Paleolimnological investigations of anthropogenic environmental change in Lake Tanganyika: III. Physical stratigraphy and charcoal analysis

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Abstract

Documenting the history of catchment deforestation using paleolimnological data involves understanding both the timing and magnitude of change in the input of erosional products to the downstream lake. These products include both physically-eroded soil and the byproducts of burning, primarily charcoal, which arise from both intentional and climatically-induced changes in fire frequency. As a part of the Lake Tanganyika Biodiversity Project’s special study on sedimentation, we have investigated the sedimentological composition of seven dated cores from six deltas or delta complexes along the east coast of Lake Tanganyika: the Lubulungu River delta, the Kabesi River delta, the Nyasanga/Kahama River delta, and the Mwamgongo River delta in Tanzania, and the Nyamusenyi River delta and Karonge/Kirasa River delta in Burundi. Changes in sediment mass accumulation rates, composition, and charcoal flux in the littoral and sublittoral zones of the lake that can be linked to watershed disturbance factors in the deltas were examined. Total organic carbon accumulation rates, in particular, are strongly linked to higher sediment mass accumulation from terrestrial sources, and show striking mid-20th century increases at disturbed watershed deltas that may indicate a connection between increased watershed erosion and increased nearshore productivity. However, changes in sedimentation patterns are not solely correlated with the 20th century period of increasing human population in the basin. Fire activity, as recorded by charcoal accumulation rates, was also elevated during arid intervals of the 13th–early 19th centuries. Some differences between northern and southern sedimentation histories appear to be correlated with different histories of human population in central Tanzania in contrast with northern Tanzania and Burundi.

Introduction

Understanding the impact of watershed deforestation on lake ecosystems requires the determination of changes in both the quality and quantity of sediment being discharged into the lake. The stratigraphic analysis of well-dated cores from deltaic regions of lakes, where sediments are initially discharged, provides critical data for interpreting the timing and magnitude of these impacts (e.g., deforestation, change in sediment composition in the lake). In large lakes, where human
impacts vary greatly between influent watersheds, palaeolimnologic studies can also provide a means of comparing sedimentologic responses of watershed deforestation across a spectrum of pre-existing watershed characteristics and impact levels. For example, a combination of watershed size and magnitude of deforestation may be responsible for changes in sediment inundation that in turn will impact the ecosystem affecting life patterns (e.g., species ecological replacement).

Here, we describe the physical stratigraphy of cores collected by the Lake Tanganyika Biodiversity Project’s Special Study on Sedimentation Impacts. A companion paper by Cohen et al. (2005a) describes the background and rationale for this study, and provides location maps, site characteristics and coring techniques used to obtain the cores described here. Another companion paper describes the geochronology and age models used here (McKee et al. 2005). Briefly, the cores described here were collected from a series of river deltas along the eastern margin of Lake Tanganyika, which span a spectrum of watershed disturbance and size characteristics. These deltas lie offshore from the following rivers (in order from south to north): the Lubulungu River (low disturbance, small-sized drainage area: 50 km$^2$, central Tanzanian coastline), Kabesi River (medium disturbance, medium-sized drainage area: 120 km$^2$, central Tanzanian coastline), Nyasanga/Kahama Rivers (low disturbance, very small-sized drainage area: 3.8 km$^2$, northern Tanzanian coastline) and Mwamgongo River (high disturbance, very small-sized drainage area: 7.7 km$^2$, northern Tanzanian coastline), Nyamusenyi River (extremely high disturbance, small-sized drainage area: 30 km$^2$, northern Burundi coastline), and Karonge/Kirasa Rivers (extremely high disturbance, medium-sized drainage area-combined area 162 km$^2$, northern Burundi coastline (see Figures 1–5 and Table 1 of Cohen et al. 2005a).

Watersheds were characterized as currently experiencing low, medium or high levels of disturbance based on the proportion of mature forest/woodland cover existing in the watershed. Low disturbance areas have forest/woodland cover in both the delta plain and upland portions of the watershed, with extremely limited or no agricultural/grazing activity. Medium disturbance watersheds have extensive agricultural development in the lowland and/or delta plain regions of the watershed, but retain forest, woodland, or mixed woodland/grassland cover in their uplands, with the entire watershed retaining between ~25 and 75% forest/woodland cover. High disturbance areas are regions where >75% forest/woodland cover has been removed. The two deltas in Burundi are additionally characterized as ‘extremely highly’ disturbed because these watersheds have undergone extensive surface slope failure.

Materials and methods

Numerous multicores were collected at each delta during this study, of which only a small number could be analyzed in detail. We selected the best cores for use in this study, based on a combination of likelihood of providing continuous records, quality and quantity of indicator materials, and comparability of coring stations vis-a-vis their distances from shore and water depths. Three splits from each core were sampled, normally at 3-cm intervals, for loss-on-ignition, sedimentological (granulometric and micropaleontologic) and palynological analysis. The 3-cm sampling interval used corresponds to the mean depth of bioturbation and sample time averaging observed in X-radiographs of deltaic cores from Lake Tanganyika. A total of 109 samples were prepared for each analysis.

For this exploratory investigation, a simple set of informative and inexpensive indicators was chosen. Granulometric analysis (grain size) provides indications of significant changes in the nature of eroded materials within a watershed and the strength of sediment delivery systems to the coring site. Because total carbonate content in most cores was low (<1%), the contribution of non-terrestrial sources of coarser-grained particles in these cores is probably negligible. Water content and bulk density were measured as supporting data for interpreting sedimentation rates. Total carbonate content and total organic matter were measured as probable indicators of benthic secondary productivity, terrestrial/aquatic productivity and organic matter flux.

The full age spectral data, associated probabilities, and standard errors for each age date, along with discussion of occasional discrepancies between $^{14}$C and $^{210}$Pb age dates, age models, and sediment accumulation rate estimates used in this study are discussed elsewhere (McKee et al. 2005). The $^{14}$C