

A Comparative Study of Land Use Impacts on Biological, Chemical, and Physical Characteristics of two stream reaches on the Northeastern Shore of Lake Tanganyika

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Introduction

Water provides invaluable services to humanity including drinking water, waste dilution, fisheries, irrigation, and power generation (Wetzel 2001). However the exponential growth of human population puts a severe strain on this finite resource. Agricultural, pastoral, building, and industrial activities tend to reduce the quality and quantity of available fresh water (Allen and Cushing 2001). The threat of human activities to limited water resources is a serious issue that must be addressed at international, national, and local levels. Currently, in the Kigoma region of East Africa 35% of water demand is supplied (H. Nkotagu, pers. com.) while population expands 1.9 – 3 % annually (O'Reilly, submitted). This expansion is coupled with substantial deforestation around Lake Tanganyika (Cohen et al. 2005). In this study we compare the physical, chemical, and biological characteristics between and within a forested and a deforested stream on the northeastern shore of Lake Tanganyika in order to gain a holistic understanding of how human activities impact freshwater resources. We predict that temperature, phosphate, silica, nitrate, ammonia, turbidity, suspended inorganic matter, conductivity, algal mass and pH will be higher in the impacted stream due to anthropogenic activities while dissolved oxygen, stream velocity and suspended organic matter will be higher in the protected stream. Mtanga is a deforested stream on the northeastern shore of Lake Tanganyika. The surrounding village uses the stream for drinking water, washing and sanitation needs. Due to loose substrate, the stream is underground at some locations during the dry season. Mtanga's catchment area consists of approximately 6.76 km² (Guerra 2007) and the surrounding geology consist of mainly quartzite (Helfrich and Rashidi 2007). Kasekera, a forested stream within Gombe Stream National Park, features thick surrounding vegetation and minimal human activity. The catchment occupies approximately 3.32 km² (Guerra 2007) and the surrounding geology includes quartzite, shale and siltstone (Helfrich and Rashidi 2007).

Materials and Methods

Field Work Onsite stream work in Mtanga occurred on the 14th, 15th, 18th, and 26th of July, 2007. Measurements of dissolved oxygen, oxygen saturation, conductivity, turbidity, and pH were taken at 50m intervals from the mouth of the stream to 1km upstream using a YSI 556 Multiprobe. Three 150ml water samples were taken at each location and at two springs for lab analysis of chemical composition. Each sample was filtered through a GF/F filter. In addition 0.75 – 1.5 liters of water were filtered through GF/F filters in order to measure suspended organic and inorganic matter in the laboratory. Each filter was weighed before entering the field and combusted at 500°C. Three replicates were taken at the mouth, 500m, and 1000m. Five randomly selected cobbles were also taken at 0m, 500m, and 1000m, stored individual in plastic bags and taken back to the laboratory for analysis of algal biomass. GPS coordinates were taken at each sampling site. Discharge was evaluated using the "velocity-area method" and "slug-injection methods" (Gordon 2004). The velocity-area method involves measurements of stream width and depth to determine the cross-sectional area of the water channel. The time for a small twig to travel a marked distance was also measured. The latter measurement was made three times and used to determine the average velocity of the stream. Discharge was then calculated from equation $Q=AV$ (where Q =discharge, A =cross-section area, and V =velocity). For the slug-injection method a tracer was prepared using salt in 1 liter of stream water. The conductivity of the tracer was measured using the YSI multi-probe. Before injection background conductivity of the stream was noted and during injection conductivity of the stream was measured and logged at 1 second interval on the YSI multi-probe until stream salinity returned to background levels. These procedures were carried out three approximate locations, the stream mouth, 500m and 1000m. Kasekera field sampling took place on the 22st and 24th of July. The above procedures were performed at the same intervals with one exception. Water samples for chemical analysis were taken every 50m until

500m. Subsequently, samples were taken every 100m until reaching 1km. No springs were found within 1km of the Kasekera stream.

Laboratory Analysis Water samples for chemical analysis were refrigerated for 1-2 days after collection and analyzed for phosphate, nitrate, nitrite, ammonia, silica, calcium carbonate (alkalinity) and chloride concentrations using Hach standard methods. Filters for suspended matter were frozen until processing. After removal from the freezer the filters were dried at 60°C and weighed in grams to the 4th decimal place. Filters were then combusted at 500°C (to burn off all organic matter) and weighed again. To measure chlorophyll *a* algae was scrubbed off each cobble with a steel brush into a plastic tray. The algae was diluted with water and the volume of resulting slurry was measured and stored in individual bottles for each rock. Samples were stored in the freezer until further analysis. After thawing, a known volume of slurry was filtered through a GF/F filter. Each filter was placed into a 15 ml centrifuge tube and 10ml of 95% ethanol was added. The tubes were then covered with foil and stored in a freezer. After 24 hours the filters were removed and samples were centrifuged for 15 min. 10 ml of sample was poured into a 4cm pathlength cuvette depending on concentration. Absorbance was then measured on a spectrophotometer at 665nm using 95% ethanol as a blank. After addition of 3 drops of 2M HCl for acidification the absorbance at 664nm was measured. The following formula was then used to calculate chlorophyll *a* concentration.

$$\text{Chlorophyll } a \text{ (ug/l)} = \text{extraction coefficient} * (A_{665} - A_{664}) * (V_s / (V * l))$$

Extraction coefficient = 29.6

A_{665} = absorbance before acidification (nm)

A_{664} = absorbance after acidification (nm)

V_s = Volume of solvent (ml)

V = volume of water filtered (L)

l = length of pathlength of cuvette (4cm)

Area was calculated by covering the rock with foil. A known area of foil was weighed (Hauer and Lamberti 1996). Using this cobble surface area was then calculated.

Statistical analysis

ANOVA tests were used to determine significant difference between parameters at Kasekera and Mtanga. The tests also determined if parameters varied significantly with distance. Comparative analysis was done excluding three points from Mtanga, including two locations where springs occurred and one where underground flow emerged. Parameters at these points varied largely from other points measured along the stream.

Results

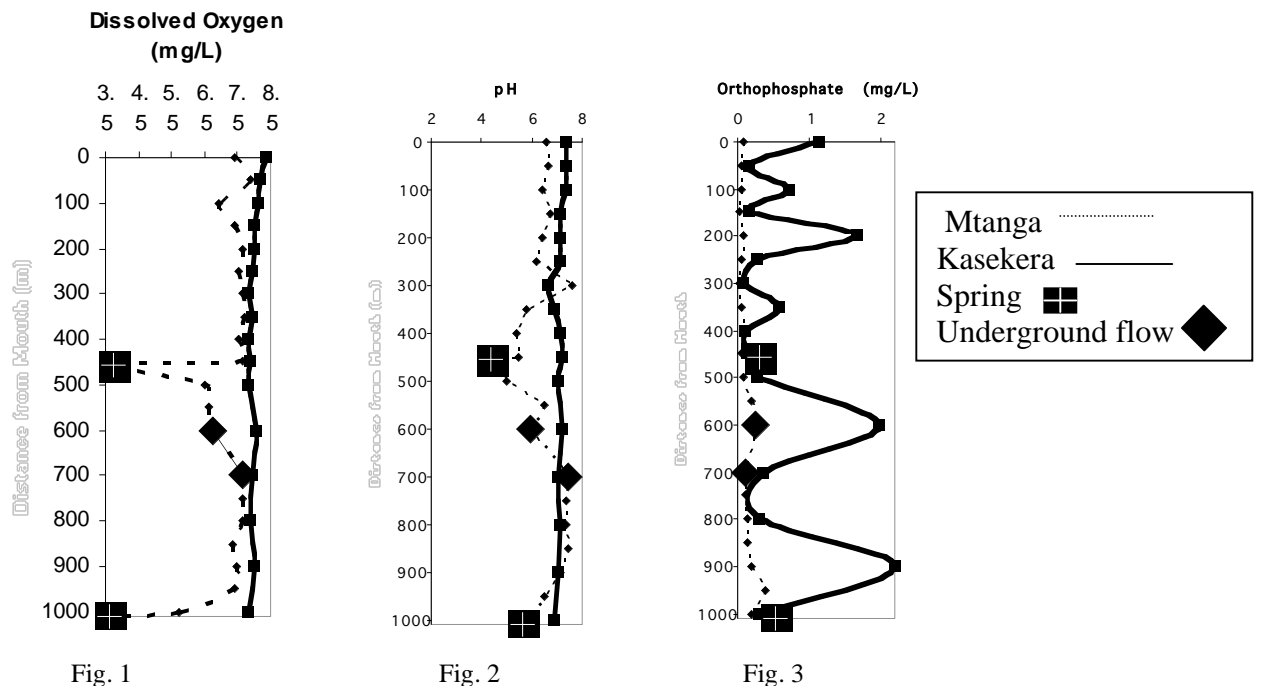
Chemical Parameters Dissolved oxygen, pH, orthophosphate, ammonia, alkalinity and chloride differed significantly between streams. Whereas dissolved oxygen, pH, phosphate and alkalinity were higher on average in Kasekera, ammonia and chloride were higher in Mtanga (table 1). Ammonia and alkalinity differed significantly by distance $p=0.00045$ and $p<0.0001$ respectively. Oxygen Saturation averaging 89.57% in Kasekera and 90.11% in Mtanga did not differ significantly. Nitrate and silica amounts also did not differ significantly between streams.

Physical Parameters Temperature and conductivity differed significantly between the two streams, with conductivity being higher on average in Kasekera and temperature being higher in Mtanga (table 1). Neither showed a significant variance with distance. Discharge was not significantly different between sites but did show a large difference in consistency at the mouth (fig. 10). Discharge, suspended mater, and silica also showed no significant difference with distance between sites.

Biological Parameters Concentration of chlorophyll a per cm² differed significantly between streams and with distance (Table 1).

Parameter	P value	P value with distance	Mean _K	SD _K	Mean _M	SD _M
Dissolved Oxygen (mg/l)	<0.0001	N/A	7.98	0.15	7.35	0.53
pH	= 0.0174	N/A	7.12	0.18	6.51	0.77
Orthophosphate (mg/l)	= 0.0054	N/A	0.6563	0.7041	0.1116	0.0857
Ammonia (mg/l)	<0.0001	= .0045	.06	0.03	0.28	0.11
Alkalinity (mg/l)	<0.0001	= .0001	21.31	2.27	13.47	6.45
Chloride (mg/l)	<0.0001	= .00016	.3125	0.1455	3.5579	2.5292
Temperature (mg/l)	<0.0001	N/A	21	0.62	25.48	0.87
Conductivity (uS/cm)	<0.0001	N/A	43	5.24	26.39	4.15
Chla (µg/l)/cm ²	<0.0001	= 0.0044	1.92	1.69	26.02	17.09

Table 1. Significant parameters, p values, means, and standard deviations for Mtanga (M) and Kasekera(K)



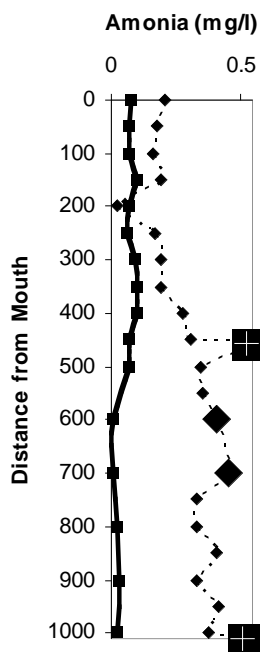


Fig. 4

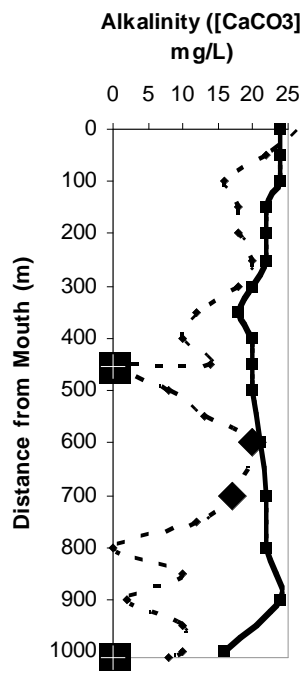


Fig. 5

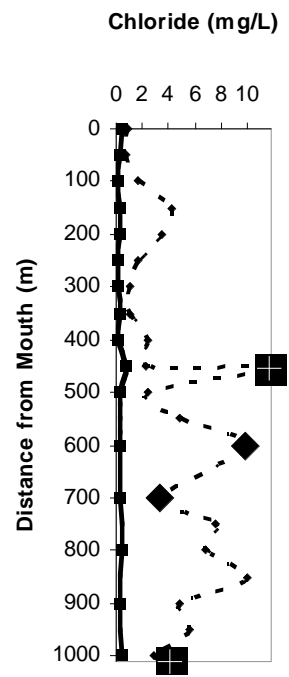


Fig. 6

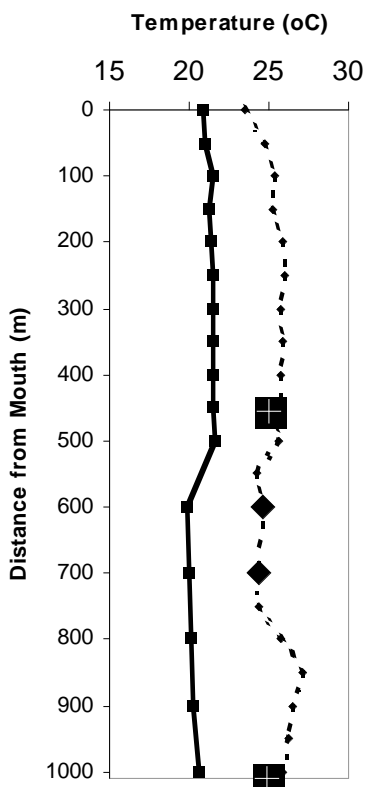


Fig. 7

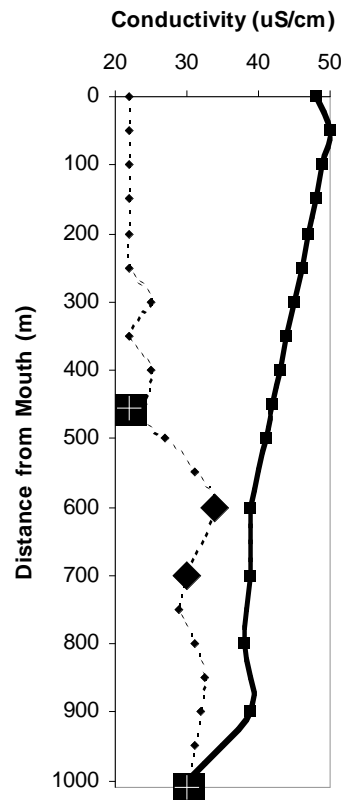


Fig. 8

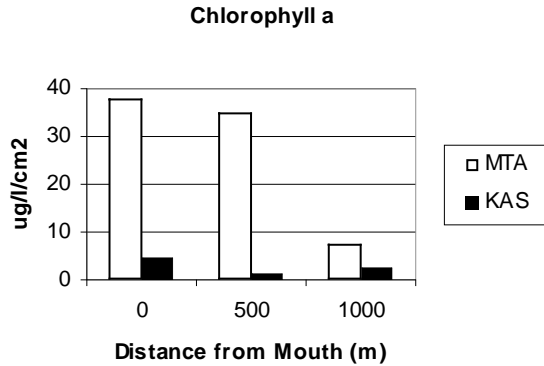


Fig. 9

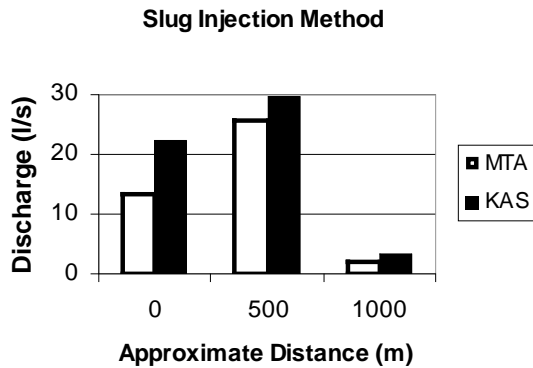


Fig. 10

Discussion

Geology is a controlling factor in aquatic systems; Kasekera and Mtanga are no exception. Contrary to our predictions Kasekera was the more basic system. Sedimentary siltstone within the Kasakera's watershed contributes carbonate which acts as a buffer keeping conditions close to neutral. This ion also gives the Kasekera higher conductivity. Also attributable to geology is the high phosphate concentration in Kasekera. Phosphate is a common chemical in sedimentary rock and thus is found in high concentrations in Kasekera; this is apparent when looking at the extreme difference in phosphate levels within the streams.

Anthropogenic impacts are however evident when looking at other factors within the streams. Temperature in Mtanga is higher, on average, than Kasekera most likely due to lack of shade providing forest cover. In fact, Mtanga temperature level falls outside of the expected range for tropical streams (Allen and Cushing 2001). As temperature is inversely related to gas saturation, dissolved oxygen levels in Mtanga were lower than that of Kasekera. Both rivers however were at approximately the same level of saturation meaning that Mtanga due to higher temperature is unable to hold as much oxygen as Kasekera. With ammonia levels five times higher in Mtanga than Kasekera there is strong indication of water pollution through human and animal wastes. High chloride levels in Mtanga contribute further evidence to human impacts perhaps of detergents used for washing which takes place directly in the river. Nutrients like ammonia can encourage the growth of algae and thus high algal biomass in Mtanga is yet another sign of stream pollution.

Opposing our prediction, discharge in the streams was not statistically different. It was expected that discharge in Mtanga would be lower to evaporation as a result of exposure to solar radiation. The lack of water volume at the mouth of Mtanga however, may still be related to human activities. Sediment

deposited most likely during the rainy season has created a wide sandy area that stretches approximately 250 meters upstream from the mouth. Water becomes ground flow upon encountering this porosity. Kasekera also has a porous area at the mouth of the river, although it is short and narrow. The river channel is maintained and sediments reduced by the dense vegetation acting as an anchor.

Both water quantity and quality have been reduced by human activities around the Mtanga river system. Nowhere is the later more evident than in the condition of one spring found 455m from the mouth of the stream (04°46.480' S, 029° 36.466'E). High ammonia, nitrate and chloride levels indicate pollution. The spring's location affects its quality. Toilets located above the stream are perhaps contributing contaminants to water that is considered relatively clean by people within the village.

Suggestions for Future Research

Longer sample time and larger sample size would add robustness to the data. In addition, differences in stream geology should be minimized to provide a clearer picture of human impacts.

Conclusions

Geology controls some stream factors but human activities also have a great effect on water quality and quantity.

Acknowledgments

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