Chapter 1
Paleontology in Ecology and Conservation: An Introduction

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Abstract Paleontology is the study of past life. The geological record preserves the history of individual organisms, populations, communities, ecosystems and earth systems through millions of years. It is a unique resource for understanding the dynamics that have shaped our current biota, and developing evidence-based models that will allow us to predict how organisms will respond to future changes to habitat, climate and the anthropogenic manipulation of communities and ecosystems. This book provides examples of the use of paleontological data in ecology and conservation science and illustrates how the addition of data from the fossil record can lead to novel insights and developments. It examines possible future directions in paleoecology and conservation paleobiology.

Keywords Paleontology • Ecology • Conservation • Paleoecology • Conservation paleobiology

1.1 Introduction

Traditionally, paleontologists have been seen as explorers, excavators, morphologists, and systematists. Their role has been seen as one of digging up fossils, describing them, and working out their relationships. Increasingly, paleontology has served as a critical tool for understanding the evolution of life, with fossils forming the basis of understanding phenotypic change through time, serving as markers in molecular clocks and allowing researchers to resolve the origins of major clades. However, understanding the process of evolution requires knowledge of the environments in which evolution takes place, and this knowledge has been the purview of paleoecologists. Using sophisticated techniques such as stable isotope analyses,

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sedimentology, autecology and synecology, paleoecologists have provided paleontologists with the environmental background that shaped and ultimately drove the evolution of the organisms under study.

Perhaps less well recognized by the general scientific community are the contributions that paleoecologists have made to ecology. The lack of synergy between paleoecologists on one side, and ecologists on the other (Birks 1996; McGlone 1996; Louys et al. 2009), has resulted in the parallel development of two bodies of research: one focused on deep time (i.e. centennial to millennial timescales) and the other on near time (i.e. seasonal to decadal time-scales). However, as Wilkinson discusses in this volume (Wilkinson 2012), the dichotomy between deep and near time is a relatively recent division, and is associated with the break up of the study of natural systems into distinct divisions (scientific disciplines). Most early scientists (or savants as they termed themselves) made no distinction between studying biological phenomena in the geological record and in the modern world.

Although modern ecology has been conducted almost entirely independently of paleoecology, several individuals and research groups have attempted to bridge these two disciplines. Wilkinson discusses the research of Marie Stopes, arguably one of the first paleontologists (in the modern sense of the word) who made contributions to modern ecology in the early twentieth century. However, as Wilkinson argues, these insights were not recognized by ecologists of the day, and were independently formulated several years later. More recently in the 1970s, marine paleoecologists began a process of understanding paleontological sequences in terms of ecological processes (e.g., Walker and Alberstadt 1975; Bretsky and Bretsky 1975; Walker and Parker 1976). However, as Bennington and Aronson (2012) argue, this work was ultimately compromised when it was realized that the different scales at which modern ecology and paleoecology operate meant that ecological processes and dynamics, as described by neoecologists, were not directly transferable to paleontological sequences.

This disparity of scale is one of the main reasons why there has not been a greater integration between neoecological and paleoecological studies. The three dimensions over which paleoecology spans are the spatial, the temporal and the taxonomic. Two chapters (Bennington and Aronson 2012; Louys et al. 2012) discuss these dimensions in some detail. Bennington and Aronson review the scale of long-term (in a neoecological sense) vertebrate, invertebrate and botanical studies from around the world, and compare these to the scales at which paleontological studies of those organisms are conducted. They find some areas of fundamental differences, however they also identify areas of fruitful overlap.

Louys et al. (2012) take this one step further, and discuss how ecological data can be collected in order for it to be comparable to paleontological data and in order to facilitate the examination of ecological theories in deep time. They argue that testing of ecological theories in deep time is essential to determining whether these theories are truly general, or simply an artifact of observing modern phenomena. They provide examples of the ways in which paleontology has influenced modern ecology in the past, and advocate a much closer association between these two fields in the future.

Interestingly, one of the primary means of comparing communities and ecosystems across large temporal scales (taxon-free analysis) is also the means of comparing these entities across large spatial scales. Taxon-free studies are focused on morphological traits, ecological niches or functional groups as opposed to taxonomic groups. Although there are inherent phylogenetic controls over the acquisition of particular traits during an organism's evolution, and the ecological niches or functional groups that organism will occupy, they explicitly preserve the evidence of how that organism or community interacts with its environment. And because these taxon-free variables can be identified either through time or across different biogeographical regions (i.e., space), this methodological approach is a critical tool for the examination of ecological principles that cross taxonomic boundaries.

An excellent example of such a study is the chapter by Lawing et al. (2012). These authors examine three morphological traits in the North American snake metacommunity ("ecometrics"), and are able to demonstrate that these traits are significantly correlated with certain environmental variables. While the principal employment of such a study will probably be for the reconstruction of paleoenvironments, extending such a study in geological time allows researchers to examine how the distribution of these traits have shifted over time, and hence how they might be expected to change in light of predicted habitat alterations and climate change (Polly et al. 2011). In their chapter Lawing et al. (2012) use the correlations to determine whether environmental changes in protected areas are reflected in snake biometrics, and find that the major biome shifts observed in those areas are predicted from the snake communities. This study highlights the conservation potential of ecomorphological approaches to the fossil record.

The conservation approach espoused by this study is an example of the surge of paleontological studies and data addressing conservation science that has emerged over the last 20 years or so, such that the need for paleontological perspectives to conservation issues is becoming widely acknowledged by both scientists and policy makers alike. This is in marked contrast to the paleontological contributions to modern ecology discussed above. This surge has resulted from the understanding that only the fossil record can provide the deep time perspective of ecosystem processes such as ecological succession, migration, adaptation, microevolution, and extinction, processes that can't be observed or predicted from neontological studies (Vegas-Villarrúbia et al. 2011).

Paleobotanists Margaret B. Davis and Brian Huntley, and vertebrate paleontologists Michael Archer, Suzanne Hand and Henk Godthelp, in the late 1980s and early 1990s, were some of the first to directly advocate for the consideration of paleontological information in conservation science (Archer et al. 1991; Davis 1989, 1991; Huntley 1990, 1991). Since then, many government and international organizations have either used paleoecological data in their reports or directly advocated their inclusion in conservation studies (e.g., Houghton et al. 1990; Alverson et al. 2003; Flessa et al. 2005; Parry et al. 2007; Solomon et al. 2007).

Moreover, the use of paleontological data for informing conservation issues has been embraced by paleontologists in many different sub-disciplines including geology, micropaleontology, palynology, paleobotany and vertebrate paleontology, so much so that 'conservation paleobiology' can be considered a separate field of its own (Dietl and Flessa 2010).

The principal aims in this nascent field are to determine baselines of natural variability in ecosystems, the identification of vulnerable species in critical need of protection and to determine the nature of biotic responses to climate change (Dietl and Flessa 2009, 2010). The conservation paleobiology chapters presented in this volume span all three of these aims.

Behrensmeyer and Miller (2012) review the contributions to ecology that can and have been acquired from the study of the paleontological subfield of taphonomy; that is the study of the processes through which biological material is incorporated into the geological record. Because this field of study specifically targets the time period between modern ecological studies and paleontological ones, it can provide unique insight into both these disciplines. The guidelines for future taphonomic research provided by these authors are an invaluable resource for the future exploration of the intersection between modern ecology, taphonomy and paleontology.

Pardi and Smith (2012) discuss species' reactions to past climate change, particularly in the late Quaternary, in order to provide reliable predictions of species' responses to human-induced global warming. They describe and provide examples of the three types of reactions that have been experienced by species in the past; namely adaptation, relocation and extirpation/extinction. They focus on the late Quaternary small mammal communities from North America, which are some of the most well-studied and best-poised paleontological collections with which to understand ecosystem responses to climate change.

Lyman (2012) presents a discussion on understanding background fluctuations in biodiversity and argues that the bottom-up processes of climate change can be distinguished from top-down processes such as anthropogentic impacts on ecosystems. Like Pardi and Smith, he also focuses on the small mammal faunas of North America. Lyman introduces the term paleozoology, which refers to the study of both faunal paleontology and zooarcheology. One important implication of his chapter is that he demonstrates that the zooarcheological record can also be used to determine natural ecosystem baselines, albeit with some caveats.

Price (2012) examines the long-term trends in koala (phascolarctid) diversity through deep time. He finds that there has been a steady decline in the number of both species and genera of koalas since the Oligo-Miocene, such that this once more diverse family is currently only represented by a single species. He highlights the conservation importance of such a trend by comparing it with that of the Tasmanian wolf. This marsupial also showed a downward trend in phylogenetic diversity throughout the last 25 million years, such that it was represented by only a single species in the Holocene, and eventually it became extinct in the early twentieth century. Price (2012) discusses some of the conservation implications of such observations.

Zimov et al. (2012) present a detailed look at the effects of global warming on the frozen soils of northern Siberia. The thawing of these soils, they argue, will release huge amounts of carbon and methane into the atmosphere. Zimov et al. further contend that the only way this can be prevented is through a rewilding program, which would seek to return this region to biodiversity levels present during the Pleistocene. They present evidence to suggest that the extinction of the megafauna in Siberia was the result of human overhunting, and advocate that returning the steppe to former biodiversity levels will return that ecosystem to health and prevent the thawing of the soils.

Louys (2012a) examines the zoogeographic history of large-bodied mammals in Southeast Asia in order to determine if any distribution patterns are indicative of extinction risk. His study finds that many extinct and critically endangered species experience widespread distributions until the Holocene, where they become very restricted in range or extinct. Endangered species experiencing the same pattern include the giant panda, the tiger and the Malayan tapir, suggesting that these species are at critical risk of extinction. Louys argues that conservation efforts for the tapir, an animal whose conservation priority is not as well recognized as the panda or tiger, needs to be increased.

Finally, Faith (2012) examines the historical and paleozoological record of South Africa's Cape Floristic Region (CFR). He demonstrates that the roan antelope was a part of that ecosystem well into historical times, and because of this argues that it should be re-introduced and be made part of conservation plans for the CFR. In this chapter, Faith successfully highlights the relationships between ecology, historical biology and paleontology.

This book therefore presents a series of reviews, new analyses and case studies that demonstrate how paleontology has been included in ecological and conservation studies, and highlights the unique insights that can be gained from such inclusions. In the final chapter (Louys 2012b) I suggest some theoretical avenues where such collaborative efforts might be successfully pursued in the future. Ultimately, it is hoped that this book highlights the critical deep time contributions that paleontology can make to ecology and conservation science, and engenders greater dialogue between the practitioners of these fields.

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