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Real and artefactual declines in phylogenetic diversity of Mesozoic dinosaurs prior to the K-Pg extinction

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A major reorganisation of terrestrial ecosystems occurred at the K-Pg boundary as non-avian dinosaurs were wiped out and major mammalian and avian radiations began or were accelerated. However, it is still debated whether dinosaurs were wiped out suddenly or were already in a prolonged decline prior to the boundary. Typical palaeobiodiversity metrics such as taxonomic richness and morphological disparity generally favour a sudden extinction, but more recently phylogenies have been employed to argue for a prolonged – tens of millions of years – decline in diversification. Here we apply a novel palaeobiodiversity metric – Phylogenetic Diversity (PD), the sum of the branch lengths of a phylogenetic tree representing overall evolution sampled in millions of years – and the largest ever phylogenetic hypothesis for the group (960 taxa) to further explore this debate.

Simulated birth-death models generated expectations of monotonic increases in PD over time under a variety of assumptions. Raw empirical data, on the other hand, shows dinosaurs as a whole, or either of the three major subclades, reaching peak PD in the mid-Cretaceous and then declining towards the K-Pg boundary. We find that PD is strongly correlated with raw richness suggesting both a redundancy between the two palaeobiodiversity metrics and a likely shared problem of sampling bias. However, by regressing PD against richness we show that there is separate signal in PD and further that subsampling to remove the signal of richness (and hence sampling) produces PD over time plots that largely do not support a pre-K-Pg decline. Furthermore, by generating a “false” J-K extinction by removing all Cretaceous data we show that raw PD is always biased towards a pattern of decline, regardless of what the true signal is. Subsampled PD on the other hand is not biased in this way.

Thus we conclude by arguing that subsampled PD is a useful new palaeobiodiversity metric when used appropriately and that raw phylogenetic metrics are likely to always suggest a decline regardless of what the true signal is. More specifically, we show that for dinosaurs as a whole, theropods, or sauropodomorphs there is no evidence for a prolonged decline leading to the K-Pg extinction. However, there we do find evidence for decline in ornithischian dinosaurs, seemingly matching similar signals from morphological diversity found by other authors.