EGU Galileo Conferences
GC5-Mass-56-1, 2019
Mass extinctions, recovery and resilience

Survival of arid-adapted plants over global biotic crises is influenced by their pollination biology

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Terrestrial vegetation response over mass extinctions is controversial, and in particular, the role of pollination biology in biotic reorganisation remains largely unexplored. The xerophyte *Ephedra* (Ephedraceae, Gnetales) harbours remarkable variation in pollination biology, but this is not reflected in the low morphological and genetic divergence of the extant clade, prompting questions regarding its origins. Ultrastructural and experimental work on living *Ephedra* suggest insect pollination is actually ancestral in the Gnetales, which originated at least in the Early Cretaceous. This extended record indicates much higher ephedraceaen diversity in the past, particularly in steppe environments. Here we explore the palynological record of *Ephedra* on the Central Asian steppe with two aims: 1) pinpoint drivers underlying a pollination syndrome shift in the Asian clade, and 2) improve understanding of arid biome response to rapid climate transitions. We find that perturbations at the Cretaceous–Paleogene (K–Pg) and Eocene–Oligocene (EO) boundaries forced catastrophic shifts in Asian steppe ecosystems, with permanent negative effects on ephedraceaen abundance and diversity. The group may have survived through an evolutionary shift to wind pollination, but not in direct response to either biotic crisis; rather it permitted wind-pollinated species to persist by decreasing their vulnerability to disturbances in plant-pollinator mutualisms. Gradual changes prior to the K–Pg and EO events also contributed to ephedraceaen demise by eroding ecosystem resilience, but in the latter crisis this was masked by a positive vegetation feedback loop. This suggests that current ecosystem monitoring may underestimate long-term arid biome susceptibility to anthropogenically-induced global change, especially for insect-pollinated plants.