Diversity and palaeoecological significance of non-pollen palynomorph assemblages in East African lake sediments

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In tropical Africa the palaeoecological visibility of (pre)historical human impact on natural ecosystems is strongly impeded by a dominant signature of climate change at decade-to-century and millennial scales. Better knowledge of the relative magnitude of past human impact is, however, instrumental to properly assess the resilience, and recovery potential, of Africa's natural ecosystems. In this study, we combined taxonomic, ecological and palaeoecological approaches to validate fossil non-pollen palynomorphs (NPPs), i.e. non-pollen micro-remains from fungi and selected groups of algae, vascular plants and invertebrates, as palaeoenvironmental indicators for climate change and human impact on East African ecosystems.

We first studied fossil NPP assemblages from the sediment record of Lake Challa, a deep crater lake located near Mt. Kilimanjaro, with the aim to assess the taxonomic diversity of well-defined East African NPPs over the past 25,000 years, and to exploit their stratigraphic turnover during major climate and environmental changes as a guide to their potential as palaeoecological indicators. By comparing 61 fungal spore types with selected pollen curves of common African trees and herbs, and with independent proxies of regional climate (temperature and rainfall) history, we revealed specific habitat requirements of individual NPP taxa. Particularly, changing habitat conditions at the Glacial-to-Holocene transition (ca. 11,500 cal. yr BP) stand out as the most important event in the distribution of fungal spore types such as *Curvularia*, *Coniochaeta* cf. *ligniaria*, *Acrodyctis*, *Tetraploa aristata*, cf. *Byssothecium* and de types HdV-1032 and HdV-1033.

To expand our knowledge of NPP taxonomic richness in East African lake sediments, we then explored modern NPP assemblages in recently deposited surface sediments of 20 small crater lakes in western Uganda, located along environmental gradients of vegetation (moist evergreen and semi-deciduous forest, wooded and open grass savannah), land use (pastoralism, crop agriculture, plantations) and lake characteristics (basin morphometry, water chemistry and aquatic production). This resulted in a comprehensive inventory of 265 distinct morphotypes, of which 28% could be identified at the species, genus or family level. Focus on the taxonomy of these microfossils resulted in taxonomic descriptions of 187 morphotypes, accompanied by high-resolution photographs and ecological information, when available.

By the year 2100, land-use change will probably be the principal driver of overall biodiversity loss, particularly in the tropics where agricultural conversion of natural ecosystems and the overall intensity of anthropogenic land use continues unabated. Because of poor knowledge of the taxonomic diversity of tropical fungi and their response to habitat changes, however, mycological tools to estimate the effects of various land-use practices on fungal diversity are scarce. We used a statistical mixed-model analysis based on the Akaike Information Criterion (AIC) to comprehensively evaluate the response of African fungal spore diversity (richness and evenness) to agricultural impact at the landscape scale. For this study we used fungal spore assemblages extracted from the recently deposited surface sediments of 24 western Ugandan crater lakes, assumed to reflect fungal communities presently living in (mostly) terrestrial habitats within each lake's crater basin. This analysis revealed that the richness of fungal spore types was inversely related to the percent area of agricultural land-cover types in human-impacted crater basins. The evenness of fungal spore diversity appeared to be related to size characteristics (i.e. the crater area/lake area ratio) of the pristine crater basins, tentatively suggesting higher biomass stability in small lakes with a relatively large catchment area. These results point to the possible threat of fungal species loss, when natural ecosystems are progressively exposed to anthropogenic land use.

Finally, two paired 200-yr NPP records from relatively small, shallow crater lakes (the presently undisturbed Lake Chibwera and the human-disturbed Lake Kanyamukali) in western Uganda were studied to distinguish signals of fungal response to site-specific historical human impact from the common impacts of regional climate variability. Both NPP records registered a strong parallel signature of fluctuations in lake level and moisture balance, mainly reflected in the abundances of the fungal spore type *Coniochaeta* spp., aquatic pollen types (*Typha*, *Nymphaea* and *Cyperaceae*) and algal colonies/coenobia (*Botryococcus*). Moreover, the marked presence of some obligate coprophilous ascomycetes, *Sordaria* spp. and *Delitschia* spp., predominantly growing on herbivore dung, also suggested intense usage of the lakes by wild and/or domestic herbivores during severe lake lowstands in the late 18th-early 19th century. From the 19th century until the present, only at Kanyamukali coprophilous fungal taxa persisted (at low relative abundances), whereas at Chibwera their signature completely disappeared. Given the continuous presence of wild animals in the savanna landscape surrounding the lakes, we surmise that a higher population density of cattle, herded by pastoralists to watering places and productive grazing areas, was consistently present at Kanyamukali. The location of Lake Kanyamukali along an ancient cattle trail and/or trading route may underscore its historical importance for transhumant pastoralism. From the mid-20th century onwards, intensified grazing and subsistence farming started in the Kanyamukali crater basin, indicated by relatively slight increases in coprophilous taxa and *Glomus* sp., an endomycorrhizal fungus associated with soil erosion.

In conclusion, this research provided new insights into important issues related to the methodology and interpretation of fossil NPP analysis, and clearly demonstrated the palaeoenvironmental significance of non-pollen palynomorphs in lake-sediment archives from tropical Africa.