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Sediment macro- and meiobenthic fauna distribution along the Kenyan continental shelf

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Abstract

Endobenthic fauna diversity, density and relative abundance were studied along the Kenyan continental shelf at four stations (Shimoni, Kwale, Mombasa and Kilifi) sampled during the *R/V Mtafiti's* maiden cruise between 12th and 21st December, 2015. A total of 16 macrobenthic taxa were recorded, with Amphipoda and Polychaeta dominating at all stations except Kilifi where no amphipods were recorded. Total densities of macrofauna ranged between 7 457 and 97 878 ind/m². The highest macrobenthic dominance (0.37), and the lowest H diversity and evenness (1.49 and 0.29, respectively) were recorded in Shimoni, while the highest H diversity values (2.18 and 2.11, respectively) were recorded at Kwale and Mombasa, respectively, and the highest evenness (0.74) at Kilifi. A total of 24 meiobenthic taxa were recorded, dominated by nematodes and copepods at all stations. Densities of meiofauna ranged between 96 and 1705 ind/10cm². The highest meiobenthic H diversities (1.67 and 1.63) were recorded at Shimoni and Mombasa, and the highest evenness (0.31) at Shimoni. The highest dominance (0.39), and lowest diversity (1.38) and evenness (0.21) were recorded at Kilifi. Sediment granulometry and total organic matter (TOM) displayed a north-south trend with the southern stations recording higher proportions of coarser sediments and low TOM, while the northern stations recorded higher proportions of finer sediments and higher TOM.

Keywords: Macrobenthic fauna, meiobenthic fauna, endobenthic, continental shelf

Introduction

The Western Indian Ocean is estimated to have a gross marine product of US$20.8 billion and an asset base valued at $333.8 billion. The main marine activities are based on fishing, maritime trade and marine resource use (Obura *et al.,* 2017). In Kenya, maritime commerce and tourism are the main economic activities directly related to the Indian Ocean in the urban centres (e.g. Mombasa) while artisanal fisheries and artisanal activities e.g. boat building are the main marine related activities in the Kenyan coastal rural areas (Kitheka *et al.*, 1998).

There are plans underway to increase economic activities along the Kenyan coast including the expansion of Mombasa port through dredging and the creation of new berths to increase the capacity of the port to handle more and larger ships, and the creation of a new port in Lamu to serve the hinterland in Ethiopia and South Sudan as part of a mega project (LaPSSET),

and offshore oil and gas exploration activities. These developments necessitate baseline data and information on the status of the marine environment for continuous monitoring and evaluation of the impacts of these projects.

Most of these projects are likely to directly or indirectly impact on the seabed (UNEP, 2006) as most potential pollutants settle in the benthic zone. The benthic zone hosts benthic fauna which live an almost sedentary lifestyle with very close association with their environment, and are able to act as indicator species due to their sensitivities to specific changes in their environment (Ansari *et al.,* 2012; Tagliapietra and Sigovini, 2010; Josefson *et al.,* 2009; Theroux and Wigley, 1998). The species abundance patterns and community structure of these benthic invertebrates therefore provide important information on marine environmental quality (Josefson *et al.,* 2009).

Benthic fauna can be categorized as either infauna (endo) or epifauna, with the former referring to those organisms that live in the sediments, while the latter refer to those organisms that live on the sediment surface. Generally, these benthic organisms are classified based on their size as either microbenthos (<0.063mm), meiobenthos (0.038-1.00mm), macrobenthos (>0.5mm), or megabenthos (>10mm) (Tagliapietra and Sigovini, 2010). Macro and meiobenthic invertebrates are among the main benthic fauna of interest in most continental shelf benthic studies.

Very limited information is available on the distribution, composition and ecology of the soft sediments and the fauna they support for the Western Indian Ocean's offshore regions (ASCLME/SWIOFP, 2012). Muthumbi *et al*. (2004) is among the recent studies conducted on the Kenyan shelf. This study reported the area as oligotrophic with higher organic contents recorded in the northernmost transect, which was attributed to the influence of the Somali upwelling system. Nematoda and Copepoda dominated the meiofauna component of the study.

The current study aims to provide more information on the status of the endobenthic communities of the Kenyan continental shelf.

Materials and methods

The study area was the Kenyan continental shelf of the Western Indian Ocean (WIO). Generally, the width of the Kenyan continental shelf varies, with the northern coast (north of Malindi) hosting a wider shelf compared to the southern coast (Schoolmeester and Baker, 2009; Kitheka *et al.,* 1998).

Four stations located along the shelf were identified and named based on the adjacent landward county, except for Shimoni. Replicate macrobenthic and meiobenthic samples were collected on board *R/V Mtafiti* during its maiden cruise between 12th and 21st December, 2015. Four stations, namely Shimoni Transitional Waters (Shimoni TW), Kwale (KTW), Mombasa (MTW) and Kilifi (KwTW) (Fig. 1) were sampled using a Van Veen grab (1000 cm²) at water depths ranging between 15 and 80 m.

Sub-samples were taken using hand corers of 6.4 cm diameter for macrobenthos, and 3.4 cm diameter for meiobenthos and TOM. The sediment core depths of the samples were dependent on the depth of the grab samples hauled (Table 1). The samples were fixed

in 4% formaldehyde solution and taken to the laboratory. No sediment samples for granulometry were collected during the maiden cruise and thus, samples for sediment grain size analysis were recovered from the samples for fauna analysis (detailed below).

Being the very first cruise, unforeseen challenges were encountered during benthic sampling. The main challenge that affected this research was the failure of the grab to haul complete samples (i.e. more than 10 cm deep sediment samples), even after several trials, and this affected sample collection for TOM analysis and sediment granulometry. No samples were specifically collected for sediment granulometry and for TOM analysis in Kwale.

Sediment granulometry was therefore undertaken using sediments that were recovered from the macrofauna samples during sieving, and after all the macrofauna individuals were collected during enumeration and identification. The sediments that passed through the 0.5 mm sieve and those trapped on the 2.00 mm sieve during macrobenthic sample preparation (sieving) were collected in a bucket. The sediments that were retained by the 0.5 mm sieve were recovered after the macrofauna individuals were identified and collected. These sediment portions were added to those collected from the 2.00 mm sieve and the filtrate from the 0.5 mm sieve, and they were then allowed to stand in the bucket until all the sediments had settled completely, decanted, air dried and then oven dried. Dry sieving, using a mechanical shaker, was then conducted using 2.00 mm, 1.00 mm, 0.5 mm, 0.25 mm, 0.125 mm, and 0.063 mm sieves. The sediments collected on these sieves were weighed and the relative grain distribution was calculated and classified based on the classification scale of Wentworth (1922). TOM samples were analysed by ashing, where the samples were oven dried at 70°C until a constant weight was achieved. The samples where then ashed in a furnace for 6 hours at 500°C, the ash free weight determined, and the difference between the two was used to calculate the TOM (Higgins and Thiel, 1988).

The samples for macrobenthic analysis were washed in the laboratory using tap water through a 2.00 mm sieve nested on a 0.5 mm sieve. The 2.00 mm sieve was used to remove larger material and organisms while the 0.5 mm sieve was used to retain and collect the macrobenthic fauna (Tagliapietra and Sigovini, 2010). The meiobenthic samples were washed through a 1.00 mm sieve nested on top of a 38 µm sieve with the 1.00 mm sieve used to remove larger material
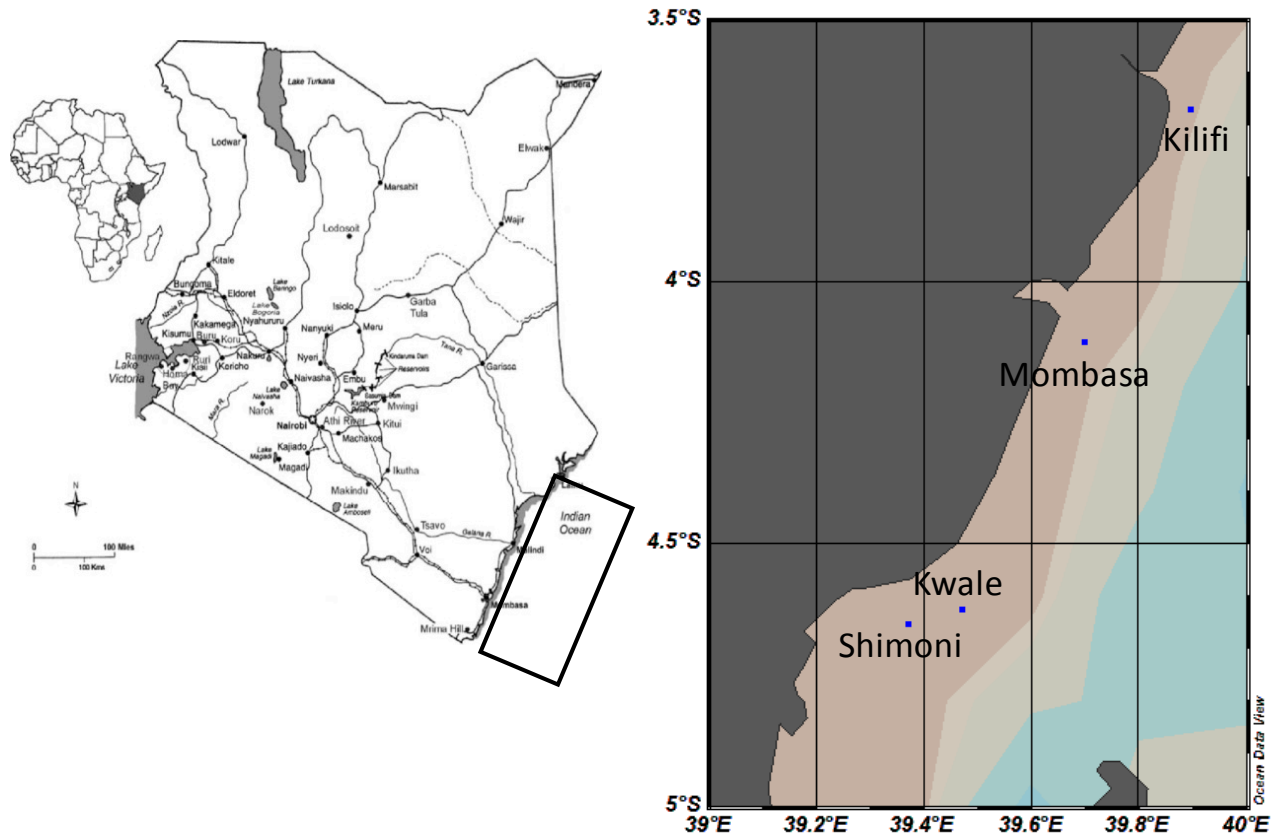
Figure 1. Map of study area showing the benthic sampling sites along the Kenyan shelf.

and larger organisms from the meiofauna samples. The meiofauna samples retained on the 38 µm sieve were then put in centrifugation tubes using $MgSO_4$ solution as the media (specific density of 1.28) and centrifuged to extract the meiobenthos from the sediment by density separation (Higgins and Thiel, 1988). Each sample was centrifuged three times and the supernatant was collected on the 38 µm sieve after each centrifugation and rinsed off the sieve using water. The samples were then preserved using 4% formaldehyde solution for further analysis. All samples (macrofauna and meiofauna) were stained in Rose Bengal solution to aid in the identification and sorting of fauna. Identification was carried out using Higgins and Thiel (1988).

Data analysis

The data was recorded and analysed for relative abundance and density in an Excel spreadsheet, with diversity indices calculated and the diversity *t* test carried out using the Paleontological Statistics Software package (PAST v2.17c) (Hammer *et al.*, 2001). Community analysis was carried out using Plymouth Routines in Multivariate Ecological Research (PRIMER v5.2.9) (Clarke and Gorley, 2002), where Bray-Curtis similarity, Analysis of Similarity (ANOSIM) and Similarity Percentages (SIMPER) were used to compare the similarities within stations, and among stations. Dendrogram and Multidimensional Scale (MDS) plots were also plotted using PRIMER based on Bray-Curtis

Table 1. Location of sampling stations and their depths along the Kenyan continental shelf.

Station	Code	Longitude	Latitude	Water Depth (m)	Sediment Depth (cm)	Number of replicates
Shimoni	ShTW	039'22.33 E	04'39.20 S	19	10	3
Kwale	KwTW	039'28.19 E	04'37.39 S	48	3	3
Mombasa	MTW	039'41.87 E	04'06.89 S	78	3	3
Kilifi	KTW	039'53.68 E	03'40.17 S	38	5	3

Simlarity. Statistical Package for the Social Sciences (SPSS) (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) was used to analyse for significant differences in the densities between stations using Analysis of Variance (ANOVA) and the subsequent post-hoc analysis was carried out using Tukey's Honestly Significant Difference (HSD). SPSS was also used to create the graphs.

Results
Abiotic parameters
The grain size analysis displayed a north-south trend, with the highest proportions of coarse sand (1-0.5 mm), very coarse sand (1-2 mm) and pebbles (>2 mm) recorded in the southernmost stations (Shimoni and Kwale), and their proportions reducing northwards where higher proportions of fine (0.25-0.125 mm) and very fine sand (0.125-0.063mm) were recorded (i.e. Mombasa and Kilifi). The highest median sand fraction was observed in Mombasa and Kwale (Fig. 2).

The total organic matter (%TOM) ranged between 2.86% and 3.59%, with Kilifi recording the highest TOM (3.59%), and Shimoni the lowest (2.86%), while Mombasa stations had 3.17% (Fig. 3). No samples for TOM analysis were collected for the Kwale station due to the challenges stated above.

Macrobenthic composition and abundance along the Kenyan Shelf
The densities varied significantly along the shelf stations (F (3,8)=15.003, *p*=0.001). Tukey's post hoc analysis indicated that Shimoni and Mombasa each differed significantly from Kwale (*p*=0.5 and *p*=0.021,

respectively) and Kilifi (*p*=0.004 and *p*=0.002, respectively), while there was no significant difference between Shimoni and Mombasa, nor was there a significance difference between Kwale and Kilifi. The highest density was recorded at Mombasa (85 864±9 324 ind/m²) despite the corer depth falling short of the recommended 10 cm depth. The second highest density was recorded at Shimoni (78 095±23 024ind/m²), followed by Kwale (40 083±11 655ind/m²) and finally Kilifi (16 261±10 137ind/m²) (Fig. 4).

Sixteen macrobenthic taxa were recorded with Amphipoda and Polychaeta being the most abundant taxa over all, followed by Ostracoda, Tanaidacea, and Nematoda. The Amphipoda had high abundance at Shimoni (58%) and Mombasa (27%) and was the third most abundant at Kwale (12%), but were not recorded at Kilifi station. Polychaeta was the most abundant taxon in Kwale (30%) and Kilifi (26%), but less abundant at Mombasa (22%) and Shimoni (15%). Ostracoda showed similar abundance at all stations (15% at Kwale, 12% at Shimoni, 12% at Mombasa, 12% at Kilifi). Tanaidacea was the second most abundant taxon at Kilifi (16%) followed by Nematoda (13%). Other taxa with recognizable abundance during this study included Copepoda, Isopoda, Oligochaeta, Tubellaria, Gastropoda and Cumacea. Nemertina, Sipuncula, Gnathostomulida, Echinodermata and Halacaroidea were the least abundant taxa and were grouped as 'others' (Fig. 5).

Diversity of Macrobenthos along the Kenyan continental shelf
Shannon diversity *t* test (pairwise) indicated that Shimoni significantly differed from all the other
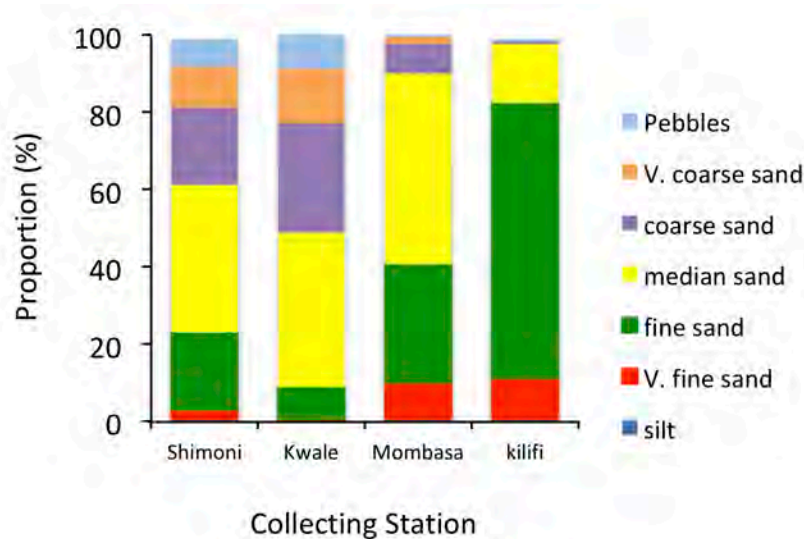

Figure 2. Granulometry distribution along the Kenyan continental shelf.
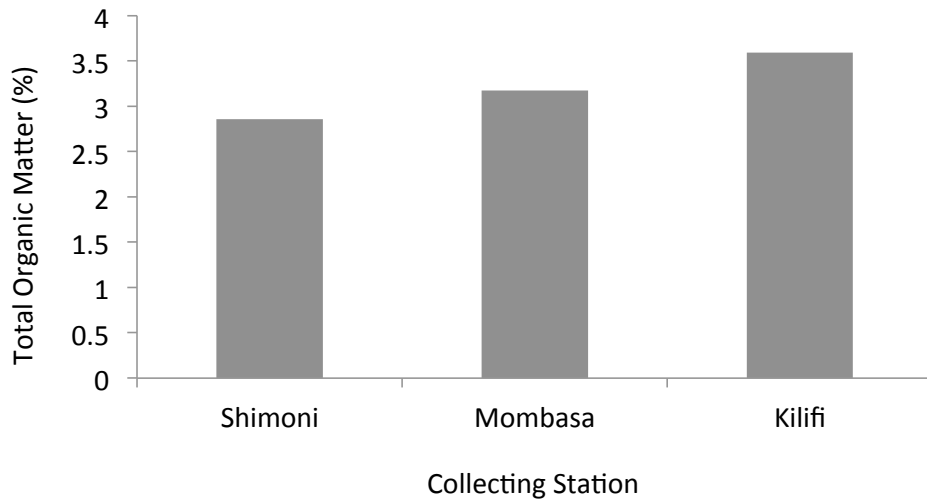
Figure 3. Percentage of total organic matter recorded from the Kenyan continental shelf.
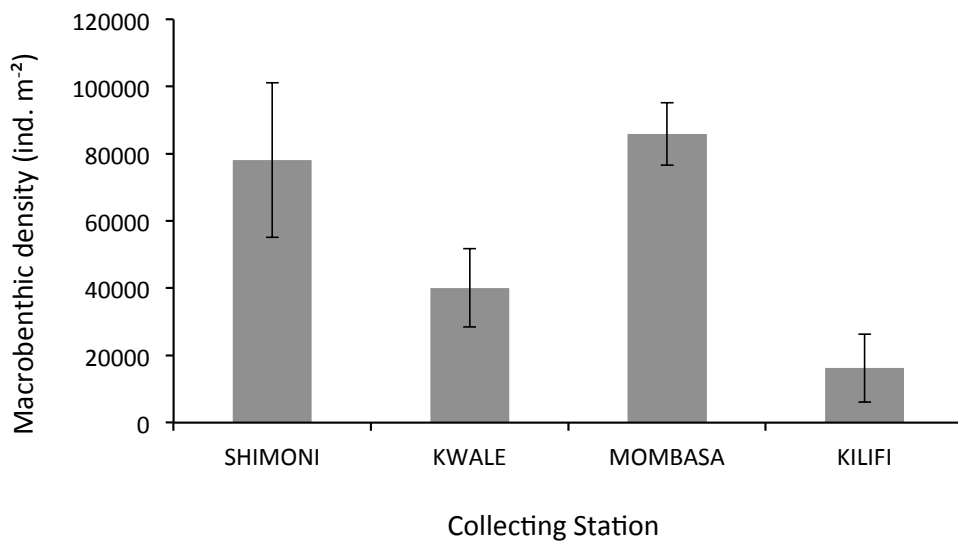

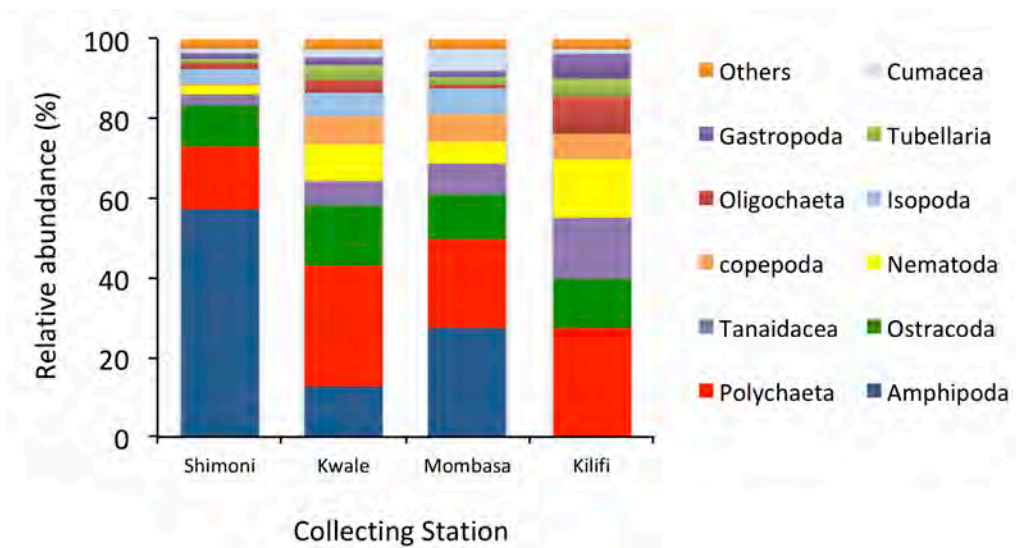**Figure 4.** Macrobenthic densities from the stations along the Kenyan continental shelf.

Figure 5. Macrobenthic relative abundance along the Kenyan continental shelf.

stations (Kwale ($t_{1052.9}$= 10.3; $p<0.0001$), Mombasa ($t_{1292.4}$=11.0;$p<0.0001$) and Kilifi ($t_{432.04}$=8.1;$p<0.0001$)).

Kwale had the highest H diversity (2.18) and the lowest dominance (0.16) while Shimoni had the highest dominance (0.37) and the lowest diversity (1.49) and evenness (0.3). Kilifi had the highest evenness (0.74), while Mombasa had the second highest H diversity (2.11) and evenness (0.59) (Table 2).

Community analysis of macrobenthic fauna along the Kenyan continental shelf

Analysis of Similarity (ANOSIM) indicated a high difference among the stations (R=0.756). Further analysis using SIMPER revealed low similarities between Shimoni and Kilifi (25.98%), Mombasa and Kilifi (28.59), while medium similarities were observed between Kwale and Kilifi (47.83), Shimoni and Kwale (47.75%),

Kwale and Mombasa (59.55%), and Shimoni and Mombasa (62.32%). The within stations similarity was high in Mombasa (84.89%), Kwale (74.16%) and Shimoni (70.5%), and least in Kilifi (53.16%) (Fig. 6).

These similarity percentages resulted in Mombasa communities clustering together in the Multidimensional Scaling (MDS) due to the high similarity within the station (84.89%), and was also closer to Shimoni and Kwale, while Kilifi was furthest from the other stations, and its stations were also further apart due to the low similarity of the communities within the station (53.16%) and the other stations (Fig. 7).

Meiobenthic composition and abundance along the Kenyan continental shelf

The meiobenthic densities differed significantly among the stations according to ANOVA analysis

Table 2. Meiobenthic fauna tally; density, mean±SD, and diversity recorded from the stations along the Kenyan continental shelf.

|	Shimoni	Kwale	Mombasa	Kilifi
	Mean±SD			
Amphipoda	145.3±50.8	15.7±6	75.3±18.6	0
Polychaeta	37±14	38.7±9.7	61.7±5.5	13.7±9.9
Isopoda	9±3	8.0±5.6	17.3±2.3	0
Tanaidacea	7.7±3.8	7.7±1.2	20±6.6	8.3±6.7
Oligochaeta	3.7±1.2	4±1.7	2.3±0.6	4±2
Ostracoda	28.7±36.7	19±3.5	32±3.6	6.3±5.5
Nematoda	4.3±2.5	12.3±5.9	15±4.6	7±3
Cumacea	2.7±0.6	2.3±1.5	15.3±0.6	1±1.7
Nemertina	3.7±2.1	1.3±1.5	4.3±2.1	1.3±1.2
Tubellaria	2.3±0.6	4.7±1.2	5.7±3.2	3.3±4.2
Sipuncula	0.3±0.6	0.7±1.2	0	0.3±0.6
Gastropoda	3.7±0.6	2.3±0.6	3.7±2.1	3.3±2.1
Gnathostomulida	0.7±1.2	0	0.7±0.6	0
copepoda	1.0±1.0	10.7±11	20.7±12.1	3.7±2.5
Echinodermata	1.3±1.2	1.3±1.5	2.3±2.3	0
Halacaroidea	0.0	0.3±0.6	0	0
Density	78095.4±23023.7	40083.5±11655.3	85863.5±9323.5	16261.2±10137.1
Taxa_S	15	15	14	11
Dominance_D	0.3725	0.1528	0.1593	0.146
Shannon_H	1.493	2.18	2.112	2.103
Evenness_e^H/S	0.2967	0.5898	0.5905	0.7444
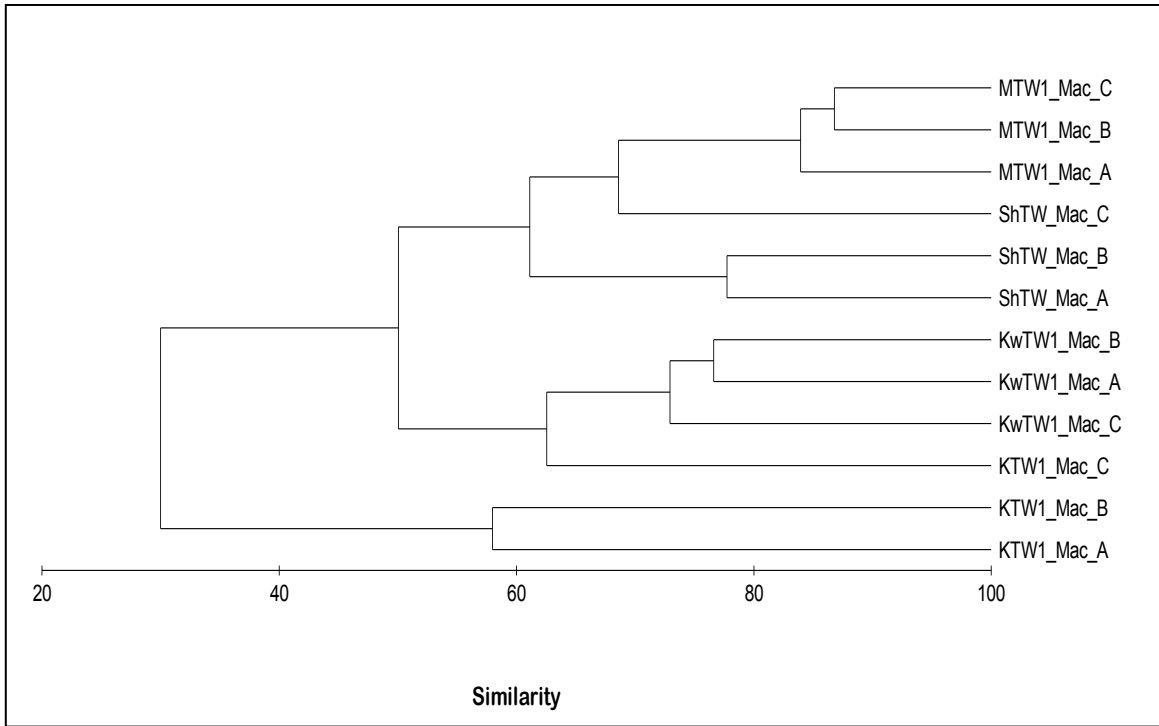
Figure 6. Dendrogram based on the Bray-Curtis Similarity analysis on the Macrobenthic fauna. MTW stands for Mombasa station, ShTW represents Shimoni Station, KwTW represents Kwale station, while KTW stands for Kilifi station. Mac represents Macrofauna samples, while (A-C) represents the replicate symbol.
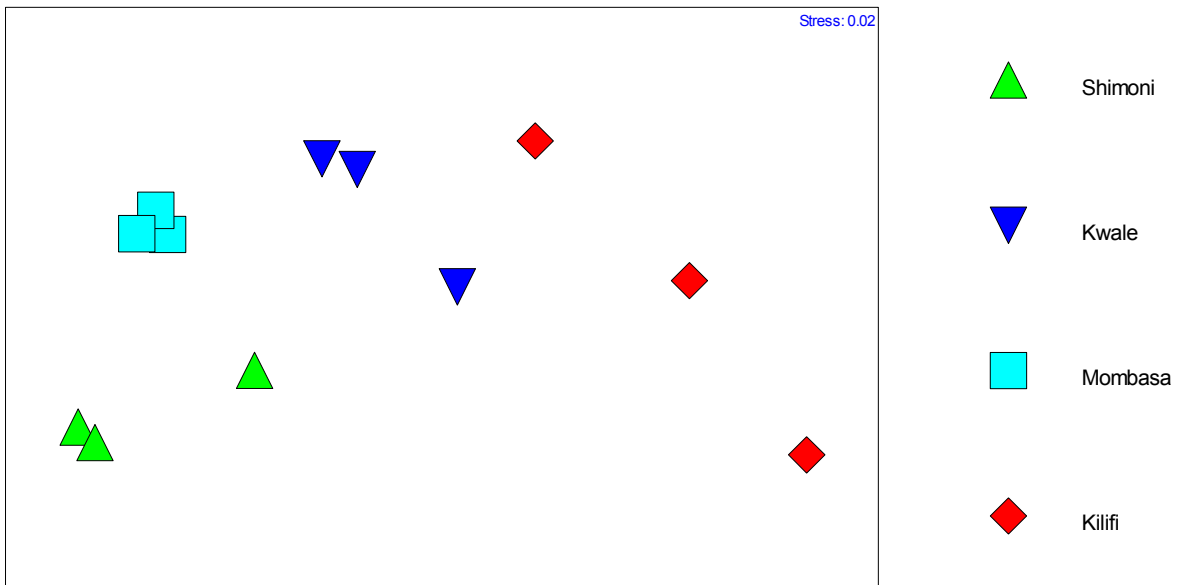
Figure 7. Multidemensional scale (MDS) plot on the macrofauna communities along the Kenyan shelf based on Bray-Curtis similarity.

(F(3,8)=19.397, p=<0.001). Post-hoc analysis revealed that Mombasa's density was significantly different from all the other stations (Shimoni, p=<0.001; Kwale, p=0.003; Kilifi, p=0.042). Shimoni's density was significantly different to Kilifi (p=0.029) but not significantly different to Kwale (p=0.229), while Kwale and Kilifi had no significant differences between them (p=0.483). The highest meiobenthic density was recorded at

Mombasa (1 286±365 ind/10 cm²), despite the corer depth falling short of the recommended 10cm depth, and was almost double that of the second highest density in this study (i.e. Kilifi, 696±92ind/10 cm²). The second lowest density was recorded at Kwale and the lowest in Shimoni (463±25 and 134±63ind/10 cm², respectively), despite achieving the recommended 10 cm core during sub-sampling (Fig. 8).

Figure 8. Meiobenthic density along the Kenyan continental shelf.

A total of 23 meiobenthic taxa were recorded and were dominated by Nematoda and Copepoda. The Nematoda had the highest relative abundance in Shimoni (43%), in Mombasa (46%) and Kilifi (58%), while Kwale was dominated by Copepoda (42%). Amphipoda was the second most abundant taxon in Shimoni (21%), while Polychae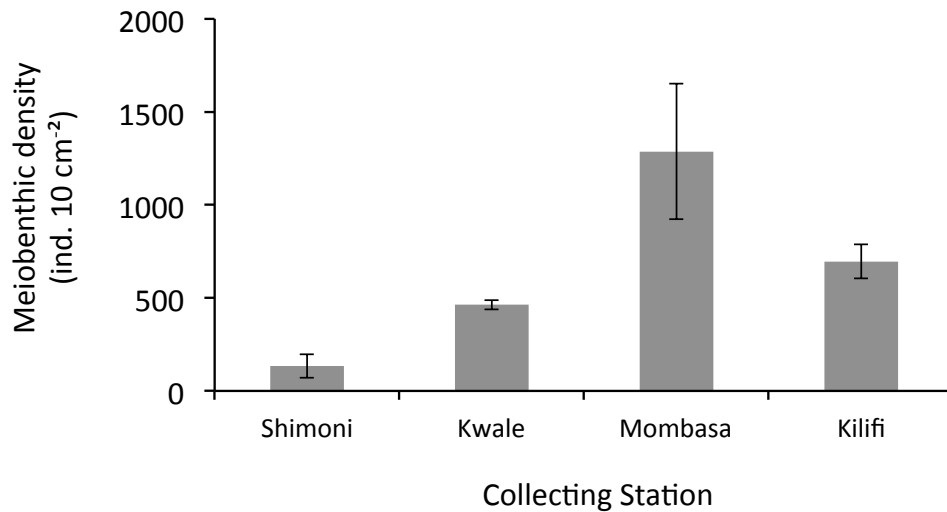ta had the third highest abundance in Kwale (12%). Most of the other taxa (Tanaidacea, Isopoda, Halacaroidea, Priapaulida, Oligochaeta, Cumacea, Rotifera, Sipuncula, Gastropoda, Gnathostomulida. Pycnogonida, Kinorhyncha, Bivalvia, Echinodermata) recorded relative abundances of less than 3% in all stations and were grouped as 'others' (Fig. 9).

Meiobenthic diversity along the Kenyan continental shelf

The Shannon diversity t test indicated that there was no significant difference among the three stations with the highest H diversity; i.e. Shimoni, Mombasa and Kwale (Shimoni and Kwale ($t_{687.68}$= 1.36; p=0.175), Shimoni and Mombasa ($t_{511.5}$= 0.401; p=0.688), and Mombasa and Kwale ($t_{2560.6}$= 1.715; p=0.087)). However, all these stations differed significantly with Kilifi which recorded the lowest H diversity; Shimoni ($t_{619.8}$= 4.407; p<0.0001), Kwale ($t_{3157.8}$= 4.4873; p<0.0001), and Mombasa ($t_{4266.9}$= 7.47; p<0.0001)). The highest H diversity was recorded at Shimoni (1.67), albeit marginally, followed by Mombasa and Kwale
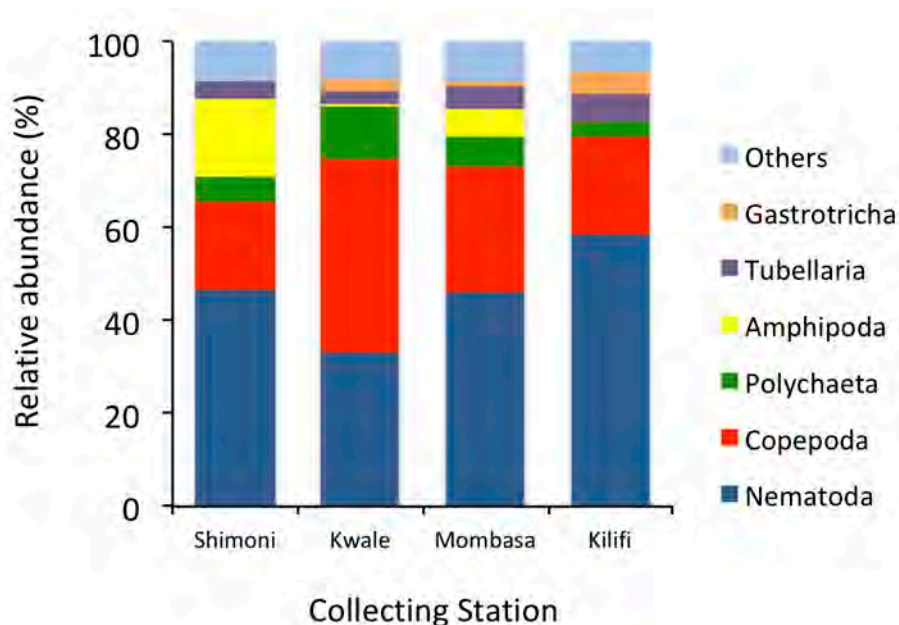

Figure 9. Meiobenthic relative abundance along the Kenyan continental shelf.

Table 3. Meiobenthic fauna tally; density, mean±SD, and diversity recorded from the stations along the Kenyan continental shelf.

	Shimoni	**Kwale**	**Mombasa**	**Kilifi**
	Mean±SD			
Nematoda	58.7±10.7	155.7±21.2	596±139.9	410.7±31.5
Copepoda	24.7±7	195.7±7	367.7±176.3	154±40.6
Polychaeta	8.3±7.5	54.7±2.5	83±23.6	22.7±1.5
Tubellaria	4.7±2.3	14.3±2.3	57.7±28.0	41±6.2
Amphipoda	28.3±33.5	1.7±1.2	80.3±25.1	0.3±0.6
Gastrotricha	0	11±2.6	20.7±9	32.7±5.7
Ostracoda	1.3±0.6	8.3±0.6	29.3±8.1	2±1
Nemertina	1±1	5±1	9±2.6	7±5
Isopoda	1±1.7	1.3±1.5	19±2	0
Tanaidacea	0.7±1.2	2.3±0.6	14.7±5	3.7±3.1
Tardigrada	3.7±2.5	8.7±5.7	7±2.6	1±1.7
Priapaulida	0	0	0	13±6.1
Cumacea	0.3±0.6	1±0	10.7±3.1	0.3±0.6
species 1	0	0	0	12±9.2
Halacaroidea	1±1	2.3±2.1	4.3±4.0	0
Rotifera	0.3±0.6	1.7±2.1	3±2	2.3±1.5
Oligochaeta	0.3±0.6	5.3±4	0.7±1.2	0.3±0.6
Gnathostomulida	0.7±1.2	1±1	0.3±0.6	2.3±1.2
Bivalvia	0	0	2.7±1.5	0.3±0.6
Gastropoda	0.3±0.6	0.3±0.6	1.7±1.5	0
Kinorhyncha	0	0.7±0.6	1.3±1.5	0
Sipuncula	0.7±1.2	0	0.3±0.6	2.7±2.5
Pycnogonida	0	0.3±0.6	0	0
Echinodermata (brittle star)	0	0	0.3±0.6	0
Density	133.6±62.9	462.9±24.7	1286.1±364.7	695.9±92.4
Taxa_S	17	19	21	19
Dominance_D	0.2684	0.2973	0.2969	0.3903
Shannon_H	1.674	1.573	1.633	1.382
Evenness_e^H/S	0.3138	0.2538	0.2438	0.2097

(1.63 and 1.57, respectively). The highest evenness (0.31) and lowest dominance (0.27) was recorded at Shimoni, while the highest dominance (0.39) and the lowest H diversity (1.38) and evenness (0.21) was recorded at Kilifi.

The meiobenthic community analysis based on ANO-SIM portrayed a high separation among the stations (R= 0.914). Upon further analysis using SIMPER, it was shown that there was low similarities between Shimoni and all the other stations (Mombasa (18.87%), Kilifi (24.19%) and Kwale (34.87%)), while the other stations had modest similarities among their communities (Mombasa and Kilifi (66.68%), Kilifi and Kwale (62.65%), and Kwale and Mombasa (53.14%)) as summarized in the dendrogram (Fig. 10).
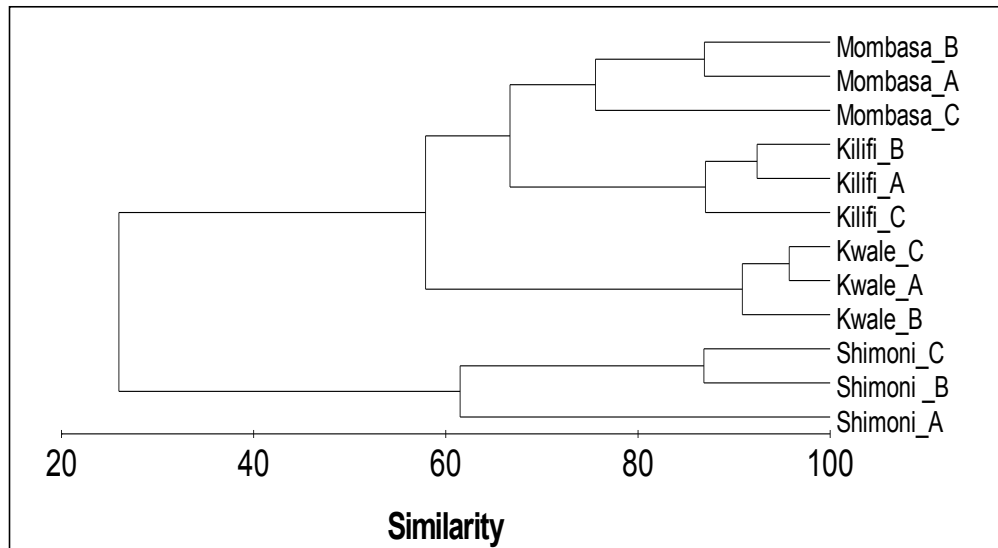
Figure 10. Dendrogram based on the Bray-Curtis similarity on the meiobenthic communities from the Kenyan continental shelf. (A-C) represents the replicate samples from the corresponding stations.
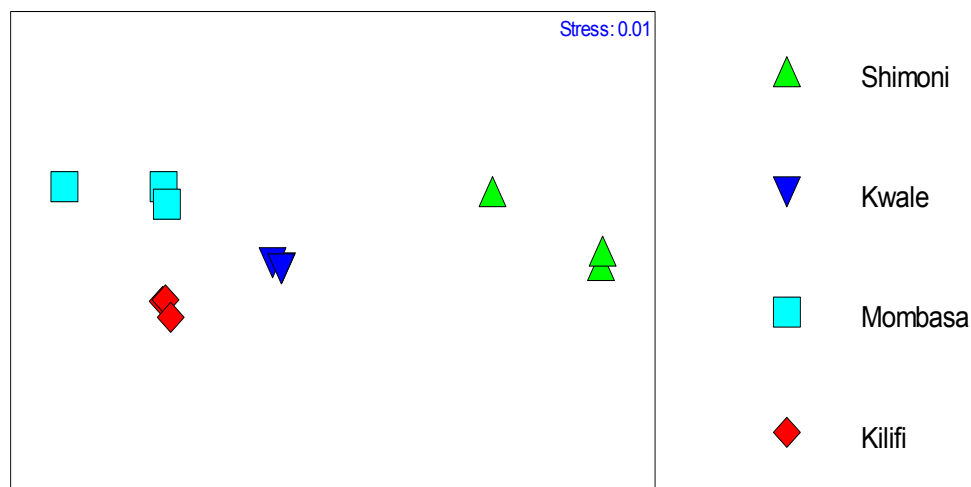

Figure 11. MDS plot of the meiobenthic communities along the Kenyan shelf.

The MDS plot showed clustering of points from the same stations, which, based on the results from SIMPER, indicated high levels of similarities within the stations, especially Kwale (92.49%), Kilifi (88.81%) and Mombasa (79%), while Shimoni's community had above average similarity among its communities (69.95%) (Fig. 11).

Discussion

The abiotic parameters portrayed a north-south trend as the southern stations had higher proportions of coarse particles which progressively reduced northwards, while the TOM values reduced southwards. The decantation method used to retrieve sediments from the macrofauna samples for sediment granulometry analysis appears to be an effective improvisation, as the results were similar to those reported by Muthumbi *et al.* (2004), where the north-south trend in grain size distribution was also reported.

This north-south trend can be explained based on the morphology of the Kenyan continental shelf which has been described as being wider in the northern parts and narrows southwards (Kitheka *et al.,* 1998). Narrower shelves have higher rates of erosion compared to wider shelves (Harris and Wiberg, 2002). Sediment deposition on the southern coast of the Kenyan continental shelf is also low due to the absence of permanent rivers draining into the ocean, resulting in lower proportions of finer sediments.

The northern coast, on the other hand, has two permanent rivers (Tana and Sabaki) resulting in higher rates of sediment deposition, especially silt and clay, and the wider shelf with gentle gradient reduces the rate of erosion (Fennessy and Green, 2016: Muthumbi *et al.,* 2004).

The TOM trend was similar to the granulometry trend, reducing southwards, and can be related to the grain size, as TOM in many cases tends to positively correlate with the proportion of fine grain size fraction compared to the coarser grain fraction (Secrieru and Oaie, 2009). The high TOM in the northern stations could also be a result of the influence of the Somali upwelling on the northern Kenyan shelf, in addition to the inputs of allochthonous organic matter through the permanent rivers (Muthumbi *et al.,* 2004).

The macrofaunal densities were high compared to most shelf studies (e.g. Wang *et al.*, 2014; Gerdes and Montiel, 1999; Gupta and Desa, 2001). These high densities were reported despite most of the stations in this study failing to attain the recommended 10 cm deep cores during sub sampling. In fact, the station with the least core depth (Mombasa, 3 cm) recorded the highest density. This can be explained by the fact that most benthic infauna are located at the upper 2 cm of the sediment (Higgins and Thiel, 1988). Also, the high densities seemed to be a direct result of the high Amphipod abundance, with stations with high Amphipoda abundances recording the highest overall macrofauna densities (Mombasa and Shimoni), while Kilifi station, which had no Amphipods, recorded the lowest overall macrofauna density.

Carvalho *et al.* (2012), and Theroux and Wigley (1998) recorded high Amphipoda abundance in areas with medium and finer grain-size compared to coarser grain fractions, in their studies. Similarly, in this study, the stations with higher proportions of median and fine sand fractions recorded high Amphipoda abundance, implying that a combination of both fine and median sand influences occurrence of Amphipoda. The areas with high abundances of Amphipoda were also observed to have high abundance of Foraminifera (pers. obs.), which were not included in this study as they are not metazoan fauna. Foraminifera have a tendency to aggregate around settling phyto-detritus as their food source (Gooday and Turley, 1990; Higgins and Thiel, 1988), which is also the main food source for the Amphipods, and may explain their high abundances at these stations.

Polychaeta were the most dominant taxa in other macrofaunal studies (Wang *et al.,* 2014; Joydas and Damodaran, 2007; Gerdes and Montiel, 1999). In this study, they were in high abundance in Kilifi, Mombasa and Kwale. Kwale's high polychaeta abundance can be attributed to the nature of the station, having higher proportions of coarse grain size as compared to the other stations, implying strong wave action and currents which have an impact on the macrobenthic communities. Areas with high tidal currents and wave action have higher proportions of coarse clean sand fractions favouring filter feeders; most of which are polychaetes species as reported by Dutentre *et al.* (2013).

Musale and Desai (2011) related the abundance of macrobenthic polychaetes to grain size and organic matter along south Indian coast, and found that Polychaeta abundance was higher in areas with loose textured sediments (high sand and sandy silt), and that polychaetes preferred low organic matter habitats and avoided high organic carbon areas. This could explain the high relative abundance of polychaetes in Kwale and low counts in Kilifi. Kilifi had low Polychaeta counts compared to all the other stations and their relative abundance was only high due to the absence of most of the other taxa such as Amphipoda which dominated in Shimoni and Mombasa. The reverse can also be used to describe the lower relative abundance of Polychaeta in Shimoni and Mombasa. The average count of Polychaeta in Mombasa was higher than that of Kwale, while the average count in Shimoni was close to that of Kwale. This implies that the lower Polychaeta relative abundances in Shimoni and Mombasa was a result of high abundance of Amphipoda in these stations, and not low counts of the polychaetes *per se*.

Macrobenthic diversity has been reported to be affected by sediment grain size. Van Hoey *et al.* (2004) recorded higher species richness, abundance and diversity in fine to medium sandy sediments, similar to those reported in Mombasa and Kwale, where the highest H diversities were observed. On the other hand, Dubois *et al.* (2011) reported low diversity in coarse sediments, as observed in Shimoni, where the lowest H diversity was recorded.

Meiobenthic densities recorded in this study were lower than most continental shelf meiobenthic studies such as Sandulli *et al.* (2010), Grémare *et al.* (2002), Huys *et al.* (1992).This could be a result of food availability which is among the main factors regulating

meiobenthic densities (Higgins and Thiel, 1988). The Kenyan shelf is described as an oligotrophic shelf (Muthumbi *et al.*, 2004), therefore it has low TOM, resulting in the low densities found in the present study. These densities fall within the range described by Soltwedel (2002) for tropical arid regions.

The meiobenthic fauna was dominated by Nematoda and Copepoda, which usually dominate in meiobenthic studies (Higgins and Thiel, 1988). Nematoda had the highest relative abundances at all stations except Kwale, where copepods had the highest abundance. Copepods have been observed to dominate in coarse grained sediments (Sajan and Dramodaran, 2007; Higgins and Thiel, 1988), as was the case in Kwale.

The relative abundance of Nematoda at the other stations fell within the range described by Soltwedel (2002) for tropical and arid regions of north eastern Africa, which were mainly influenced by sediment grain size and food availability in the form of TOM. This abundance therefore matches the study site which is categorized as being oligotrophic (Muthumbi *et al.*, 2004), and can partly explain the nematode abundance patterns in the study area.

Other meiobenthic taxa usually occur in small numbers (Soltwedel, 2002) as observed in this study, however, it is important to note the high Amphipoda abundances recorded in Shimoni and Mombasa which corresponded with the high Amphipoda abundance in the macrobenthic fauna. Most juveniles of macrobenthic fauna fall within the meiofauna category, resulting in this high Amphipoda abundance in the meiobenthic fauna in Shimoni and Mombasa (Higgins and Thiel, 1988).

Meiofaunal H diversity indices were relatively higher in the coarse sand and medium sand dominated stations (Shimoni, Kwale and Mombasa) compared to Kilifi, which had very high proportions of very fine sand. Similar findings have been reported by Sandulli *et al.* (2010), where the stations with high proportions of coarse and medium sand fractions recorded the highest abundances compared to the stations with fine sand. This can be attributed to the increased habitat heterogeneity in the medium and coarse grained sediments, increasing various niches, and therefore increasing diversity (Higgins and Thiel, 1988). On the other hand, the slightly higher TOM in Mombasa may explain the slightly higher diversity and density compared to the other stations. The high dominance value in Kilifi could be due to the high abundance of Nematoda compared to the Copepoda. This may be due to the high proportion of finer sediments which favour nematodes over copepods (Sajan and Damodaran, 2007; Higgins and Thiel, 1988).

Conclusion

This study is a product of the maiden cruise of *R/V Mtafiti* which aim to provide information about the benthic community assemblages on the Kenyan shelf. Despite the various challenges faced, the results of the study agreed with earlier studies conducted along the Kenyan shelf, specifically with Muthumbi *et al.* (2004). The benthic fauna community assemblages were described based on the prevailing and measured abiotic parameters, mainly grain size and TOM, which are among the main factors shaping most benthic studies (Higgins and Thiel, 1988). However, it will be interesting to study the influence of the other abiotic parameters (such as current speed, sediment deposition, depth) on these communities.

This study has provided insights into how the benthic communities along the Kenyan shelf are assembled, and with further studies, it will be possible to better understand the status of the Kenyan shelf benthic communities, and thus provide much needed information that is a prerequisite for making informed decisions on any conservation or development initiatives along the Kenyan shelf.

Acknowledgements

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