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Tracing climate variability in East African lakes with a chironomid-based model for paleosalinity reconstruction

H. Eggermont(1), O. Heiri (2), D. Verschuren (1)

(1) Research group Limnology, Department of Biology, Ghent University, Ledeganckstraat 35, 9000 Gent, Belgium (hilde.eggermont@ugent.be / Phone: +32-9-2645262), (2) Department of Palaeoecology, Laboratory of Palaeobotany and Palynology, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, Netherlands

We surveyed subfossil chironomid remains preserved in surface sediments of 73 low- to mid-elevation lakes in tropical East Africa (Uganda, Kenya, Tanzania, Ethiopia) to develop inference models for quantitative paleosalinity reconstruction. Using a screened calibration data set of 67 lakes with surface-water conductivity between 34 and 68,800 μS/cm, trial models based on partial least squares (PLS), weighted-averaging (WA), weighted-averaging partial least squares (WA-PLS), maximum likelihood (ML), and the modern analogue technique (MAT) produced jack-knifed coefficients of determination (r^2) between 0.83 and 0.87, and root-mean-squared errors of prediction (RMSEP) between 0.27 and 0.31 $\log_{10}$ conductivity units, values indicating that fossil assemblages of African Chironomidae can be valuable indicators of past salinity change. However, output of all models suffers to a greater (WA and WMAT) or lesser (WA-PLS, PLS and ML) extent from weak correlation between chironomid species distribution and conductivity in freshwater lakes, and an apparent threshold response of African chironomid communities to salinity change near $\sim$3000 μS/cm.

We then analyzed the sediment record of a fluctuating lake in the Kenya Rift Valley (Lake Naivasha) to assess the relative performance of existing and new salinity-inference models based on African Chironomidae in the time domain. This was done by evaluating sample-specific prediction errors, analogue matches and goodness-of-fit statistics of the fossil chironomid assemblages. Furthermore, we compared the chironomid-based salinity reconstructions with time series of historical instrumental data and with independent reconstructions of past hydrological changes based on sedimentology and fossil diatom assemblages. The new salinity-inference models, calibrated with abundance-weighted sub-fossil chironomid assemblages extracted from surface sediments, improve on previous models that were calibrated with presence-absence data of modern chironomid species distribution in African lakes by considering a much greater number of taxa and by providing a higher probability of good modern analogues for the fossil assemblages in the calibration data set. Our performance analysis further revealed significant variation among the various numerical techniques in reconstructed salinity trends through time, due to their different sensitivity to the presence or relative abundance of certain key taxa, combined with the above-mentioned threshold response of African chironomid communities to salinity change near 3000 μS/cm. Simple WA and WMAT models were found to produce the most trustworthy salinity reconstructions because the step-like transition of inferred conductivity near 3000 μS/cm which typifies these models mirrors the relatively rapid transitions between fresh and saline lake phases associated with climate-driven lake-level change. Statistical camouflaging of the chironomids' threshold response in WA-PLS and ML models results in less trustworthy reconstruction of past salinity variation in lakes crossing the freshwater-saline boundary. We conclude that selection of a particular inference model should not only be based on statistical performance measures, but consider chironomid community ecology in the study region and the amplitude of reconstructed ecosystem changes relative to the modern environmental gradient represented in the calibration data set.