

# Comparing organic carbon, carbonate content and fine grain fractions of Mtanga and Kasekera river sediments

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## Introduction

Variability in character, volume and distribution of riverine sediments deposited in near-shore environments of a modern rift lake can be controlled by tectonic setting, watershed bedrock geology, the size of the watershed, wave-energy level of the shore environment, and anthropogenic activities, namely farming and deforestation on the steep lake shores (Johnson et al., 1995). Lake Tanganyika (3°18'-8°47'S, 29°05'-31°18'E) offers a superb system to study the latter variable, due to the contemporary variability in human impacts along the lake shore and the preservation of sediment records that document past changes in human activity (Cohen et al., 2005a). In Cohen et al. (2005a) and its companion papers, workers used sediment core records from six different drainage systems, controlling for watershed size, slope and bedrock geology, to study the effect of human activities on deltaic sedimentation. Numerous lines of evidence document the sedimentological and ecological effect of deforestation on near-shore environments. For example, synchronous with rises in human population densities, <sup>14</sup>C and <sup>210</sup>Pb geochronologies indicate rises in mass sedimentation rates, ostracode records show major declines in diversity, and δ<sup>15</sup>N records suggest an increase in soil nitrate to the lake nutrient pool (Mckee et al., 2005; Cohen et al., 2005b; O'Reilly et al., 2005).

Other proxies are useful in studying the effect of deforestation on near-shore environments. Coarse grained delta deposits are associated with deforested water catchments (Cohen et al., 2005a). Therefore analysis of fine grained fractions of different delta deposits can show evidence of human impact levels. Secular and spatial changes in the total organic carbon (TOC) of lake sediments can indicate changes or differences in benthic secondary productivity, pelagic primary productivity, and organic matter flux into the lake from terrestrial systems (Palacios-Fest et al., 2005). Similarly, total inorganic carbon (TIC) studies can be used to study differences in biogenic carbonate (shell material) distribution. TOC and TIC studies of lake sediments can only be preliminary data sets; further study is needed to differentiate the TOC into lacustrine/terrestrial contributions and the TIC into biogenic and authigenic (i.e. abiotic calcite and aragonite) fractions.

## Study Area

In 2006, the fine grain, TOC, and TIC distributions of the forested Kalande and deforested Ngelwa systems were compared (Jankowski 2006; Strickler 2006). In an effort to continue this line of investigation, modern deltaic sediments of two watersheds north of Kigoma, Tanzania were studied as part of the Nyanza 2007 field season. The Mtanga (3°46.503'S, 29°36.227'E) and Kasekera (3°40.194'S, 29°37.377'E) watersheds are of comparable size, slope and bedrock geology. A major (but not only) difference between them is their current level of human impact. The Mtanga watershed is home to village of several hundred people. The Kasekera is located within Gombe Stream Park, protected land since the late 1960s and home to a handful of park rangers and officials. This paper discusses the differences in the fine grain, TOC and TIC distribution between the two stream beds and deltas. Selections of sediment samples were also observed under a microscope to assess the relative abundance of charcoal and terrestrial organic matter in the sediments of the two sites.

## Hypotheses

It is expected that Kasekera TOC will be higher than Mtanga TOC, due to both the presence of more terrestrial material onshore at Kasekera and the depressed benthic and surface productivity at Mtanga due to sediment pollution. Similarly, TIC values for Kasekera might be higher because of a greater abundance of snails and ostracodes in the clearer waters, but this depends on the biogenic/autigenic contributions to the TIC value.

It is also expected that Mtanga will have more coarse clastic particles in its deltaic and stream samples than the Kasekera due to increased erosion and mass wasting of the deforested water catchment. Negative result for these hypotheses would still be very useful for lake management strategy development, as it would support the model that afforestation efforts are most effective in large watershed systems in preventing ecological harm.

## Methods

### *Field Methods*

Sediment samples of the Mtanga and Kasekera watershed were collected both onshore, in the stream beds and offshore, in the delta system. Starting at the stream mouth and continuing one kilometer upstream, surface sediments were collected every 50 meters until 500 meters upstream, at which point the sampling interval was extended to every 100 meters. Three samples were collected at each interval - from the north, central and south part of the stream bed. 46 samples were collected onshore at the Mtanga stream, and 48 samples were collected onshore at the Kasekera stream. Offshore samples were collected using a 10x12 inch Ponar grab sampler during two transects at each site – one on-delta, and the other off-delta. The attempted depth intervals for sample collection were every five meters water depth until 30 meters, and then every 10 meters depth until 80 meters. Water depth was determined using a Lowrance echosounder, recorded when the grab sampler hit the lake bottom. The Ponar was brought aboard the deck of the *R/V Echo*, and placed on a plastic lid. The water was drained from the grab sampler before it was opened, and it was opened slowly to preserve the stratigraphic integrity of the grab sample. The upper one centimeter was selected from the collected sediment, and placed into Whirl Pak plastic bags using a metal spoon that was washed with lake water in between sample collection. The plastic lid was also washed with lake water in between grab samples. 23 grab samples were collected offshore of the Mtanga stream, and 20 grab samples were collected offshore of the Kasekera stream.

### *Lab Methods*

#### TOC-TIC

Loss-on-ignition techniques were used to assess total organic carbon (TOC) and total inorganic carbon (TIC) of both onshore and offshore samples. For each, a combusted (at 900° C for two hours) ceramic crucible was pre-weighed. Five to six grams of wet sediment was placed into each. The one exception to this was the Kasekera on-delta grab sample from 52.7 meters, where grab sample recovery was very poor and only 0.5 g of wet sediment was used. To prevent sampling bias, the wet sediment were mixed and homogenized in the Whirl Pak bags before the sample was weighed out. A plastic spoon was used, and it was washed with tap water and wiped with a Kimwipe in between samples. The crucibles were then placed in a drying oven set to 110° C, and allowed to dry for 18 to 24 hours. The crucibles were reweighed for the dry weight, and then placed in the muffle furnace for two hours at 550 to 600° C to burn off the organic matter. Using metal tongs, the crucibles were removed from the furnace and allowed to cool in metal trays for 10 minutes. The crucibles were reweighed for the dry sediment without organic matter (-TOC) weight. The crucibles were then placed in the muffle furnace at 900 – 950° C for two hours. After cooling, the crucibles were then weighed a final time for the dried sediment without TOC and TIC (-TIC) weight. Using the crucible, dry sediment, -TOC, and -TIC weights, TOC and TIC percentages were then back-calculated.

To assess the relative abundance of charcoal and terrestrial organic matter in Mtanga and Kasekera sediment, the 63 to 125 micron dry fraction was analyzed in seven Mtanga and seven Kasekera samples. The bottom of a 5.5 cm diameter Petri dish was covered with graph paper (1 mm length squares, approximately 1,850 squares in one dish). About 0.1 g of the specified dry fraction was spread evenly over the grid surface. The dish was then analyzed under a Nikon SMZ-2T dissecting microscope, and, where a grain fell on an intersection of the graph paper lines, it was classified as either a charcoal, terrestrial organic matter (e.g. root, leaf, or branch fraction), or an inorganic clastic. One hundred intersections were thus described.

#### Clastic Particle analysis

A Spectrex laser particle grain size analyzer was used to determine the size and amount of particles distributed in the streams and deltas. The Spectrex counter measures grains between 1 and 92 microns by analyzing *in situ* the angle of refraction of a laser beam through a container holding sediment diluted 100:1 with water. All sediments were wet sieved through a 63 micron sieve into a bowl. All sediments were allowed to settle out of suspension for at least two hours. Water was siphoned off till about 150mL remained. The remaining water and sediment was rinsed out of the bowl into a 250mL flask; the added water brought the sample to 200mL. The flask was agitated to re-suspend all particles and 10mL of sample was siphoned and placed into a centrifuge tube. After 10 minutes in the centrifuge, 5mL of water was siphoned out and 5mL of hydrogen peroxide was added. Samples were placed into a hot water bath for an hour. Centrifuge tubes were periodically shaken; this and the heating process contributed to breaking down organic particles. All samples were rinsed twice with water and centrifuged to remove any remaining hydrogen peroxide. 1 mL of sample was removed with a micropipette after re-suspending particles by vigorous shaking. The sub-sample was then placed into a blemish-free Spectrex container holding 100mL of water. The bottle was inserted into the laser particle counter with a magnetic stir-bar for analysis.

#### Statistical Methods

All onshore TOC and TIC values represent the average of the north, south and central basin values. The exceptions are the 800 meter sample at Mtanga, where only a central sample was collected, and the 1000 meter sample at Kasekera, where the south TOC calculation did not work properly, and only the central and north samples were used. Linear regressions were used to determine trends in mean grain size of clastic particles. To determine any differences in TOC and TIC between the two streams and the two deltas, the 95% confidence intervals for the slope and y-intercept of linear regression depth/distance trends were used. If the intervals overlapped, it was concluded that there was no statistical difference between the compared data sets given our current sampling density. This statistical method was not ideal, given that most of the TOC and TIC data sets correlated poorly with depth or distance. A more appropriate analysis would have been an ANCOVA test, but this was not possible given the available software resources.

### **Results and Interpretation**

The Mtanga and Kasekera TOC and TIC data sets from the onshore and delta sediment samples were compared to assess differences in organic matter and carbonate mineral abundance between the two sites. Off-delta transects were not compared because analysis of the bathymetric data suggests that the Kasekera “off-delta” transect was collected on a small delta lobe (Guerra, this volume). The results are compared graphically in Figures 1-4. Linear regressions are shown on each graph with corresponding  $r^2$  value to test for any correlation between TOC and TIC and water depth for offshore samples or distance from the stream mouth for onshore samples. The 95% confidence interval tests, described above, were used to test for statistical differences between TOC and TIC levels between Kasekera and Mtanga. This is in contrast to the Ngelwa/Kalande TOC and TIC analysis, which used average TOC and TIC values to compare abundances between sites.

TOC correlated minimally with water depth on delta at Mtanga ( $r^2$  value of 0.39), but did not correlate at all at Kasekera on delta ( $r^2$  value of 0.11). Similarly, TOC on shore showed no correlation with distance from the stream mouth at either Kasekera or Mtanga ( $r^2$  values of 0.16 and 0.25, respectively).

Poor correlation between TOC and depth or distance is consistent with Jankowski 2006, but is not consistent with Jimenez 2005, who studied TOC distribution on the Luiche Platform and TAFIRI Bay. The Mtanga and Kasekera grab sample transects were taken from narrow sediment platforms with steeply sloping profiles (Guerra, this volume), as were the Ngelwa and Kalande grab samples. This is not the case at the Luiche Platform or TAFIRI Bay, and is a likely reason for the difference in findings (Jankowski 2006). The confidence interval tests for TOC abundance between the Kasekera and Mtanga rivers and delta transects revealed no difference between slopes or y-intercepts for the paired trends. This is inconsistent with the Ngelwa and Kalande study, but the methods of comparison differed between studies.

TIC of the onshore samples did not correlate with distance from the stream mouth at Mtanga and Kasekera ( $r^2$  of 0.15 and 0.24, respectively). TIC of the on-delta grab samples at both Mtanga and Kasekera correlated the best with depth/distance of the 8 trends tested (with  $r^2$  values of 0.50 and 0.65, respectively). Confidence interval tests reveal a statistical difference between TIC abundance between Kasekera and Mtanga. Onshore, Mtanga has more TIC in river bed samples; on the delta, Kasekera exhibits greater abundance. Quantitative data does not exist at present describing the relative contributions of shell fragments and abiotic carbonate (aragonite and calcite) to the TIC values. Qualitative descriptions of the grab samples, however, noted that the Kasekera grab samples had more shell fragments than the Mtanga grab samples. Similarly, ostracode abundance work in this field season revealed a greater abundance in the Kasekera than Mtanga delta system (Sipahioglu, this volume).

The charcoal/clastic sediment classification data is also consistent with more shell material at Kasekera. In the seven Kasekera sediment samples, almost none reveal charcoal or terrestrial organic matter in the 63 to 120 micron fraction. The exception is the delta grab sample from 6 meters water depth, where one fragment of a root was counted. The Mtanga delta, by contrast, does have charcoal and terrestrial plant fragments in this fraction (see Figure 5). This is not an especially surprising finding, since fire is suppressed in Gombe National Park and burning is common in Mtanga. It is, however, encouraging because it is evidence that only modern (within the last 5-6 years) sediments were sampled in this study. Furthermore, it implies that terrestrial material is contributing relatively more to the TOC values in Mtanga than in Kasekera. Since TOC numbers are statistically the same, Kasekera sediments, by inference, contain more aquatic organic material than Mtanga sediments, which may imply more shells. This in turn implies that aquatic productivity is higher at Kasekera than at Mtanga, where high sediment volume may result from deforestation and increased erosion (Uwesu, this volume). Large sediment input volumes have demonstrably negative ecological effects on near shore environments (Cohen et al., 1993).

As with TOC and TIC, clastic particle sizes were compared graphically to identify differences between the two watersheds shown in figures 6-9. In comparing the mean grain sizes distributed between the two streams onshore, analysis shows that Kasekera has a mean grain size that ranges from 10 to 30 microns, whereas Mtanga ranges from 15 to 73 microns. Kasekera also shows less variability between its mean grain sizes. When looking on the delta we see the same trend. Mtanga (7 to 68 microns) has greater variability as well as a coarser mean grain size than Kasekera (4-24 microns). This could be an indication of higher energy and mass wasting caused by deforestation.

Fine grain particles could be an indication of energy levels within the system. Therefore the Kasekera delta might experience less sedimentation which would favor benthic organisms and lead to a higher proportion of shell fragments in the sediments or better preservation of abiotic carbonate. Higher TIC values in Kasekera sediments might therefore be consistent with this finding. Furthermore, after 10 meters water depth, TIC values and mean grain size are well correlated, with an  $r^2$  value of 0.6239, though including the two data points from the two shallowest depths drastically reduces the  $r^2$  value.

Linear regressions were also used to examine correlations between distance upstream and grain size. Analysis shows that the Kasekera systems has a significant  $r^2$  value ( $r^2=0.4821$ ) as compared to the Mtanga system ( $r^2=0.0411$ ). Kasekera exhibits the classic pattern of coarse grains far upstream and finer grains near the stream mouth. The Mtanga system is a poor representation of this model because of possible influences of higher rates of erosion coming from stream banks and canyon walls due to deforestation. Higher energy could effect the variation in sedimentation by not allowing the sorting of particles as found in last years study of Ngelwa (Deforested) and Kalande (Forested) by Strickler.

Linear regression models for the on delta transect were also made. Grain size correlated poorly with depth at Mtanga ( $r^2=0.2196$ ) whereas Kasekera ( $r^2=0.6004$ ) correlated extremely well. Sedimentation and mass wasting could be contributing to a higher variability at Mtanga. Steep slopes also seem to correlate very well with coarse grain sizes. Grabs that were sampled on a steep slope are coarser than ones sampled on a flat or smooth gradient slope. Steep slopes could contribute to turbidity and gravity flows that disperse finer sediments into deeper water.

The analysis of the data from the suspended matter shows no significant difference between suspended matter in the two streams. Kasekera has less variance and less mean grain size than Kasekera. Although there is some difference between Kasekera and Mtanga suspended matter there is not enough data to interpret the information by itself but may be used to support other data provided.

## **Conclusions**

At present, the available dataset does not reveal any difference in abundance in TOC between the forested Kasekera and the deforested Mtanga. A difference does exist between TIC abundance. Charcoal analysis shows a difference between terrestrial organic flux into the two deltas, with more at the deforested site. Furthermore, ostracode data and charcoal analysis suggests that the difference in TIC is due to a greater abundance of shelled organisms in the Kasekera delta system, which in turn may be connected to the effects of deforestation.

Mtanga has more coarse grained particles dispersed over the onshore and deltaic systems than Kasekera. The Mtanga also exhibits more variability in clastic grain sizes. Kasekera also exhibits the pattern of fine grain size distribution found in classic river systems. TIC maybe well correlated with mean grain size, either by favoring benthic organisms or by favoring preservation of abiotic carbonates.

At this point in the data analysis, these conclusions remain tenuous. The deltaic environments of Kasekera and Mtanga are different for reasons besides deforestation; as one example, one river drains the Mtanga watershed, whereas several drain the Kasekera watershed (see Guerra, this volume). The multiple streams of the Kasakera watershed could contribute to the lower energy in the stream and on delta environments.

The two smaller streams of Kasekera may not be able to transport as many large particles as the one stream of the Mtanga. Our conclusions require further testing. TOC values can be parsed into constituent terrestrial and aquatic fractions using C/N ratios or stable isotopes of carbon, and the TIC values into biotic and abiotic fractions through more rigorous mineral analyses. A better understanding of these fractions is essential for testing whether the aquatic environment is being negatively affected by a deforested Mtanga watershed.

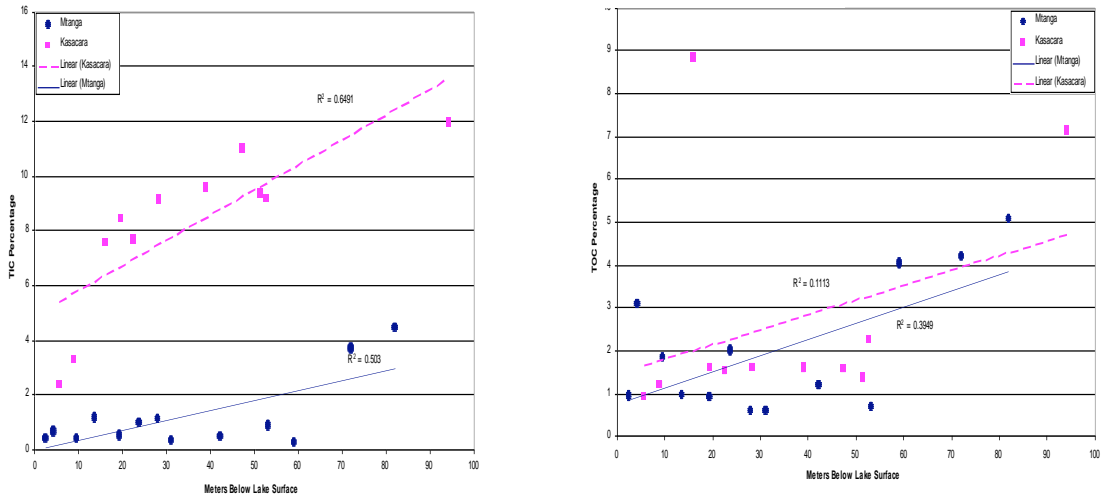
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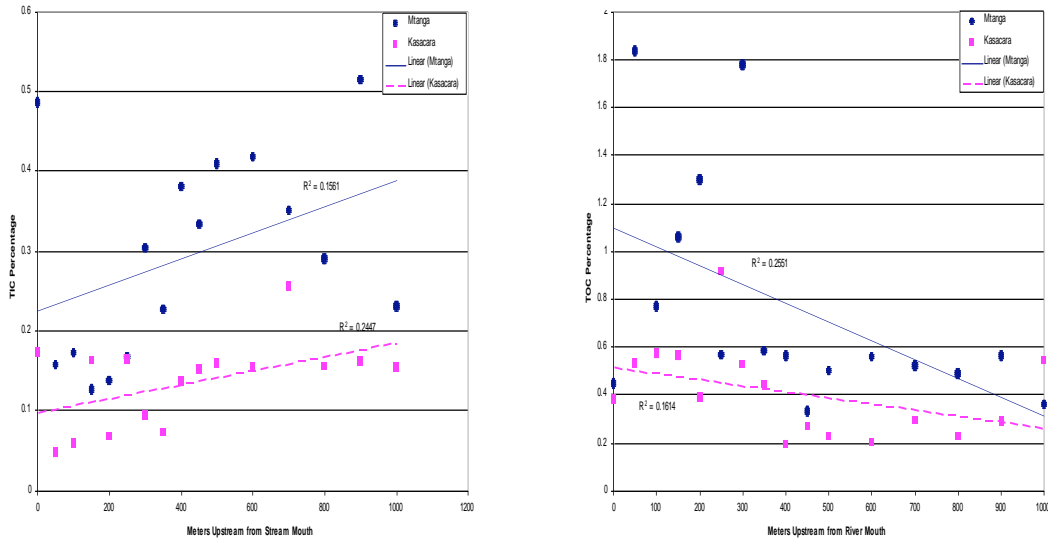
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## Mtanga and Kasekera Delta Transects

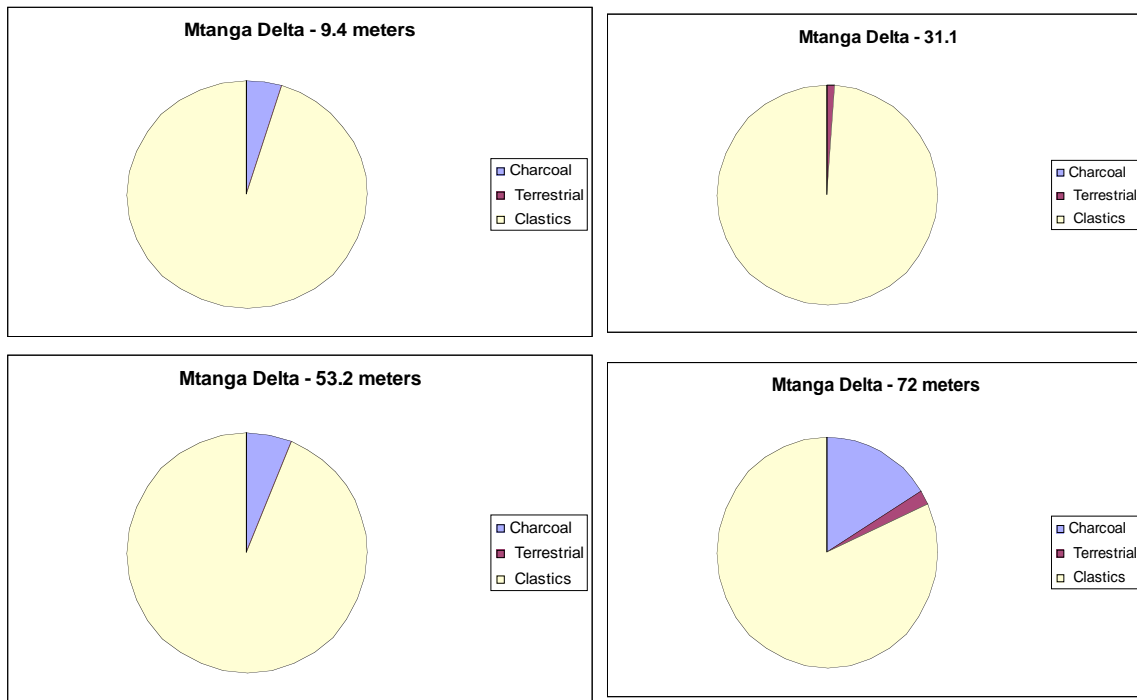


Figures 1 and 2: TIC and TOC percentage of the Kasekera and Mtanga delta transect samples.

## Mtanga and Kasekera Stream Samples



Figures 3 and 4: TIC and TOC percentage of the Kasekera and Mtanga stream samples.



**Figure 5:** Charcoal classification for 63-125 micron sediment samples from the Mtanga delta. Water depth listed for each pie chart. Kasekera delta samples are not displayed because most, except for one grain of one sample, were inorganic clastics.