

Diving into the Unknown World of Soft Substrate Snails

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Introduction

Current knowledge of soft substrate gastropod assemblages of Lake Tanganyika is extremely limited compared to our knowledge of the lake's rocky substrate assemblages. Literature regarding Lake Tanganyika's soft substrate gastropod species is restricted to two studies and a Lake Tanganyika gastropod diagnostic field guide (West *et al.* 2003). The soft substrate molluscan studies include a preliminary Nyanza Project, which examined the distribution of soft substrate molluscs with changing bathymetry off the Luiche platform (Kinyanjui 2002) and a paper that examined the affects of sediment disturbance on aquatic animal biodiversity, including four soft substrate gastropod species (Alin *et al.* 1999). This paper examines two separate aspects of a paired stream comparison with an underlying goal to document and better the current understanding of living soft substrate gastropod communities of Lake Tanganyika.

Growing human population in Kigoma Region has placed demanding pressure on its land, including that bordering Lake Tanganyika. Over the past fifty years much land has been cut and burned in order to provide vast areas for housing and cassava farming (Cohen 2005). Deforestation not only poses a terrestrial environmental threat, but affects the lacustrine environment as well (Cohen 1993). A correlation has been observed between the development of new villages and increased sediment loading into the lake from local village streams (Cohen 1993). Sediment influx causes a decrease of water clarity reducing the amount of light energy and may also cause an increase of nutrient and toxin input into the lake (Alin *et al.* 1999). Previous studies have indicated that an increase of anthropogenic sedimentation results in a decrease of species richness and, in general, abundance in Lake Tanganyika's rocky substrate molluscan communities (Alin *et al.* 1999, McIntyre *et al.* 2005).

Anthropogenic sedimentation may also have a potential effect on soft substrate molluscan communities that inhabit the deltaic environments of deforested watersheds draining into the lake. The first aspect of this project will focus on comparing ecological variables, such as species richness, evenness, and abundance of living soft substrate gastropod communities between two separate watersheds that feed into Lake Tanganyika: Mtanga stream, which flows from a deforested watershed, and Kasekera stream, whose watershed is located within Gombe National Park and is protected from habitat degradation (see Guerra 2007 – this publication). We predict that an increase of sediment influx from the deforested watershed (Mtanga) will negatively impact soft substrate gastropod communities by decreasing species diversity and evenness in comparison to our reference stream (Kasekera).

The scale of the area a population inhabits at any given time compounds the issue of quantifying what sort of environmental variation results in changes in species abundance and distribution. Aside from large-scale variation in species assemblages there can also be small patterns, which make obtaining samples that accurately represent a population difficult. Gastropods found on rocky substrates in Lake Tanganyika have notoriously patchy distributions (Michel *et al.* 2003). The same can be found for many soft-sediment communities in many marine systems (Morrisey 1992). Due to the little available data on soft-substrate gastropods in Lake Tanganyika it is unclear if they also exhibit such patterns. It is predicted that at certain scales these communities will be patchy as well. Here we analyze species abundance and community composition at three scales. It is predicted that within each scale ecological measures of community composition will show more similarity to areas with similar distances apart and orientation to the stream mouth and river delta. The smallest scale consists of four quadrats spaced over 10m distance, these together comprise a Site, the next largest scale of comparison. Three sites were positioned, 1) directly off, 2) 50m from the stream mouth and, 3) 450m from the stream mouth at each of two streams. The largest scale is between the two streams at Kasekera and Mtanga, each comprising distinct watersheds along the north Tanzanian coast of Lake Tanganyika north of Kigoma.

Methods

Sample Location

The two streams in this study were selected to allow comparison of catchments and offshore characteristics of systems that differ in land use practices. Both the Mtanga and Kasekera streams have been altered by human activities in the past; however, the Kasekera Stream watershed now lies within Gombe Stream National Park. This has allowed for reforestation within the last fifty years by controlled land use and fire suppression. Mtanga Stream still remains highly impacted from the surrounding village. Here, frequent burning of hillsides and the planting of cassava leave much of the watershed surface susceptible to soil erosion and pollution. Sampling sites within each system were determined using bathymetric maps of the near shore areas (Guerra 2007). The maps extend 500m north and south of the stream mouths and 400m out from the shore. Both stream's depositional environments have similar characteristics of importance to this study. These include a delta extending in a southwesterly direction and an underwater canyon, the last is sited just north of the stream mouth at Mtanga and directly in front of the stream mouth at Kasekera. Two on-delta sites and one off-delta site were sampled for each stream (Fig. 1). At each stream, Site 1 and Site 2 were on-delta with Site 1 directly lakeward from the stream mouth and Site 2 located 50m to the south. Site 3 was an off-delta site located the other side of the underwater canyons delimiting the northern edge of the delta platforms and 450m to the north of Site 1.

Sample Design

Sampling was done in soft sediments at approximately 5m water depth as determined by a dive computer during collection. Each site comprised four quadrats spaced 3m apart along a transect while maintaining a constant depth. Quadrats were squares of 1m² area constructed from nylon rope weighted on each corner with a sand bag. The quadrat was divided with rope into quadrants due to the limited size of the sample bags; each sample bag represents sediment collected from one quadrant (0.25m²) of the quadrat. Two SCUBA divers using small hand shovels collected the top 1cm of sediment in each quadrant (ca 250cm³). Unfortunately, we were unable to collect datable diver cores due to the very compact, sandy nature of the substrate at most sites. The top 1cm of sediment is estimated to have been deposited in the past 50 years or less based on sedimentation rates of similar systems (Cohen pers. comm. 2007), the time period during which the watersheds have noticeably diverged in terms of vegetation cover and, presumably, runoff. Collection was done on three different days; Mtanga Sites 1 and 2 were collected on 15th July, 2007; Mtanga Site 3 was collected on 18th July; and all Kasekera sites were collected on 24th July. Each quadrant sample was wet sieved with 2mm and 500µm aperture sieves. Mollusks in the 2mm fraction were collected during sieving. Those in the 500µm were picked from the remaining sediment fractions under a 10X dissecting scope.

For the purpose of this study, only living or recently dead (Cohen 1993) snails were picked to permit analysis of a narrowly time-averaged assemblage that would factor out any seasonal differences that might occur in assemblages of small and probably short-lived gastropods. Recently dead snails are defined as whole, pristine shells lacking any sign of wear and breakage; the presence or absence of the periostracum was not taken into consideration for defining recently dead snails. Predated shells could not be distinguished with confidence from shells that have been broken due to taphonomic processes; therefore, broken shells were disregarded all together.

The picked snails were identified and counted under a 20X dissecting scope. Gastropod species identifications were made using West *et al.* (2003), except for *Lavigeria* and *Synolopsis* species in which we followed the results of unpublished systematic revisions (Todd pers. comm.). Our species counts from the fine 500µm hand sieve excluded those species that brood their young (*Lavigeria* sp. AA and *Stanleya neritinoidea*) with the assumption that these tiny dead snails probably represent brooded young or snails that died after being newly released from the mother's brood pouch. In each case these would not have been members of the soft sediment gastropod community.

Analysis

Species richness was counted and PAST, a statistical analysis program (Hammer 2007), was used to calculate evenness, and Simpson's Diversity Index for individual site species abundances for both watersheds (Kasekera and Mtanga) and for both watershed's total species counts (sum of species abundances for Site A, B, and C). A two-way ANOVA was performed using JMP IN statistical software to determine if significant differences in species richness, evenness and Simpson's Diversity Index exist between, 1) differently orientated sites (Site A, B, C) within a watershed; 2) between watersheds; or, 3) both. To determine significance between evenness and watershed at the site level (Site A, B, C) t-tests were undertaken. Bray-Curtis cluster analyses were performed in PAST using, 1) species abundance and, 2) species presence/absence counts to compare patterns in spatial distribution across watersheds.

Results

Forested vs. Deforested

Of the 18 gastropod species collected, nine species are characterized as soft substrate taxa, eight as hard substrate taxa, and one as characterizing free-flowing streams (West *et al.* 2003). Across the paired watersheds the species richness (*S*) of sites ranged from 7-11 species, evenness ranged from 0.1360-0.5795, and Simpson's Diversity ranged from 0.5062-0.7288 (Table 1).

Kasekera watershed shows greater species richness and Simpson's diversity values for all sites than the Mtanga watershed (Fig. 4). A two-way ANOVA showed significant correlation of watershed between species richness ($p=0.0078$) and Simpson's Diversity ($p=0.0014$) (Table 2).

For all sites combined, Kasekera shows overall greater species evenness. At the scale of sites, however, Kasekera only has greater species evenness at site A in comparison to Mtanga (Fig. 4). A two-way ANOVA shows no correlation of species evenness between the paired watersheds ($p=0.5444$) (Table 1). Due to the high dominance of *Synolopsis minuta* at Mtanga Site A (Fig. 2), t-tests were performed for a more detailed examination of species evenness at the site scale across the watersheds. Between Mtanga watersheds site A shows a significant difference within species evenness ($p=0.0142$), but there is no significant difference between Sites B and C (Table 3).

Spatial Variation

Cluster analysis of abundance yielded a high degree of similarity of quadrats within sites (Fig. 5b). The only quadrat which does not group directly is MC4, with the remaining three quadrats in Mtanga-Site A grouping closely. In this case it appears there is an association between MC4 and all of Mtanga-Site C. At the next highest order it does not appear there is any patterns grouping Sites according to orientation whether it be on-delta or off-delta. Mtanga-Site B (on-delta) and Kasekera-Site C (off-delta) group as do Kasekera-Site A (on-delta) and Mtanga-Sites A (on-delta) and C (off-delta). Kasekera-Site B separates from all other sites sampled. Grouping of sites according to the stream system is also evidently not occurring as seen above. Cluster analysis of presence and absence showed very little similarity at any scale. At the quadrat scale there were no sites in which all four quadrats clustered together. Only Kasekera-Site C and Mtanga-Site A had at least three quadrats clustering together as a group. All other quadrats follow much looser and interwoven patterns of similarity. No association could accurately be made at both the site and delta orientation levels.

Discussion

Forested vs. Deforested

Based on our paired watershed study there seems to be a correlation between deforestation and decreased species richness (Fig. 4). This result is consistent with previous anthropogenic sedimentation studies of rocky substrate gastropod assemblages of Lake Tanganyika (Alin *et al.* 1999, McIntyre *et al.*

2005) and our initial hypothesis. Our results showed no significant difference in species evenness at the scale of the watershed between the impacted and non-impacted areas.

Mtanga site A shows significantly lower evenness compared with Mtanga sites B and C (Fig. 4) and the Kasekera sites. This suggests a highly localized effect to be affecting gastropod faunas directly off the stream mouth at Mtanga. Further examination of species abundances at Mtanga Site A reveals a 93% dominance of *Syrnolopsis minuta* (Fig. 2); however, the abundances of *Syrnolopsis minuta* are similar at both Kasekera Site A (384 inds.) and Mtanga Site A (309 inds.) (Appendix 2). In comparison to Kasekera site A, Mtanga showed dramatically lower species abundances for all other species, if at all present. The probable loss of abundance and species richness at Mtanga Site A may be the result of one of two possible factors or of both operating together. These effects might reflect the highly patchy distribution of Lake Tanganyika's gastropods (Michel *et al.* 2003) or alternatively they might reflect anthropogenic impacts.

Of the two possible explanations for the loss of species' abundance anthropogenic impact appears to be most applicable to our study. Within Lake Tanganyika, *Syrnolopsis minuta* is a widespread and apparently eurytopic species (West *et al.* 2003; Todd pers. comm.) that we infer is likely to be resilient to changing environmental variables. We hypothesize that some foreign substance (i.e. chemical) is being introduced into Mtanga's watershed, which is being deposited near shore directly off the stream mouth or remain in the water (Site A). As a result of this localized disturbance, we interpret the gastropod assemblage of Site A as having experienced a sharp decline in species richness and abundance, excepting *Syrnolopsis minuta*.

Spatial Variation

Similarity between the abundances of quadrats within sites indicates there is a correlation on small spatial scales within 10 meters. It does not appear there is enough habitat variability within this distance to show variation in abundance of individuals in each species. Sampling locations separated by 50 meters or more show little association. On-delta sites 50m apart are not significantly more similar to each other either within or between watersheds. The lack of similarities for presence and absence of species found in each quadrat was likely the result of rare species, which may be difficult to sample without extensive effort.

If paired habitats possess compositionally recognizable faunas between sites then this will offer the possibility of reconstructing paleoenvironments based solely on fossil species assemblages. This would be highly beneficial to future paleoenvironmental work in Lake Tanganyika. However, similar faunal patterns were not present suggesting that other variables account for the composition of gastropod communities opposed to strictly on-delta and off-delta habitats. Therefore, future studies reconstructing Lake Tanganyika's soft substrate paleoenvironments cannot be based solely on gastropod assemblage composition, since other variables are likely to affect species distributions (i.e. grain size) and these must be taken into consideration.

Future Research

Our project was confined to studying the effects of anthropogenic sedimentation of soft substrate gastropods at the community level. Based on observations between the watersheds there seemed to be obvious individual-level species differences; individual species of *Stanleya neritinoidea*, for example, appeared to be much larger in shell size at Kasekera in comparison to Mtanga. Maximum shell size is often ecophenotypically controlled in mollusks and is frequently used as an indication of habitat suitability in molluscan ecological studies (McIntyre *et al.* 2005). Therefore, examination of individual-level effects of anthropogenic sedimentation on gastropod species may reveal significant correlations between watershed and individual level measurements.

Acknowledgments

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References

- Alin, S. R., Cohen, A. S., Bills, R., Gashagaza, M. M., Michel, E., Tiercelin J., Martens, K., Coveliers, P., Mboko, S. K., West, K., Soreghan, M., Kimbadi, S., and Ntakimazi, G. 1999. Effects of landscape disturbance on animal communities in Lake Tanganyika, East Africa. *Conservation Biology* **13**: 1017-1033.
- Cohen, A.S., Bills, R., Cocquyt, C. Z., and Caljon, A. G. 1993. The impact of sediment pollution on biodiversity in Lake Tanganyika. *Conservation Biology* **7**: 667-677.
- Cohen, A.S., Palacios-Fest, M. R., Msaky, E. S., Alin, S. R., McKee, B., O'Reilly, C. M., Dettman, D. L., Nkotagu, H., and Lezzar, K. E. 2005. Paleolimnological investigations of anthropogenic environmental change in Lake Tanganyika: IX. Summary of paleorecords of environmental change and catchment deforestation at Lake Tanganyika and impacts on the Lake Tanganyika ecosystem. *Journal of Paleolimnology* **34**: 125-145.
- Hammer, Ø. (accessed 2007) PAST PAlaeontological STatistics program. Ver. 1.74. <http://folk.uio.no/ohammer/past/>.
- JMP IN, Version 4.0.4 Academic. 2001. Duxbury Press and SAS Institute.
- Kinyanjui, D.M. 2002. Soft Substrate mullusc species distribution on the Luiche platform, with implications for lake level and paleoecological reconstruction. *Nyanza Project 2002 Annual Report*: 41-47.
- Michel, E., Todd J.A., Cleary, D.F.R., Kingma, I., Cohen, A.S. and Genner, M.J. 2003. Scales of endemism: Challenges for conservation and incentives for evolutionary studies in a gastropod species flock from Lake Tanganyika. *Journal of Conchology. Special Publication* **3**: 1-17
- Morrisey, D.J., Howitt, L., Underwood and A.J., Stark, J.S. 1992. Spatial variation in soft-sediment benthos. *Marine Ecology Progress Series* **81**:197-204.
- West, K., Michel, E., Todd, J., Brown, D., and Clabaugh, J. 2003. *The Gastropods of Lake Tanganyika: Diagnostic Key, Classification, and Notes on the Fauna*. 130pp. SIL, Dorchester, U.K.

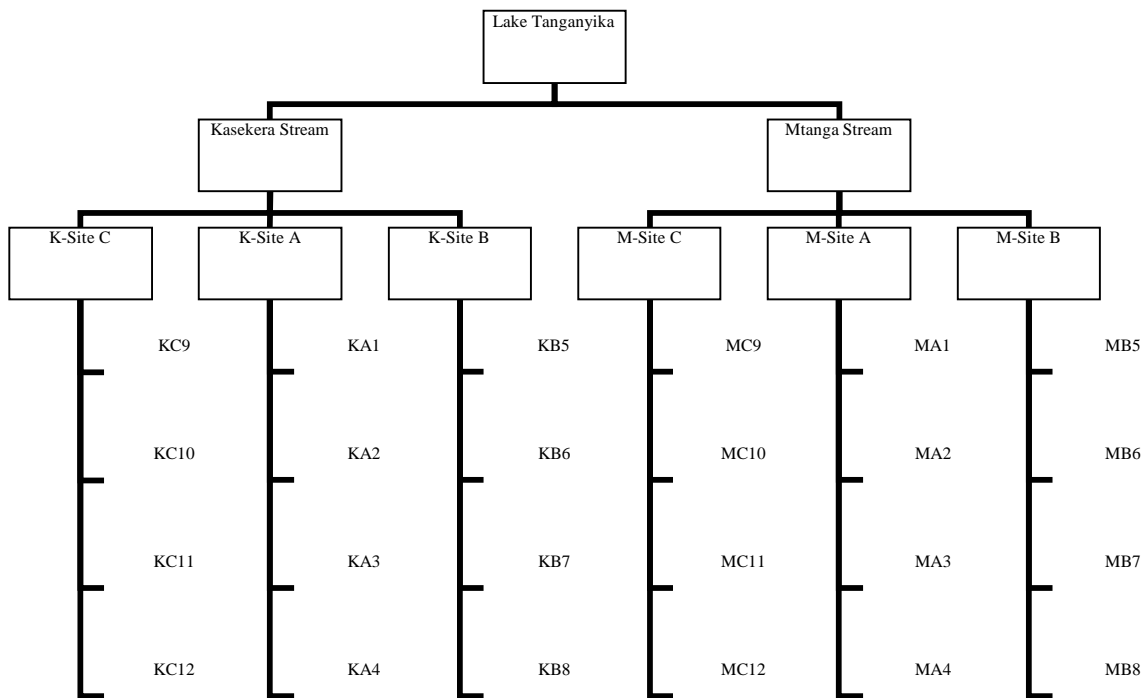
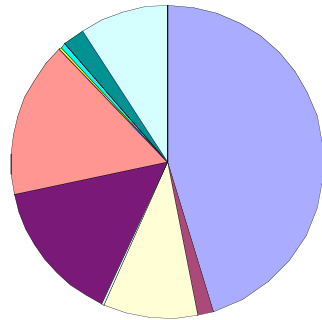


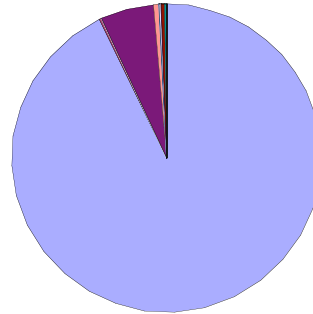
Figure 1. Hierarchy of sample collection. Each watershed, Kasekera Stream (K) and Mtanga (M) consist of 3 sites: Site A, Site B, and Site C with 4 quadrats per site. Numbers indicate the order of collection at each stream.

Example: KC9- Kasekera Stream, Site C, quadrat 9.

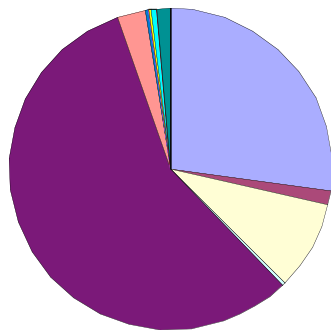
Kasekera Site A Species Abundance



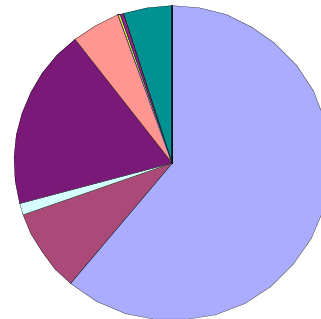
Mtanga Site A Species Abundance



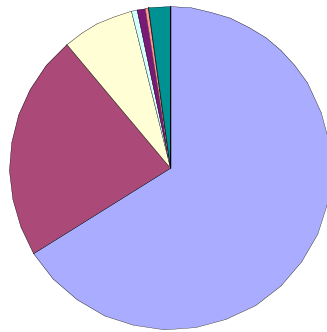
Kasekera Site B Species Abundance



Mtanga Site B Species Abundance



Kasekera Site C Species Abundance



Mtanga Site C Species Abundance

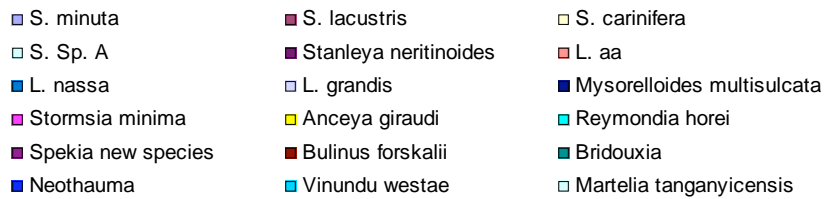
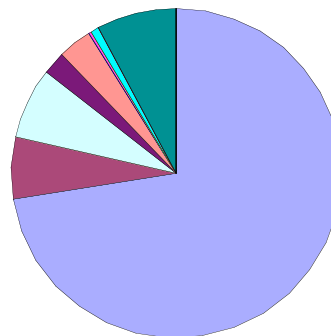


Figure 2. Species abundance for each sampled site (4m²) on Mtanga and Kasekera stream deltas.

**Kasekera Stream
Species Abundance Total**

**Mtanga Stream
Species Abundance Total**

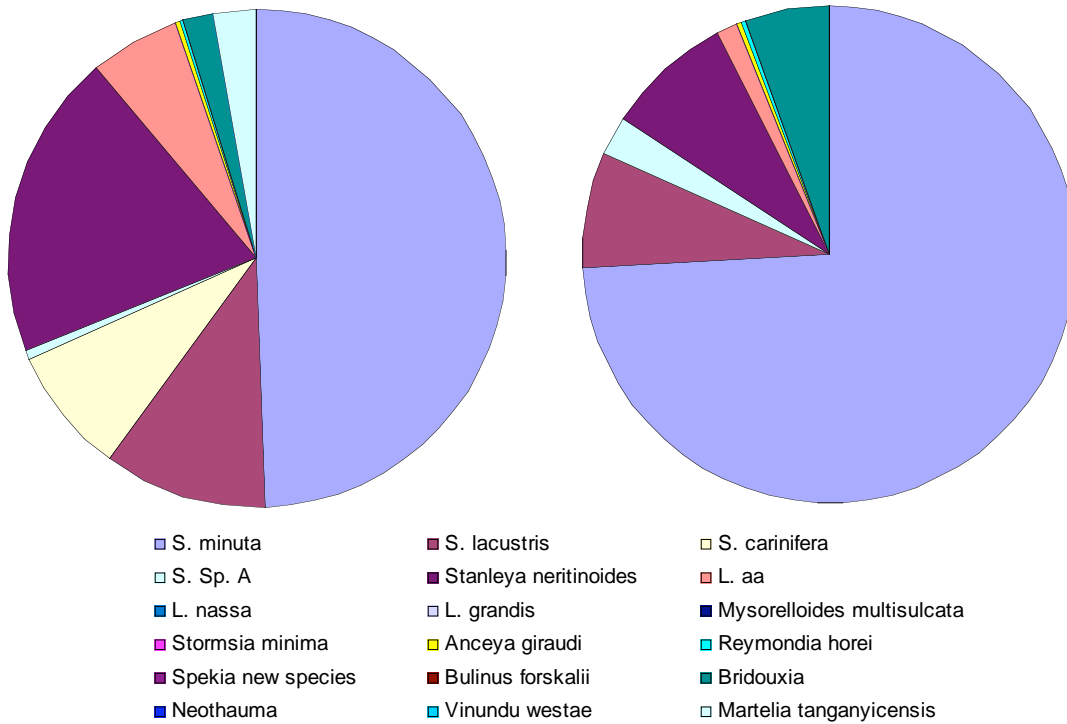


Figure 3. Species abundance totals for all sites at Kasekera and Mtanga streams. Notice the dominance of *Symolopsis minuta* at both streams.

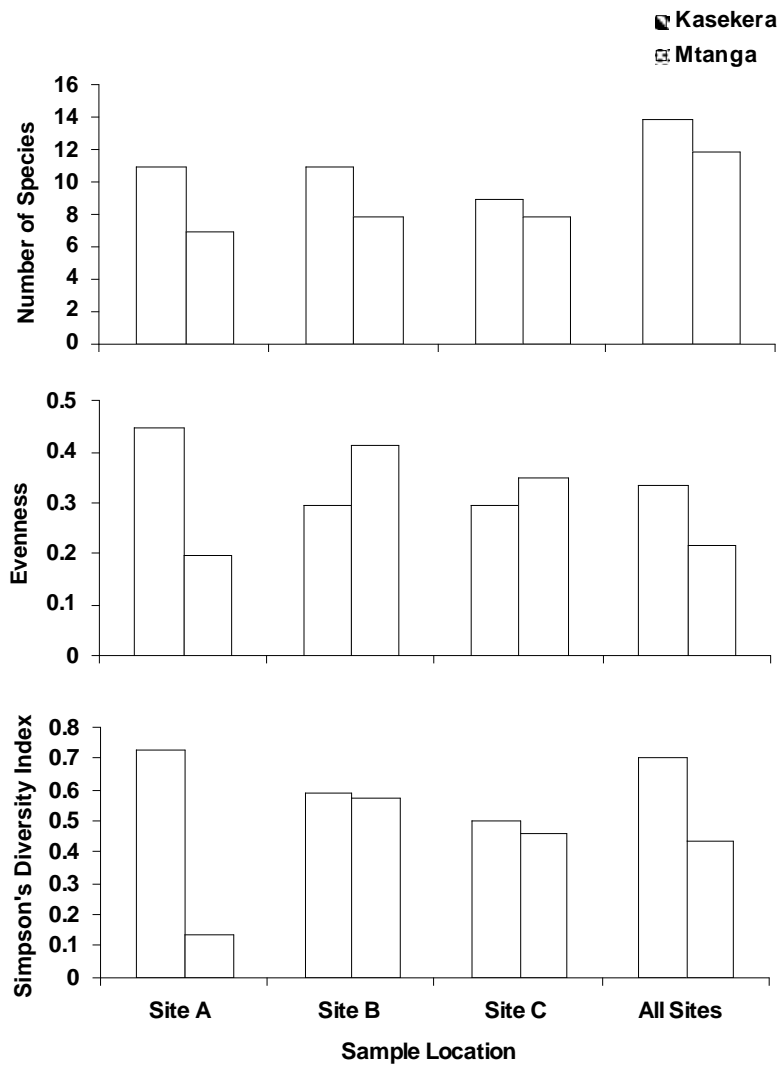


Figure 4. Summary of richness, evenness, and Simpson's Diversity comparison for each sampled site at Kasekera (stripes) and Mtanga (checkered) streams.

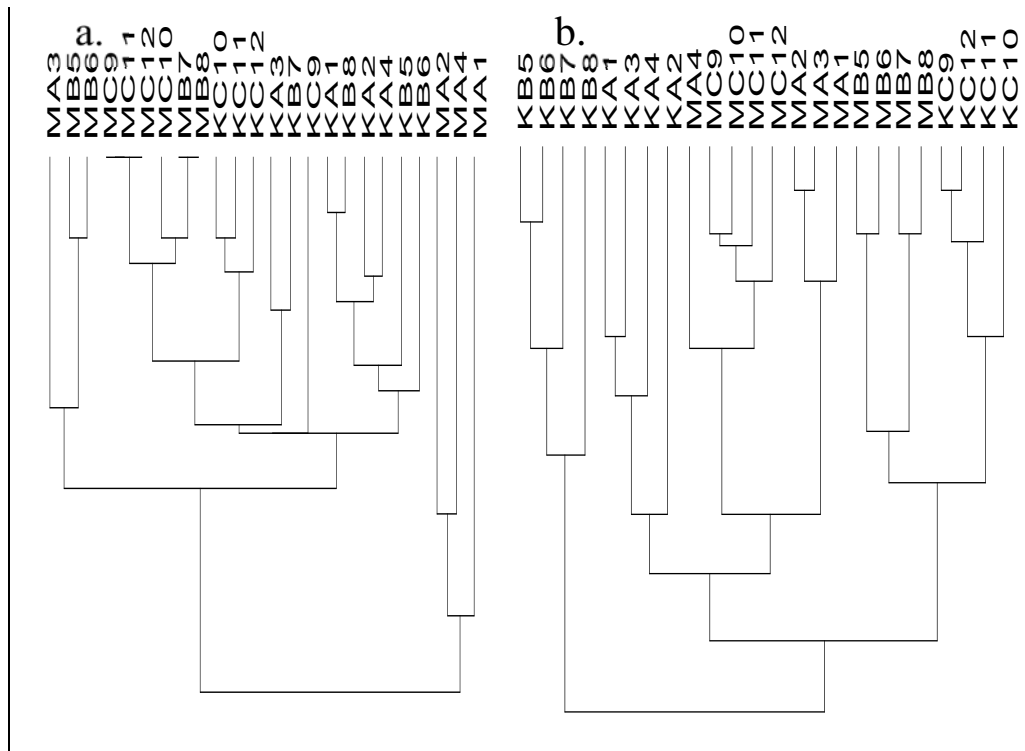


Figure 5. Bray-Curtis cluster analysis for gastropod presence/absence (a) and abundance (b) for 1m² 24 quadrats in 5m water depth near the Kasekera and Mtanga Streams. Length of horizontal bars indicates similarity.

Table 1. Species richness, evenness, Simpson's Diversity for all sites (A, B, C) within the Mtanga (M) and Kasekera (K) watershed. Watershed (Mtanga and Kasekera) totals were computed from summed species abundances from all 12 sampled quadrats from within the watershed.

Site	Species Richness	Evenness	Simpson's Diversity
MA	7	0.1982	0.3276
MB	8	0.4156	1.2010
MC	8	0.3539	1.0410
M Total	12	0.2217	0.9784
KA	11	0.4513	0.7288
KB	11	0.2995	0.5934
KC	9	0.2957	0.5062
K Total	14	0.3389	0.7029

Table 2. Two-way ANOVA of species richness, evenness, and Simpson's Diversity Index for the two aspects of our study. The test is significant if the p-value (Prob > F) is less than $\alpha = 0.05$. Significant value if *.

	Forested vs. Deforested Watersheds				Site Orientation			
	d.f.	SS	F Ratio	Prob > F	d.f.	SS	F Ratio	Prob > F
Species Richness	1	22.4074	8.4899	0.0078*	2	4.9630	0.9402	0.4050
Evenness	1	0.0027	0.3785	0.5444	2	0.0284	1.9644	0.1631
Simpson's D	1	0.2596	13.1892	0.0014*	2	0.1771	4.4981	0.0225*

Table 3. T-test summary of p-values for species evenness between the same site orientations across paired watersheds (Kasekera and Mtanga). Significant value if *.

Site Orientation	d.f.	p-value
Site A	3	0.0142*
Site B	3	0.1160
Site C	3	0.8657

Appendix 1. Collected assemblage of gastropod species from near shore soft substrate (5m water depth) at the Mtanga and Kasekera. Typical habitat of species: hard substrate (H), soft substrate (S). X Presence of species is represented by X. *** represents free flowing stream species. (West *et al.* 2003)

Taxa	Hard/Soft Substrate	Mtanga	Kasekera
<i>Syrnolopsis minuta</i> Bourguignat, 1885	S	X	X
<i>Syrnolopsis lacustris</i> Smith, 1880a	S	X	X
<i>Syrnolopsis carinifera</i> Smith, 1889	S		X
<i>Syrnolopsis</i> sp. A (herein)	S	X	X
<i>Stanleya neritinoidea</i> (Smith, 1880a)	S	X	X
<i>Lavigeria</i> sp. AA of Michel <i>et al.</i> , 2003	S	X	X
<i>Lavigeria nassa</i> (Woodward, 1859)	H		X
<i>Lavigeria grandis</i> (Smith, 1881b)	H	X	
<i>Mysorelloides multisulcata</i> (Bourguignat, 1888)	S		
<i>Stormsia minima</i> (Smith, 1908)	H	X	X
<i>Anceya giraudi</i> (Bourguignat, 1885)	H	X	X
<i>Reymondia horei</i> (Smith, 1881a)	H	X	X
<i>Spekia zonata</i> (Woodward, 1859)	H	X	
<i>Bulinus forskalii</i> (Ehrenberg, 1831)	***	X	
<i>Bridouxia leucoraphe</i> (Ancey, 1890)	H	X	X
<i>Neothauma tanganyicense</i> Smith, 1880b	S		X
<i>Vinundu westae</i> Michel, 2004	H		X
<i>Martelia tanganyicensis</i> (Dautzenberg, 1908)	S		X

Appendix 2. Raw data counts of species abundance for Mtanga (M) and Kasekera (K) sites (A, B, C). Mtanga and Kasekera totals are the summed value of all sites (A+B+C).

	MA	MB	MC	M Total	KA	KB	KC	K Total
<i>Syrnolopsis minuta</i>	309	909	476	1694	384	209	795	1388
<i>Syrnolopsis lacustris</i>	1	129	40	170	14	10	275	299
<i>Syrnolopsis carinifera</i>	0	0	0	0	81	68	86	235
<i>Syrnolopsis</i> sp. A	0	17	46	63	4	2	8	14
<i>Stanleya neritinoides</i>	18	276	14	186	124	434	11	569
<i>Lavigeria</i> sp. AA	2	76	23	31	136	21	2	159
<i>Lavigeria nassa</i>	0	0	0	0	1	4	0	5
<i>Lavigeria grandis</i>	1	0	0	1	0	0	0	0
<i>Mysorelloides multisulcata</i>	0	0	0	0	0	0	0	0
<i>Stormsia minima</i>	0	0	1	1	0	0	1	1
<i>Anceya giraudi</i>	0	4	0	4	1	1	0	2
<i>Reymondia horei</i>	0	0	6	6	5	5	0	10
<i>Spekia zonata</i>	0	1	0	1	0	0	0	0
<i>Bulinus forskalii</i>	1	0	0	1	0	0	0	0
<i>Bridouxia leucoraphe</i>	1	76	51	128	19	9	25	53
<i>Neothauma tanganyicense</i>	0	0	0	0	0	0	1	1
<i>Vinundu westae</i>	0	0	0	0	0	1	0	1
<i>Martelia tanganyicensis</i>	0	0	0	0	78	0	0	78

