

Deforestation impacts and small-scale variation in ostracode distributions on the Mtanga and Kasekera River deltas, northeastern Lake Tanganyika

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Introduction

Ostracodes are environmentally sensitive micro-crustaceans that live in any type of aqueous environment. They first appeared approximately 500 million years ago and over 50,000 known species exist today (Ito *et al.*, 2003). They secrete a calcium carbonate shell from the surrounding water and molt up to nine times throughout their lifespan, which is approximately one year. They have proven to be very useful in paleoecological and paleoclimatic studies because their shells are easy to separate out from the surrounding sediment and they have a high preservation potential.

Lake Tanganyika contains nearly 200 species of ostracodes, most of which are endemic and have not yet been formally described (Cohen, 1994). Fossil assemblages of ostracodes provide a high-resolution tool for analyzing benthic communities and are useful in interpreting paleoecologic changes in lake ecosystems such as those caused by human disturbance (Alin *et al.*, 1999; Alin & Cohen 2003, 2004; Park & Cohen, 2003). However to properly interpret fossil data from lake cores it is important to understand the distribution and spatial variance of the species in the modern lake.

Within Lake Tanganyika, Wells *et al.* (1999) found that intensive watershed disturbance is characterized by substantial declines in abundance, species diversity, and changes in ostracode community populations by comparing the large, heavily impacted Ruzizi and Karonge River delta systems to unimpacted sites in the lake. Van Alstine (2002) characterized the taphonomy and abundance of ostracodes over the smaller, high energy, Luiche River delta platform and found a significant correlation between taphonomic variables and environmental conditions. Hubbard (2006) described the taphonomy and abundance of ostracodes in moderate energy, Tafiri Bay, Kigoma and also found strong correlations between taphonomic variables and water depth. Wells *et al.* (1999) found ostracode abundance to decrease substantially on human-impacted river deltas. Studies by both Van Alstine (2002) and Hubbard (2006) found a correlation between breakage, redox staining and water depth. A strong correlation was found between abundance and %TOC on the Luiche platform (Van Alstine, 2002), but no correlation was reported in Tafiri Bay (Hubbard, 2006). Within the lake, the high species diversity and regional endemism of ostracodes means that patchiness is a problem for interpreting paleoenvironments from cores, and a better understanding of small-scale distributional variability is needed.

This study aims to 1) describe the taphonomy and abundance of fossil ostracodes found in surface sediments of two geographically similar river deltas (Mtanga and Kasekera rivers) north of Kigoma, Tanzania with different degrees of deforestation, and 2) compare those results with previous studies to determine if there is a more general applicability. I will also compare the abundance and taphonomic indices of samples across similar depths on the deltas of both the forested and deforested sites to determine the spatial variability between samples of given depths in similar environments.

Mtanga River is located approximately 30 km north of Kigoma, Tanzania and flows west into Lake Tanganyika. The watershed covers 3.76km² and is an area that has been seriously deforested due to fires, agriculture, pastoral practices, and community growth. Kasekera River is in Gombe Stream National Park, 60 km north of Kigoma, Tanzania and also flows west into Lake Tanganyika with a watershed covering 3.32km² (Guerra, 2007 this volume). Gombe Stream National Park was created in the 1970s to be a 'natural' preserve for chimpanzees, baboons, and other animals to make their home. Deforestation activities are prohibited and actively prevented in this area and this includes the extinguishing of wild fires.

Methods

Field Methods

A high-resolution bathymetric map was created across both deltas (Guerra, 2007). Ponar grab samples were taken aboard the *RV Echo* from both deltas (see methods Husson and Romano, 2007 this volume). For purposes of this study, the on-delta transects are those that begin from the river mouth and extend lakeward (M1 and K2).

Divers collected replicate samples across the top of the deltas at depths of 5-25m. The 5m samples were sub-sampled from the A1 quadrats collected for gastropod analysis (see Keating and Wing, 2007 this volume). The 10-25m replicate samples were collected by Marc Mayes and myself through underwater navigation of squares. We recorded a compass bearing of the main transect line and swam along the lake bottom until target depths were reached. A marker flag was placed in the sediment to mark the appropriate depths until we reached the deepest depth (25m). We then turned 90 degrees and swam approximately 30m to the north of the transect line along similar depth using kick cycles to measure distance (1 kick cycle = 25 kicks = 30 m), which is where we took our sample. We then turned another 90 degrees to orient ourselves towards the shore and swam up to shallower depths to collect samples at the remaining intervals (20, 15, 10). The same procedure was used to collect samples on the south side of the transect line.

Sample collection was made using a tablespoon to carefully scoop the top 1cm of undisturbed sediment from the lake bottom into a pre-labeled whirl-pak bag until the bag was approximately half full. Sampling was done over approximately a 625 cm² area. The sediment was allowed to partially settle and excess water was squeezed out of the bag before sealing. The bag was then placed inside a diver grab bag and then carried to the surface.

Laboratory Methods

One gram of wet sediment was dried in an oven for 6 hours to determine dry weight. One gram of wet sediment was wet sieved through a 63 µm sieve for analysis. Several grams of unsieved sample was labeled and stored in sealed plastic containers for future analysis. The sieved sample was washed into a scored petri dish and examined using an Olympus SZH stereomicroscope at 25-60x magnification.

Each sample was completely counted to determine the number of ostracode valves present and then total abundance per gram was calculated by using the equation (total valves/dry weight). The taphonomic indicators that were counted per sample were: 1) broken valves (over 50% complete) vs complete valves; 2) juveniles vs adults; 3) valves as carapaces vs disarticulated valves; 4) valves that exhibited oxidation staining, and 5) valves that exhibited reduction staining. One gram of every sample was counted. The data was then entered into a spreadsheet and percentages per sample were calculated. The remainder of the sample was processed for TOC, TIC, grain size, mineralogical content, percent charcoal, gastropod abundance and diversity (Husson & Romano, 2007; Helfrich & Rashid, 2007; Keating & Wing, 2007, all this volume).

Statistical Methods

All data was recorded into Excel spreadsheets for analysis and graphs plotted to identify trends. JMP IN (2001) statistical software was used to run a general linear model to determine if any relationship existed between the location of a sample (which river system, on- or off-delta, and water depth) and the various taphonomic variables (%juvenile, %oxidized, %breakage, %reduced, %carapace, %unstained, and abundance). If a significant P value was returned for location, a Tukey test was performed to determine how the sampling locations differed. A linear regression was created to determine if there was a relationship between %TOC and ostracode abundance for each transect and for all samples at each location. A chi-squared test was performed for every variable (%juvenile, %oxidized, %breakage, %reduced, %carapace, %unstained, and abundance) across every replicate sample depth (5, 10, 15, 20, and 25m) for each delta to determine if the samples were statistically similar.

Results

Juvenile vs. Adult ratio

There was no significant relationship between site location and juvenile to adult ratio. However, there was a significant relationship with water depth for both transects at both Kasekera and Mtanga (Fig. 1). The juvenile to adult ratio decreases with depth ($P=0.0003$).

Broken vs. complete valves

There was no significant relationship between % broken valves and depth but a significant relationship was found between % broken valves and site location. There was a greater % of broken valves found on the Mtanga delta transect ($P=0.03$)(Fig. 2).

Complete carapace vs. disarticulated valves

No significant relationship was found to exist between % complete carapace and depth, location or site.

Oxidation staining vs. reduction staining vs. unstained valves

Oxidation staining decreases with depth at all locations ($P=0.0094$) and higher percentages of oxidized valves are found at Kasekera ($P=0.0043$) (Fig. 3). Conversely, percentage of unstained valves increases with depth across all locations ($P=0.0262$) and a higher percentage of unstained valves are found in the Mtanga delta transect ($P=0.0045$). There was no significant relationship found between reduction staining, site location, or transect location, but there was almost a significant relationship between staining and depth ($P=0.0749$).

Abundance

Abundance increases with depth across all transects ($P=0.0052$) and the ostracode abundance on the Kasekera River delta is significantly higher than any other site location ($P=0.0001$)(Fig. 4). A Tukey test determined that the K1 transect was statistically very different from the other transects.

Abundance vs. %TOC

No relationship was found to exist between %TOC and ostracode abundance when a linear regression was applied. However, when a second degree polynomial regression was applied to transects K2, M1 and M3 individually, an average r^2 value of 0.45 was obtained. Transect K1 did not return a significant r^2 value.

Variance between samples of similar location

The chi-squared test performed on each interval, for each transect, for each river system revealed no clear pattern. Significant relationships were found to exist only for: Kasekera 20m depth % juvenile ($\gamma^2 = 0.892$), Kasekera 10m depth % broken ($\gamma^2 = 0.933$), Kasekera 15m depth % broken ($\gamma^2 = 0.737$).

Discussion

High juvenile to adult ratios often indicate a more stressful environment in which the ostracode lives. Higher juvenile to adult ratios were found to increase with depth across all transects but were not found to increase across site locations which indicates these stresses are not related to degree of deforestation. In all transects ostracode abundance increases with depth.

The amount of oxidation decreased with depth across all transects and this result is concordant with previous studies by Hubbard (2005) and Van Alstine (2002). Therefore, percentage oxidation may be a good index by which to determine water depth in paleoenvironmental reconstruction. I also found that the amount of oxidation was greater at the Kasekera delta transect which I believe may be due to a difference in water chemistry (greater abundance of dissolved Fe) or slower burial (the valves in Mtanga do not have as much time for oxidation to occur

due to increased sediment load from deforestation). This is suggested by the highest percentage of unstained valves occurring at Mtanga River delta where the percentage increases with depth.

Additionally, the Mtanga delta exhibits a greater percentage of broken valves compared to all other transects. This would be expected from a deforested stream that has a high sediment load with a lot of reworking on the delta. I did not find a relationship between % breakage and water depth.

The relationship of reduced valves to increasing water depth was almost significant, and it is possible that had the sample size been larger (with increased taphonomic counts) this relationship would prove to be significant.

I did not find a significant relationship between abundance and %TOC until the K1 transect was removed from the regression. A Tukey test indicated that K1 was statistically different in abundance from the other samples so removing it from the regression is justified. Further analysis is needed to determine the relationship of TOC to abundance and the differences in the K1 transect.

Ostracode abundances are clearly higher on the Kasekera delta compared to the Mtanga delta indicating that deforestation does have a substantial effect on benthic communities. Further analysis is needed to determine the nature of these effects across the system with species identification and incorporating environmental conditions. This information will help to explain the changes between the two sites, but also the differences seen between the taphonomic data collected between the Luiche delta, Tafiri Bay, Kasekera, and Mtanga River deltas.

Problems

The primary problem here was lack of time which meant that not all taphonomic counts reached 100 valves in samples with particularly low abundance, and juvenile to adult ratios could not be assessed for all the samples. Additionally, costs of going into the field, and high demand for scuba tanks limited the number of replicate samples taken. Other physical limitations such as diver depths and use of the ponar for grab samples may have allowed some mixing of the top 1cm of sediment with underlying sediment.

Future work

Within the next year I would like to complete taphonomic counts of 100 valves for all samples collected. Additionally, I would like to determine species diversity and abundance for each sample and compare the differences between the Kasekera and Mtanga watersheds. I would also like to compare the differences between the replicate samples taken from similar depths. Using the data gathered from the rest of the geo-team on this project, I will like to do a CCA and ECA analysis using environmental correlatives to better understand the distribution of species across the delta systems and the affects of deforestation on small watersheds.

As for recommendations for future projects I would like to have more samples covering a greater area of the Mtanga and Kasekera River deltas to study the differences between the sites as well as variation. I think it would be useful to repeat this study in the future using two different forested/deforested watersheds to compare results with this study. I also think another study on spatial variability is needed with more replicates of similar depth.

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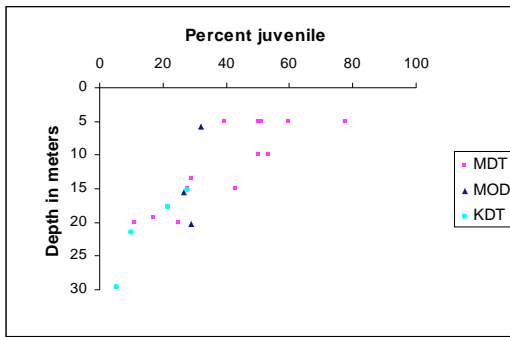


Figure 1. The ratio of juvenile to adult ostracode shells decreases with depth for all transects. (P=0.0003)

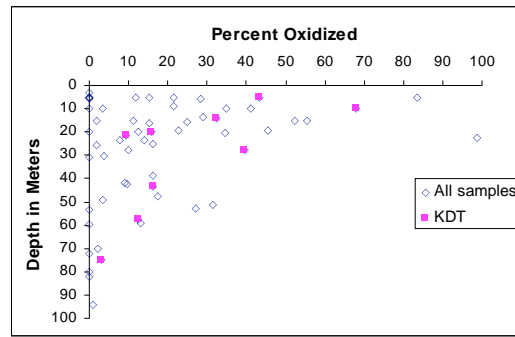


Figure 2. Percentage of broken valves by depth. There is a higher percentage broken valves at Mtanga than on other sites. (P=0.03)

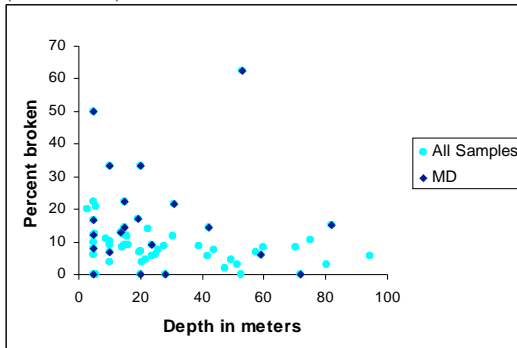


Figure 3. Percent of oxidized valves declines with depth (P=0.0094). Kasekera has a greater percentage of oxidized valves compared to the other sample locations (P=0.0043)

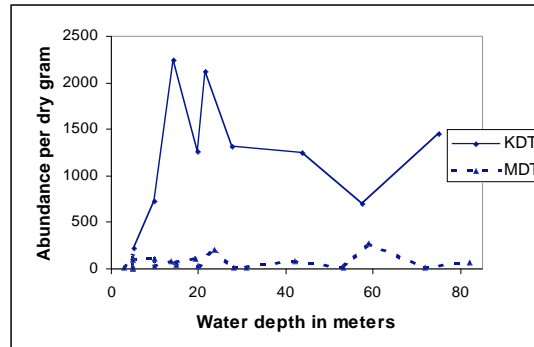


Figure 4. Comparison of abundances with water depth across Mtanga and Kasekera River deltas. Abundance is clearly greater in the Kasekera delta (P=0.0001)

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