

# **The Distribution of Clastic Particles across the Littoral Zone of the Forested Kalande Stream and the Deforested Ngelwa Stream**

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## **Introduction/Purpose of Study**

Lake Tanganyika (31°8′-8°47′S, 29°05′-31°18′E) is the largest and oldest of the East African Rift Lakes and holds many biological and geological secrets within its astonishingly complex ecosystem. Lake Tanganyika's main water source is surface rainfall and direct runoff; most of the rain is trapped by the high escarpments and fed into streams and rivers surrounding the lake (*Inland Waters of Tropical Africa*). These catchment systems transport sediment like clay, sand (fine to coarse grained), and silt into the lake. The fraction of each type of sediment deposited on the littoral zone depends on the running rivers and streams energy and the physical properties of the watershed (steep or gentle slope, forested or deforested catchments).

Lake Tanganyika has been under the threat of an array of human activities such as watershed deforestation, which highly impacts the fluvial ecosystems within the lake's surrounding watersheds (Cohen et. al 2005a). Deforested watersheds are much more vulnerable to erosion; vegetation cover slows down surface runoff, which then reduces the erosive powers acting on a watershed. Soil erosion rates in highly impacted areas can range anywhere between 28-100 metric tons per year (O'Reilly et. al. 2005). Notable climatic changes, such as ENSO events, increase the vulnerability of soil and cause higher sediment discharge in deforested areas (Cohen et. al 2005b). When compared to an undisturbed site, core sediments from a highly disturbed site shows distinct compositional changes, such as increased concentrations of lateritic soil particles and terrestrial plant debris relative to undisturbed sites (Cohen et. al. 2005b). It has also been shown that impacted watersheds have higher suspended sediment transport rates than pristine, undisturbed water catchments (Nkotagu 2000).

This study assesses the impact of watershed deforestation on the distribution of clastic particles across the littoral zone of the forested Kalande stream and the deforested Ngelwa.

## **Study Sites**

The two study sites selected, Kalande and Ngelwa streams, represent undisturbed and impacted environments respectively. The Kalande stream watershed is located within Gombe Stream National Park and the Ngelwa stream watershed is located near the Ngelwa village. Gombe Stream National Park is located 16 km north of Kigoma and covers only 52 sq km. It is a narrow strip of mountainous terrain and it is bordered in the east by the peak of the eastern Rift Valley escarpment. The typical vegetation cover found in the park is composed of closely-spaced trees and an undergrowth of coarse grass.

The village of Ngelwa has a fairly small population (<100) and the surrounding escarpments have been cleared for farming purposes. Recent visitors collecting samples in the area state that the stream is highly polluted (Nyanza '06 Participant, Strickler).

The two watersheds are similar in size, with an area of 1.6 km<sup>2</sup> for Kalande and 1.7km<sup>2</sup> for Ngelwa. The Kalande and Ngelwa streams lie at S04°42.6, E029°36.6 and S04° 45.448, E029°36.344, respectively.

## **Methods**

Bathymetric data of Kalande and Ngelwa's littoral zone was recorded in order to establish where grab samples would be taken. Three E-W depth transects for Ngelwa (NP06-DT1, NP06-DT2, NP06-DT3) and Kalande (NP06-DT4, NP06-DT5, NP06-DT6) were taken on the *R/V Echo* using a Raytheon V8010 color echo sounder and recorded by hand in a field notebook. The geology team then determined which transect would be used for grab sampling. Grab samples were collected using a small ponar grab sampler along depth transects NP06-DT3 on 7/4/06 (start: S04°45.5, E029°36.6 end: S04°47.4 E029°35.4) and NP06-DT4 on 7/15/06 (start: S04°42.6, E029°36.6 end: S04°41.4, E029°34.2). A 5-meter depth grab sample was collected

first and then samples were taken at 10 meter depth intervals between 10-80m and at 20 meter depth intervals between 80-140 meters.

Approximately 30-40g of sediment from each grab sample was wet sieved through a U.S.A. standard 63  $\mu\text{m}$  sieve in order to prepare for coarse grain size analysis. The fraction  $<63\mu\text{m}$  was caught in a bowl and set aside for fine grain-size analysis, while the fraction  $>63\mu\text{m}$  was dried in an oven at  $110^{\circ}\text{C}$ . The dried samples were then passed through 500 $\mu\text{m}$ , 425 $\mu\text{m}$ , 250 $\mu\text{m}$ , 125 $\mu\text{m}$ , and 63 $\mu\text{m}$  mesh sieves for approximately 8-10 minutes using a standard hand-operated sieve shaker. The fine fraction  $>63\mu\text{m}$  represented  $<3.5\%$  in all samples and is not discussed further here. The particles caught within each sieve were classified as very fine sand (63-125 $\mu\text{m}$ ), fine sand (125-250 $\mu\text{m}$ ), medium sand (250-500 $\mu\text{m}$ ), and coarse sand ( $>500\mu\text{m}$ ), using the Udden-Wentworth grain size scale. The particles caught in the sieves were weighed and percentages of each were calculated using the total mass of the dry weight of the sample in EXCEL. Plots showing the fraction of very fine, fine, medium, and coarse sand at various depths were created. A presence/absence survey of shell fragments within the samples was also generated.

## Results

The distribution of sand-fraction clastic particles within the Kalande transect is shown in figure 1. Fine sands are present and dominate the sand fraction sediment content at most depths. The proportion of medium sand across all depths ranges between 5-28%. The amount of coarse sand is  $<15\%$  at most depths. At a depth of 60.5m very fine sands dominate, making up over half ( about 58 %) of the sample followed by fine sand at 20%, whereas medium and coarse sand comprise less than 10%.

Figure 2 shows the variations of grain size across the sampled depths in the Ngelwa transect. The largest disparity among the two sites exists in the amount of very fine and coarse sand. The presence of very fine sand across the sampled depths is much lower in Ngelwa than Kalande, whereas the amount of coarse sand is *greater* in Ngelwa than Kalande. The percent weight of very fine sand is below 10% at most depths and those depths above 10% do not have a very fine sand fraction higher than 32%. Coarse sand fractions range from 5-33% of the total dry weight. Fine sand comprise an average of 20% for samples collected at 5.9 m, 11m, and 18.2 m depths and average 30% of the total sand fraction for those collected at 33 m, 39 m, and 50.5 m depths. The sample collected at 64m gives the lowest fine sand fraction (17%). The largest discrepancy among all grain size classes across all depths is seen at 18.2m where the medium sand fraction reaches a value close to 40%. Medium sand fractions for the remaining depths range from 16-33%.

When adding the sand fractions it is important to note that they do not sum up to 100%. This is due to the fraction that went through the 63  $\mu\text{m}$  even after wet-sieving the samples. This shows that wet sieving does not get rid of all the fine particles in a sample unless, more time and water are used during the process. Also, a minimal amount ( $<3\%$ ) of the total dried sample was lost during the hand sieving process.

There was no clear correlation between grain size and distance from shore in Ngelwa and Kalande (Figures 3-6). One is expected to see a decrease in coarse grain size and an increase in very fine grain size as distance from shore increases, but no significant  $R^2$  values were found between the two sites.

Although the purpose of this study was to look at the distribution of grain sizes within the two sites a presence/absence survey of shell fragments within the samples was completed. This decision was mainly due to the large presence of shells in one transect and the absence in the other. Table 1 shows a summary of the findings. The abundance of shell fragments in the grab samples was determined qualitatively by macroscopic observation. An absence means that shell fragments were not macroscopically visible. A  $<5\%$  value is classified as a rare presence in the sample, 5-15% is a common occurrence, and an abundance of shells is represented as anything above 15%. In general, the Ngelwa samples display a much higher abundance of shell fragments than Kalande.

## Conclusion & Discussion

Water movements and differences in water velocity from streams and rivers tend to cause sediment size to decrease as distance from shore increases, but no clear grain size gradient pattern exists within the two sites across the sampled depths. The data lacks a clear, definable trend. Instead, a very random distribution of clastic sediments is evident across all depths. For the most part, the irregular patterns uncovered may be due to the complex and unpredictable geomorphology of a rift lake. This demonstrates that the distribution of clastic sediments in the littoral zone of Lake Tanganyika is not entirely controlled by water movements and differences in water velocity from entering streams and rivers.

In general, there is a much larger portion of coarse grain sand in the Ngelwa samples. The coarser grains in Ngelwa can be explained by higher rates of mechanical weathering occurring on the deforested escarpments. Since there is far less vegetation cover the exposed rocks expand and crack and boulders plummet down the catchment. There are no trees or well rooted vegetation to trap falling rocks; therefore, very coarse sand and rocks are deposited in streams and ultimately into the littoral zone of the lake.

The higher presence of shells found in the deforested grab samples correlates well with Jankowski's total inorganic carbon (TIC) data generated from the same grab samples. Jankowski shows a much higher percentage of carbonate minerals in the Ngelwa samples when compared to Kalande, which is consistent with the shell presence/absence survey conducted in this study. A common notion of aquatic fauna is that they tend to be found in areas of low disturbance, but "there are clear associations of particular taxa with high disturbance levels, and these species can be shown to become more common under increasingly disturbed conditions" (Cohen et. al. 2005b).

#### *Kalande*

In general, there is a larger proportion of very fine and fine sand in the Kalande transect. The greatest anomaly in the data was that the fraction of medium and coarse sand increase as depth increases when the opposite is expected. These are not 'normal' or common distributions of sediment and this irregularity can be attributed to the steep underwater escarpments. The coarse and medium allochthonous sediments could have been transported by a creep flow process, gravity, or even by random deep water energy pulses caused by heavy rainfall events. A close and detailed examination of the bathymetry of the study site is needed in order to validate the assumptions made. The random distribution of allochthonous sediments may also be attributed to the presence of a sub-lacustrine delta, which would explain the high presence of fine and very fine sand across the sampled depths. A very clear and expected pattern was seen at 60 m of depth where the very fine sand fraction dominates, followed by fine, medium, and coarse sediment. It is possible that the random distribution of allochthonous sediments stops at about 60m of depth, at the margin of the sub-littoral zone where autochthonous sediments dominate.

#### *Ngelwa*

One notable difference between the two sites is that unlike the Kalande Stream, the Ngelwa Stream obliquely enters the lake (refer to E. Astley paper for map). Thus, the transect used for grab sampling was also angled to the shoreline in order to line up with the mouth of the stream. Although depth rapidly increased along the transect this didn't necessarily mean that the distance from shore increased. This can explain the presence of high coarse and medium sand fractions and relatively low fine sand fractions present in the deep water samples. It should also be noted that two other streams enter the lake just south of the Ngelwa stream and they may also contribute significant amounts of allochthonous sediment, which helps explain why there are higher fractions of coarse sediment at the deeper samples. High coarse sand fractions can also be attributed to the presence of deep, eroding underwater canyons near areas of grab sample collection. It is also unknown whether a sub-lacustrine delta forms perpendicular to shore or in line with the stream mouth and this missing information may help interpret the random allochthonous sediment distribution.

### **Future Work & Recommendations**

The main purpose of this study was to look for notable differences in allochthonous sediment distribution in the littoral zone of a forested and deforested watershed. It is beyond the scope of this paper to explain in detail the random distribution of sediments caused by the complex geomorphologic factors of a rift lake. Future projects should extensively collect bathymetric data of the two study sites in order to explore in more detail why a random distribution of clastic particles was found instead of the expected grain size gradient when distance from shore increases. It should also be noted that only one transect was sampled for each site and more transects should be sampled in order to understand in more detail the distribution of sediments near the two streams. Also, further research on shells should be conducted in order to explain why a much higher presence of shells was observed in the deforested grab samples.

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**Figure 1.** Sand fraction proportional distributions across sampled depths for Kalande.

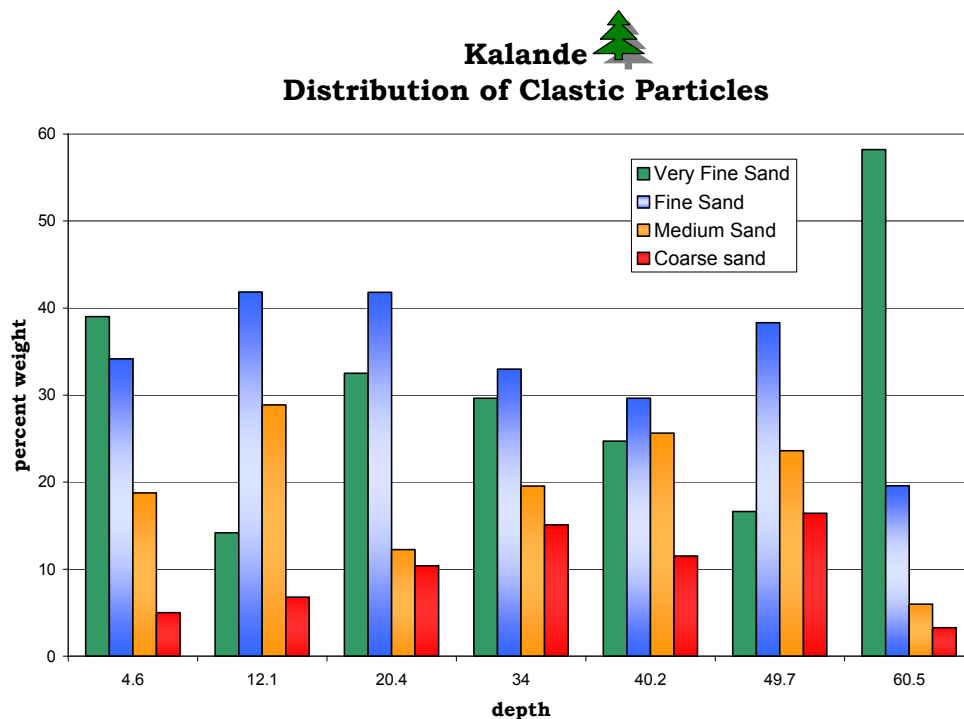


Figure 2. Sand fraction proportional distributions across depths sampled for Ngelwa.

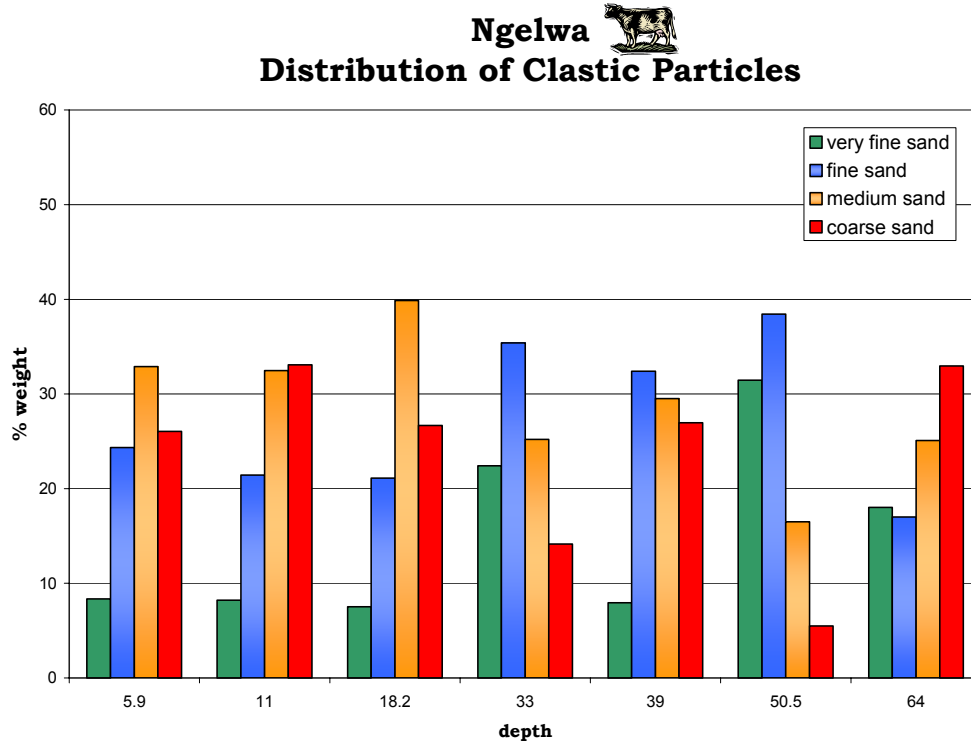
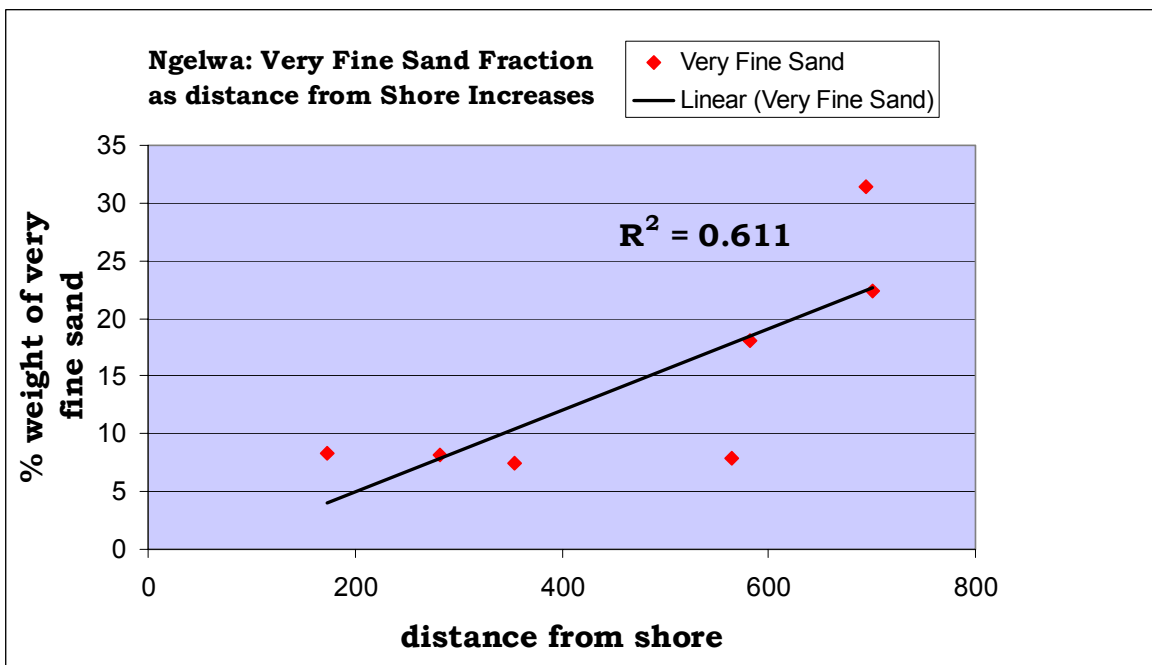
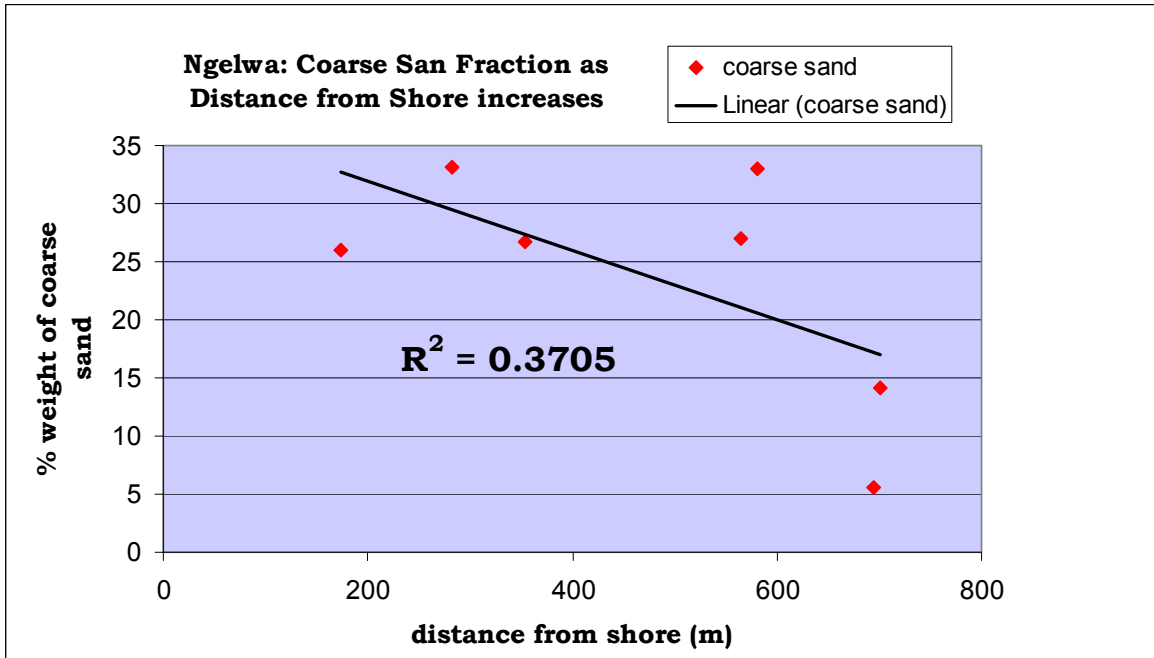


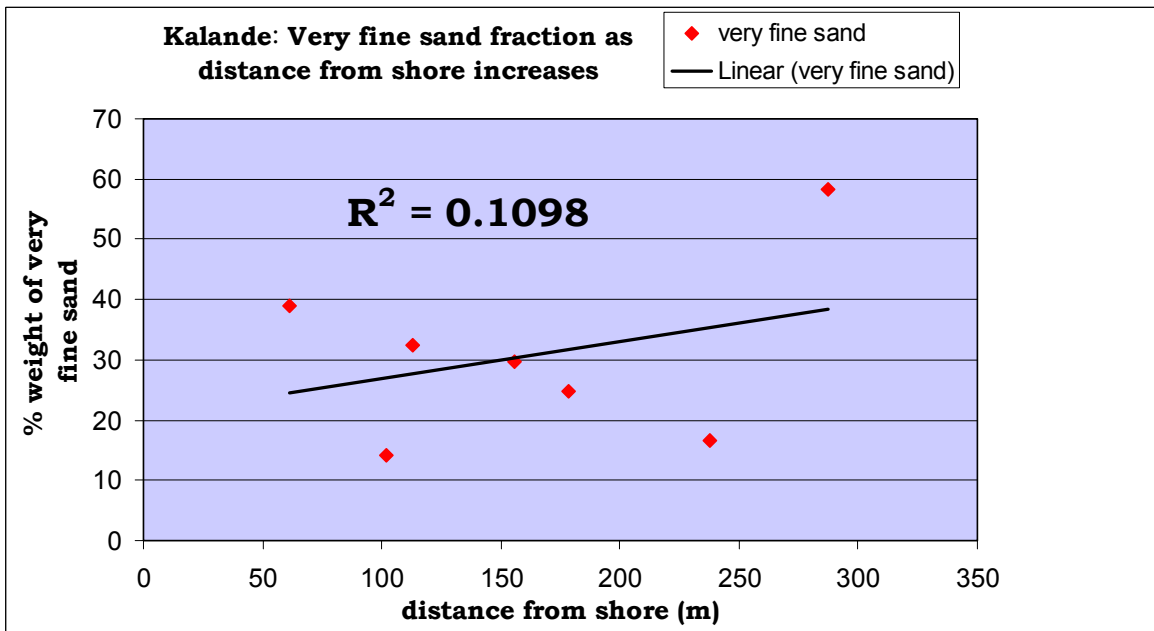
Figure 3. Very fine sand fraction distribution in Ngelwa as distance from shore increases. The  $R^2$  of % weight vs distance from shore is not significant.



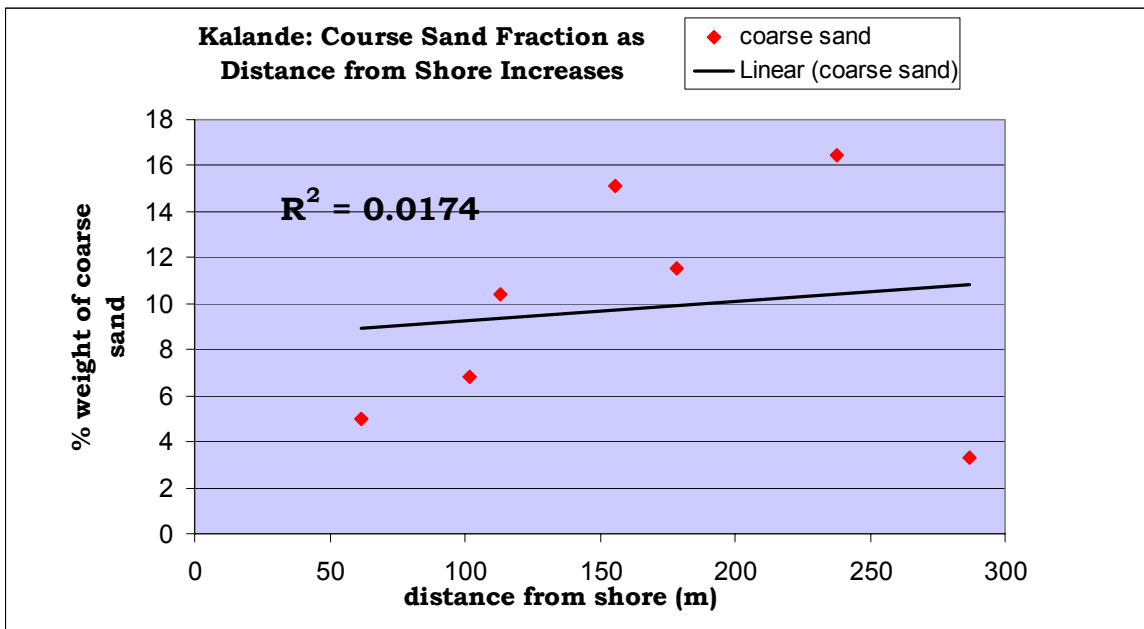
**Figure 4.** Coarse sand fraction in Ngelwa as distance from shore increases. Fairly high coarse sand fractions are present throughout most depths. There is no significant correlation of coarse fraction % with depth.



**Figure 5.** Very fine sand fraction as distance from shore increases for Kalande. There is no clear, definable pattern present, and fine sand fraction does not increase with distance from shore as expected.



**Figure 6.** As distance from shore increases the coarse sand fraction in Kalande does not decrease. Instead, there is an increase in coarse sand and a sudden, pronounced drop. A very low correlation exists between coarse sand fraction and distance from shore.



**Table 1.** Results of presence/absence survey of shell fragments between the two transects. The depths shown are approximate, binned by depth interval. Abundance of shells was determined qualitatively by macroscopic observation of occurrence in grab sample material.

Absent: Not macroscopically visible

Rare: < 5%

Common: 5-15%

Abundant >15%

Approx. Depth	5m	10m	20m	30m	40m	50m	60m
Ngelwa	rare	common	common	common	common	rare	rare
Kalande	absent	rare	rare	absent	absent	absent	absent

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