of science.

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