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What is the best way to measure extinction? A reflection from the palaeobotanical record

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ABSTRACT

Documenting extinction phenomena remains a vital topic in palaeontology, especially in the context of the marine fossil record. It has been widely assumed that the methods that have been developed in these studies are of universal application throughout palaeontology, but there have been few attempts to test them with plant fossils. We explored the adequacy of the most common methods for documenting extinction events and the associated loss of diversity through time by exploring the monographic knowledge of tracheophytes, especially the record of non-flowering seed-plants. The measure of extinctions was addressed by evaluating diversity fluctuations and the corresponding sampling biases, by measuring levels of taxonomic extinctions, and by exploring disruptions to similarity patterns between time units. Results revealed a strong relationship between diversity and sampling effort based on various different sampling proxies. This suggests that it is vital to take into account the effect of sampling bias when trying to use palaeobotanical diversity dynamics to quantify the real scale of extinction. After testing 16 metrics in two different temporal frameworks, by using criteria like the adjustment between the descriptive extinction metric and the derived probabilistic profile, the interpretation of extinction intensity was overall improved by using normalized metrics that discounted short-lived taxa. Results also revealed that sample size has a significant effect on such analyses and must be evaluated independently for each study before data interpretation. Complementarily, the results showed how the main disturbances of diversity curves generally attributed to extinction events are reflected as abrupt reductions of similarity coefficients between successive time units, which are clearly revealed using clustering methods.

Contents

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1. Introduction

During the 1970s, an enthusiastic group of palaeontologists led by Thomas Schopf, David Raup, Stephen Jay Gould and Jack Sepkoski initiated what Sepkoski (2005) later called "the quantitative revolution" in the study of the fossil record. By adopting numerical techniques that had become prevalent in the biosciences, they were able to re-examine patterns of taxonomic distributions within that record and thereby address some of the central questions in the study of past life (Fig. 1). Rooted in the pioneering work of Newell (1959), Sepkoski (1978, 1979, 1984) in particular investigated changes in taxonomic diversity in the fossil record and developed kinetic models to try to explain his observations. During the intervening years this topic has continued to attract the attention of palaeontologists (e.g., Flessa and Jablonski, 1985; Gilinsky, 1994; De Renzi et al., 1996; Foote, 2000a,b, 2001; Peters and Foote, 2001; Ausich and Peters, 2005; Foote, 2005, 2007; Peters and Ausich, 2008; Clapham et al., 2009; Markov, 2009; Aberhan et al., 2012).

There have been two recurrent topics in these and earlier, non-quantitative studies. The first has been the irreversible lost of taxonomic diversity that has occurred at a number of times during Earth history that have become known as "mass extinctions" (Phillips, 1860; Simpson, 1944, 1949b; Newell, 1952; Simpson, 1953; Newell, 1959, 1962, 1963, 1965, 1967; Valantine, 1969; Foote, 2007; Jablonski,

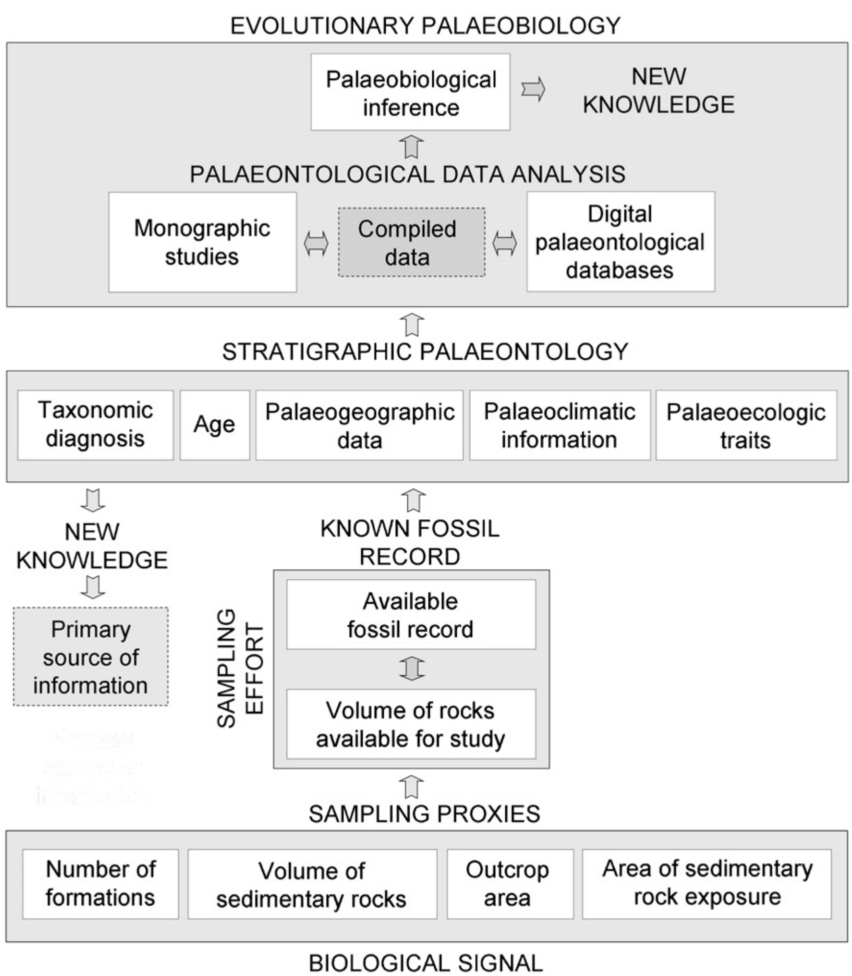

Fig. 1. Flux diagram illustrating the two main levels of management which palaeontology operates on to extract new knowledge from the fossil record by taking into account the inherent constraints due to the nature of the fossil data and sampling biases.