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Meiofauna and nematode community assemblage as sediment disturbance indicator in Mida Creek, Kenya

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Abstract. *Wafula M, Muthumbi A, Wang'ondu V. 2019. Meiofauna and nematode community assemblage as sediment disturbance indicator in Mida Creek, Kenya. Ocean Life 3: 24-37.* Meiofauna is a group of benthic fauna mostly found in the sediments' upper centimeters (cm), including Copepoda, Polychaeta, and Nematoda. This study focused on determining nematodes' potential as bio-indicators of sediment disturbance caused by bait harvesting. Furthermore, bait harvesting was common, albeit with different intensities, on the different beaches of Mida Creek, Kenya, on November 2013. Sediment samples were collected along two transects within the mud flat running from the mangrove forest edge to the edge of the subtidal zone. Along the transects, 1 m² was placed at 20 m intervals. A replicate of 2 sediments core (3.4 cm diameter, 10 cm deep) was taken from each quadrat. Next, samples were fixed using 5% formalin, stored in plastic bottles, and then transported to the laboratory for processing and identification. The nematodes were used because it could bring out a clear difference in their distribution, community assemblage, diversity, and abundance due to sediment disturbance compared to other meiofauna. Of the total meiofauna, 3,988 individual nematodes were identified to the genus level. In addition, Nematoda was the most abundant taxon of all other meiofauna taxa. The bait harvesting through digging was more pronounced in Mayonda due to its wider mud flat width. The result showed a clear difference in the distribution, diversity, and community assemblage of the nematodes seen in all the sites. A sum of 83 nematode genera was encountered in Mida Creek. Kirepwe had 58 genera, Dabaso had 46 and Mayonda had 35. Mayonda had the highest nematode diversity, then followed by Kirepwe and Dabaso. On the contrary, Dabaso had the highest nematode density, then followed by Mayonda and Kirepwe. The meiofauna had a high community similarity, while nematode community similarity was lower at different levels of sediment disturbances. That makes the nematodes better bio-indicators as compared to meiofauna as a group. Therefore, this study points out that digging out polychaetes causes sediment disturbance. The disturbance affects the benthic fauna distribution, community assemblage, diversity, and abundance. Moreover, *Terschellingia* and *Spirinia* were distributed across all sites, even though in disturbed quadrats the numbers reduced significantly. On the contrary in disturbed quadrats, *Viscosia, Pontonema, Synochium, Haliplectus,* and *Pheronus* increased in numbers. To measures such as educating the fishermen on the effects of digging polychaete should be emphasized to safeguard marine biodiversity and its ecosystem.

Keywords: Bait, meiofauna, nematode, polychaete, sediments disturbance

INTRODUCTION

The Benthic communities are organisms that live in and/or on the sediments of oceans, lakes, and rivers, also referred to as benthos (Graf 1989, Hadi et al. 2018). These include both flora and fauna (Graf 1989). Benthic endofauna is divided into; infauna - those living in the sediments, and the epifauna - those that live on the sediments (Fredrik et al. 2011). Both benthic infauna and epifauna could be classified into microfauna, meiofauna, macrofauna, and megafauna. Microfauna is organisms that are lessthan 32 μm, while meiofauna range between 32 μm and 1,000 μm in size. The macrofauna range between 500 μm and 2 mm (Eggleston et al. 1999), while megafauna is organisms larger than2 mm in size (Lalli and Persons 1997; Johnson and Michael 2009). Sometimes juveniles of macrofauna could be classified as meiofauna, whereas some mature adult microfauna can be classified as meiofauna, too (Funch and Kristensen 2002).

In the marine ecosystem, the benthic communities can be found from the highest intertidal levels to the deepest trenches making the sediment the second largest habitat on earth (Nascimento et al. 2010). Due to the difference in depth, the organisms that are found at different depth zones are affected differently by environmental factors such as light, pressure, salinity, temperature, prey and predator interactions, organic matter, and sediment granulometry (Johnson and Michael 2009). For instance, shallow water benthic communities are bigger and larger than in deep water due to the high input of food in the form of decomposed organic matter in shallow waters compared to deep waters (Heip et al. 1985). On the contrary, these shallow water benthic fauna found near the coastal zone are more prone to human interference than deep communities (National Ocean and Atmospheric Administration Marine Debris Program, 2016). However, in understanding the benthic community, it is hard to generalize how these communities are structured because of the complexity of the soft aquatic bottom (Wilson 1990). Therefore, to understand the benthic community, the benthic invertebrates are determined by how individuals acquire nutrients. Furthermore, most ocean bottoms are situated

below the photic zone, meaning they depend on organic matter for food from the phytoplankton bloom (Graf 1989). Therefore, determining the organic matter is important in determining the benthic community (Graf 1992).

Meiofauna includestaxa like the Nematoda, Copepoda, and Polychaeta, among others (Renaud-Debyser 1963), and are mostly found in the upper centimeters (0-50 cm)of the sediments in abundance due to food availability, sediment type, and oxygen content (Grant 1981). Due to the semi-sessile nature of infauna and their close association with sediments, benthic fauna,specifically the nematodes, can be used as indicators of different parameters affecting the environment, such as oxygen deficiency, salinity change, pollution, seabed disturbances, among others hence referred to as bio-indicators (Finch et al. 1998).

Benthic fauna is affected by both environmental and human factors (Finch et al. 1998). For example, the most common baits used for fishing by fishermen around Mida Creek are hermit crabs, gastropods, and polychaetes (choo). However, they prefer the polychaetes over the hermit crabs and other gastropods because the polychaetes are easily captured, causing sediment disturbances. Several studies have assessed sediment disturbances, heavy metal contamination, and oil and petroleum spillage. However, the use of nematodes as bio-indicators can be an alternative method. This alternative method can be used to test and assess contamination due to heavy metals, oil spillage, and sediment disturbance. This study finding can show that nematodes can be used as bio-indicators and as an alternative assessment method of sediment disturbances. Furthermore, this is because nematodes as bio-indicator are cost-effective compared to the different available chemical methods.

This study aimed to detail as follows (i) to assess the potential value of meiofauna and the nematode community assemblages as an indicator of sediment disturbance following polychaete harvesting at Mida Creek, Kenya, (ii) to determine the distribution of the nematodes genera due to sediment disturbance, (iii) to determine the diversity of meiofauna and nematodes genera due to sediment disturbance. Finally, (iv) to determine the community assemblage of meiofauna and nematode genera due to sediment disturbance.

MATERIALS AND METHODS

Description of the study area

The Kenyan coastline is approximately 536 km long, bordering the countries of Somalia and Tanzania to the north and south, respectively (Ochieng and Erftemeijer 2003; UNEP 2006). Towards the North of Mombasa, about 111 km, the 32 km^2 Mida Creek stretches inland from the Indian Ocean into the Arabuko Sokoke Forest along the Kenyan coastline. It is a broad water tidal creek that is lined with palm trees surrounded by mangrove forest that support about 500 species of birds, different species of crabs, and monkeys (Kennedy 1990; Dahdouh-Guebas et al. 1999; Kairo et al. 2002; IUCN 2015) with which the three sampling sites are within the Mida Creek.

At Mida Creek, harvesting of polychaetes happens everywhere, especially in all three mud flat sites but at different intensities due to the width of the sites, from the land to the lowest tide of the ocean. Three sampling sites within the creek were identified as follows; Kirepwe (Kir), Dabaso (Dab), and Mayonda (May). Kirepwe (S03°27.28': E039°58.490') is an island in the creek; Dabaso is locatedon the eastern edge of the creek (S 15°03 20.53´: E 039°59.23´) and Mayonda to the west of the creek (S03°19.274': E039°59.098') (Figure 1).

Sampling design

This study was part of a larger project investigating the impacts of bait harvesting on thebenthic invertebrates in the mud flats in Mida Creek, Kenya. From that study, sediment sampleswere collected to analyze sediment organic matter, grain size, and meiofauna from the three sites (Kirepwe, Dabaso, and Mayonda).

Two line transects located 200 m apart at each site were identified within the intertidal zone (from the shoreline to the low water mark). Quadrats of 1 m x 1 m were laid out at 20 m intervals along theline transect, with quadrats A and B being in the mangrove forest zone, quadrat C was at the edgeof the forest, while the rest of the quadrats D, E, F, and G were in the mud flat. The number of quadrats identified along the transect length was dependent on the width of the intertidal zone, where Kirepwe had only 4 quadrats (QA, QB, QC, and QD), Dabaso had 6 quadrats (QA, QB, QC, QD, QE, and QF) and Mayonda had 7 quadrats (QA, QB, QC, QD, QE, QF, and QG) (Figure 2).

Sample collection

Two replicate sediment samples were collected from the mangrove forest edge (QC) towards the mudflat (QD, QE, QF, QG). A hand corer of 3.4 cm diameter was used to collect the sediment samples for analysis of meiofauna, grain size, and sediment organic matter up to a depth of 10cm. The samples for sediment organic matter analysis were placed in ziplock bags, carried in a cooler box, and put in the freezer on arrival at the laboratory. Samples for sediment grain size analysis were carried in plastic bottles without preservation. The samples for meiofauna were immediately fixed in a 5% formaldehyde solution for preservation in plastic bottles. All samples were well labeled with the date, site, transect, and replicate and transported to the University of Nairobi, Kenya, hydrobiology laboratory for processing and analysis.

Laboratory analysis

Determination of sediment grain size

In the laboratory, a sub-sample of sediment was weighed and dried in the oven at 70ºC until there was no change in weight. The dried block sample was then loosened gently not to tamper with the original sediment particles and sieved on different sieve sizes on a mechanical shaker {2.00mm to 63 µm, i.e., 2.00 mm, 1.00 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.063 mm (from ASTM D6913-04, 2009)}. The proportion of sediment collected on each of the sieves was weighed and calculated as a percentage of the total sample weight.

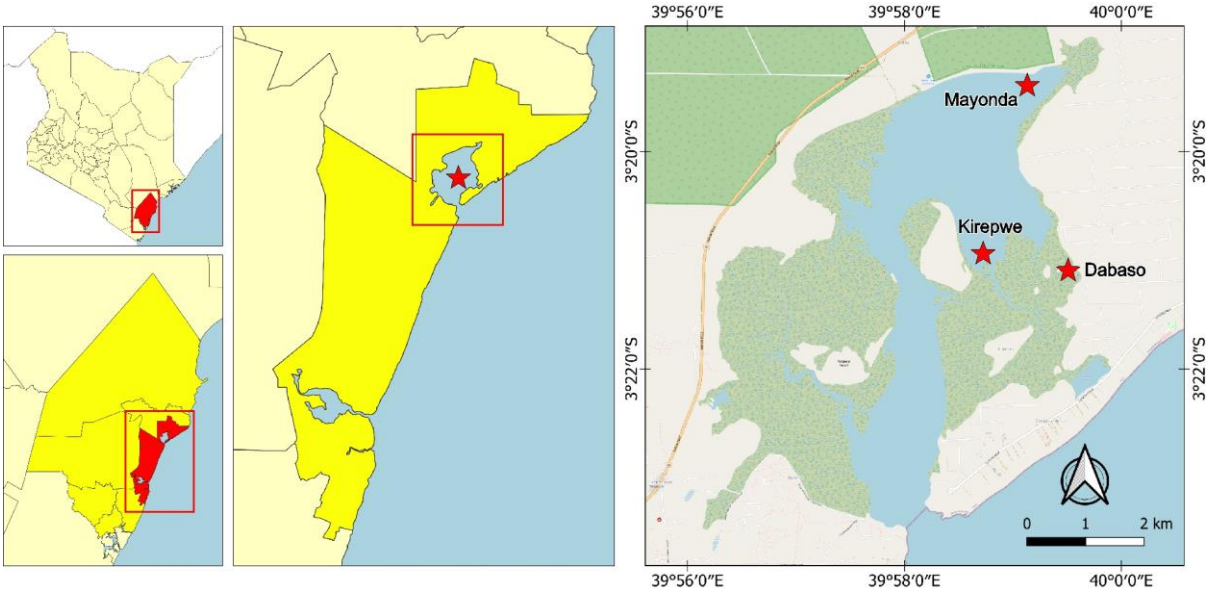

Figure 1. Map of Mida Creek, Kenya, showing sampling sites

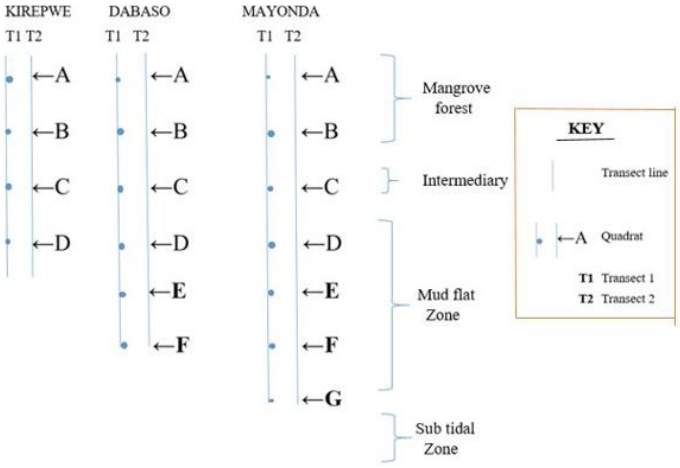

Figure 2. Sketch of the sampling design concerning sites, transects, and quadrats

This study re-calculated sediment grain size data from one transect (Transect 1) in each site (Kirepwe, Dabaso, and Mayonda). Quadrats QC and QD at Kirepwe, quadrat QC, QD, QE,and QF for Dabaso, and Mayonda quadrat QC, QD, QE, QF, and QG were considered because these were the quadrats considered for nematode identification.

Determination of sediment organic matter

Sediment samples were dried in the oven and weighed before ashing at 600ºC using a muffle furnace for six hours. The difference between the dried and ash weights was calculated and expressed as a percentage proportion of the total sediment weight to represent the sediment organic matter.

This study re-calculated sediment organic matter data from one transect (Transect 1) in each site (Kirepwe, Dabaso, and Mayonda). Quadrats QC and QD at Kirepwe, quadrat QC, QD, QE, and QF for Dabaso, and Mayonda quadrat QC, QD, QE, QF, and QG were considered because these were the quadrats considered for nematode identification.

Meiofauna analysis

The sediment samples for meiofauna analysis were rinsed with normal tap water over a 1 mm sieveto exclude macrofauna and any other debris and collected on a 38µm sieve. Magnesium Sulphate ($MgSO_4$) with a specific density of 1.28 g/cm³ was used to wash the fraction retained on the 38 µm sieve into a centrifugation tube. $MgSO_4$ was added to the three-quarter mark of each centrifugation tube with different samples and balanced. The samples were centrifuged 3 times for 10 minutes at 6,000 rpm. After each centrifugation, the supernatant was decanted onto a 38 µm sieve, rinsed thoroughly with water, and put back into well-labeled sample bottles using water and 4% formaldehyde solution. Three drops of Rose Bengal were added to the

bottle and left overnight for staining before sorting. Before the analysis of meiofauna was done, the samples were washed through a 38 µm sieve with tap water to remove traces of formaldehyde solution.

Enumeration of meiofauna

The sample was shaken well, and a small amount was poured into a counting chamber (Counting dish) for enumeration. Using a dissecting microscope at magnification X100, the sample was observed from the top left square across to the top right square. In the row below, observation was done from the right to the left side of the counting chamber to the end. This process was repeated until all samples were analyzed. All the meiofauna organisms were picked, identified, enumerated, recorded, stored in sample bottles, and kept safe in the laboratory.

Nematode analysis

For this study, meiofauna samples from only one transect (Transect 1) in each site (Kirepwe, Mayonda, and Dabaso). Therefore, Quadrats QC and QD at Kirepwe, quadrat QC, QD, QE, and QF for Dabaso, and Mayonda quadrat QC, QD, QE, QF, and QG were considered for nematode identification.

Two hundred nematodes were picked from each replicate sample and processed to make permanent slides. That was done first by picking the nematodes and placing them in embryo dishes containing De grise 1 (99 parts formaldehyde {4%} + 1-part glycerine) solution while covering it with no time restrictions. Then, in the evening, the embryo dishes were uncovered, placed in a desiccator with ethanol in the lower chamber, and placed in an oven set at 45ºC overnight.

In the morning, the embryo dishes were removed from the desiccator, half covered, and returned to the oven set at 45ºC. Three drops of De grise 2 (95 parts ethanol {96%} + 5-part glycerine) solution were added using a dropper along the sides of the embryo dish. The process was repeated after every 2-3 hours. In the evening, De grise 3 (50 parts ethanol {96%} + 50-part glycerine) solution was added to the embryo dishes in the oven and set at 45ºC overnight. This procedure was done to replace the water in the nematode with glycerine. The next morning, the embryo dishes were removed from the oven and placed in another desiccator with blue copper (ii) sulphate crystals to dry the samples overnight. Slides and coverslips were placed in ethanol overnight to clean up any oils. The slides and coverslips were removed from ethanol the next morning and dried using clean tissue paper.

Mounting of nematodes onto slides

Clean solid wax was placed in the glass petri dish and left in the oven overnight to liquefy, after which it was allowed to solidify. Next, a wax ring was made on the clean slide using a heated brass rod. A small droplet of pure glycerine was placed inside the wax ring using a needle. With a fine needle, at least ten nematodes of the nearly same diameter were placed in the glycerine, one at a time, ensuring that they did not lie on each other. A cover slip was placed on top of the slide, ensuring no air bubbles were trapped in the glycerine. The slides with the nematodes were heated slowly by placing them at one end of a bridge while the burner heated the bridge from the other end until the wax melted slowly. The slides with nematodes were then removed from the bridge and left to cool and labeled appropriately depending on the sample from which the nematodes were picked.

Nematode identification

Identification of the nematodes to the genus level under the stereo microscope. The immersion oil objective lens was used to watch each nematode, and the key to Platt and Warwick's (1988) identification of the genus level was made. Several characteristics were used to identify the different nematode genera, including the type of cuticle, either punctuated or annulated, the type of buccal cavity and size of teeth, reproductive systems, length and size of the nematode, and the tail form.

Data analysis

The data analyzed was from Kirepwe T1: QC and QD, Dabaso T1: QC, QD, QE, and QF, while Mayonda T1: QC, QD, QE, QF, and QG. Sediment organic matter and sediment grain sizes were re-calculated. The data identified genus categories and diversity, abundance, distribution, and densities were calculated and analyzed. All the genera of nematodes encountered were tabulated on the MS EXCEL and analyzed for relative abundance and distribution. The multidimensional scaling (MDS) and TWINSPAN for community analysis were done using PRIMER 5. The diversity indices (Dominance and Shannon diversity) were analyzed using the PAST. Bar graphs were drawn using MS EXCEL and SPSS. Significance tests for sediment organic matter, densities, relative abundance, distribution, and diversity between the sites were done using MS EXCEL and PAST.

RESULTS AND DISCUSSION

Sediment organic matter (SOM) content

The percentage of Sediment organic matter at Kirepwe was 4.1±2.48. The sediment organic matter percentage mean was highest at Dabaso (8.1±7.01), while Mayonda had the least percentage mean of 2.6±0.64. One-way ANOVA indicated that sediment organic matter was not significantly different across the sites ($F= 4.00$; $df=2$; $P=0.13$) (Figure 3).

Sediment grain size distribution

The silt was the least in mean proportion in all the sites. However, Kirepwe had a mean proportion of 4%, making it the highest in silt, while Dabaso had 3%. Mayonda had only 1%. One-way ANOVA indicated that silt had a significant difference across the sites. That played an important role in the results for meiofauna and nematode diversity, distribution, and community assemblages ($F= 14.4$; $df= 2$; $P= 0.000156$).

Very Fine sand was second least across all the sites. Kirepwe had a mean proportion of 5%, Dabaso had 7%,

and Mayonda (2%) had the least mean proportion of very fine sand, like silt.The very fine sand also played a key role in the meiofauna and nematode diversity, distribution, and community assemblages. However, one-way ANOVA indicated that very fine sand was not significantly different across the sites (F= 0.69; df= 2; P= 0.513).

Kirepwe had a mean proportion of Medium sand of 29%, while Dabaso had the least mean proportion of medium sand of 22%. Mayonda had the highest mean proportion of medium sand at34%. Medium sand plays an important role in the colonization of other meiofaunal taxa. One-way ANOVA indicated that medium sand was not significantly different across the sites (F= 1.77; df= 2; P= 0.193) (Figure 4).

Meiofauna and nematode density

The mean density of meiofauna ranged between 1183±613.7-1429±492 individuals/10 cm^2. Mayonda had the lowest mean of meiofaunal densities of 1183±613.7 individuals/10 cm^2, Dabaso had the highest meiofaunal density of 1429±492 individuals/10 cm^2 while Kirepwe's meiofaunal density was 1309±220.9 individuals/10 cm^2 (Figure 5).

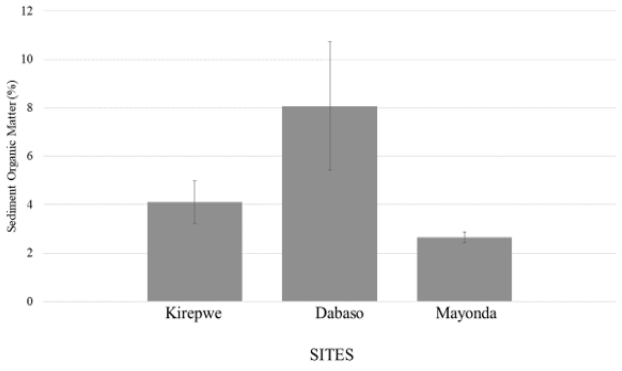

Figure 3. Sediment organic matter percentage mean in Kirepwe, Dabaso, and Mayonda (Kenya). The errorbars represent standard error

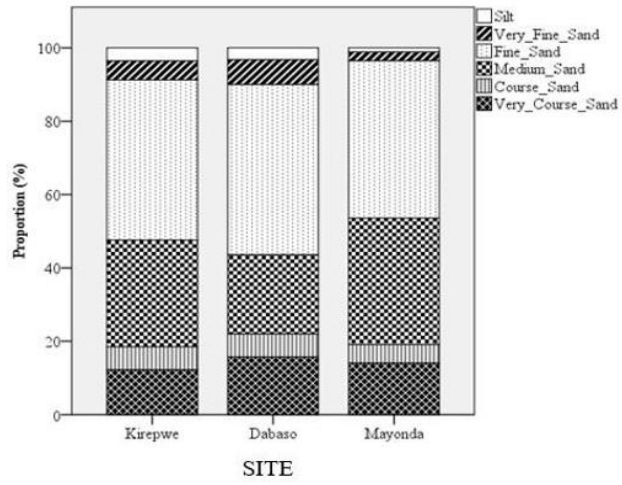

Figure 4. Sediment grain size mean proportion (%) at Kirepwe, Dabaso, and Mayonda (Kenya)

Nematode density ranged between 734±153.9-1042±374.1 individuals/10 cm^2. Kirepwe had the lowest nematode density of 734±153.9 individuals/10 $cm^{2,}$ while Mayonda had a medium density of 782±385.1 individuals/10 cm^2. Dabaso had the highest nematode densities of 1042±374.1 individuals/10 cm^2.

One-way ANOVA indicated that the mean meiofaunal and nematode densities did not differ significantly across the sites (F= 0.09; df= 2, P= 0.91) and (F= 1.14; df= 2, P= 0.33), respectively (Figure 5).

Relative abundance of nematodes and the other meiofauna

Some of the 12 taxa of meiofauna were observed in the three sites sampled, with the Nematoda taxon being the highest in relative abundance across all the sites. The meiofauna taxa encountered included the Nematoda, Oligochaeta, Isopoda, Cladoceran, Amphipoda, Gastrotricha, Insecta, Rotifera, Polychaeta, Thermobanaceae, and Tardigrada. The relative nematode abundance was lowest at Kirepwe with 56%, while the relative abundance of other meiofauna taxa against the nematode wasthe highest (44%). The highest nematode relative abundance was at Dabaso (71%), while the other meiofaunal relative abundance was the lowest (29%). Mayonda nematode relative abundance was 59%, while the other meiofauna taxa relative abundance was 41%. One-way ANOVA indicated that the nematode abundance did not differ significantly across the sites (F= 1.14; Df= 2, P= 0.33) (Figure 6).

Distribution of nematode taxa

Some of the 3,985 individual nematodes from 83 genera were identified across the three sites (Kirepwe, Dabaso, and Mayonda). However, the distribution of nematode genera differed across the sites, with Kirepwe having the highest number of genera (58), followed by Dabaso (46), while the least number of genera was at Mayonda (35).

However, most genera were thinly distributed (below 6.3%) across all the quadrats. For example, only 2 genera were above 6.3%, that is, *Spirinia* (18.8%) and *Terschellingia* (13.5%), while 18 genera had an overall distribution of between 1.2% and 6.3% across all the quadrats (Table 1).

Nematode genera, *Spirinia*, *Terschellingia*, and *Daptonema*, were observed across all the sites; however, they were not recorded in some quadrats in Mayonda. *Pheronus* was restricted to a single quadrat in Dabaso (QC) but was widely distributed in Mayonda. *Dorylaimid* (plant-parasitic nematode), *Viscosia*, *Pontonema*, *Synonchium*, and *Haliplectus* were widely distributed in the quadrats and restricted at Mayonda. (Table 1).

One-way ANOVA indicated that the nematode distribution did not differ significantly across the sites (F= 0.9; df= 2; P= 0.99).

Meiofauna and nematodes diversity

The meiofaunal and nematode diversity H' was highest at Mayonda with 1.3 and 2.7, respectively. The lowest diversity of both meiofauna and nematode was at Dabaso,

with 0.9 and 2.5, respectively. Meiofauna and nematode diversity at Kirepwe was 1.2 and 2.6, respectively (Figure 7).

The meiofaunal diversity (Shannon Wiener H') in Dabaso and Kirepwe differed significantly from that of Mayonda (P<0.05), (t= -22.501(21740)) and (t= 9.7601(21316)) respectively. In addition, the meiofaunal diversity (H') between Dabaso and Kirepwe also differed significantly (P<0.05) (t= -13.14(19635)). In summary, the meiofaunal diversity H' differed significantly across all sites.

The nematode diversity (Shannon Wiener H') indicated that Kirepwe and Dabaso differed significantly from that Mayonda. (P<0.05), (t=-3.8212(2772.8)) and (P<0.05), (t= -4.347(2312.3)) respectively. On the other hand, the *t*-test indicated that Kirepwe nematode diversity H' did not differ significantly from that of Dabaso (P>0.05) (t= 0.8721(2777.9)).

The highest nematode dominance (d) was in Dabaso (0.14), while nematode evenness was the second highest (0.27). Kirepwe's nematode dominance was second highest (0.13), with the least nematode evenness (0.23). Mayonda had the lowest nematode dominance (0.09) and the highest nematode evenness (0.43) (Figure 8).

The calculated probability at a 95% confidence interval of both dominance and evenness of nematodes between the three sites was (0.0765>0.05) and (0.27>0.05), respectively, showing no significant difference.

Meiofauna and nematodes community assemblage

Generally, the meiofauna communities from the three sites had a very high similarity of at least 75%. As a result, the different sites and quadrats were mixed out in the cluster analysis, as shown in the dendrogram. The higher the similarity in the community, the lower the chance to conclude whether the community has undergone any disturbances. Therefore, the meiofauna community is not ideal to be used as a bio-indicator in this study (Figure 9).

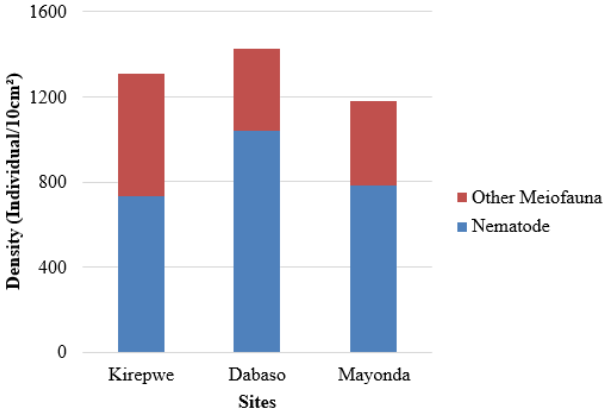

Figure 5. Other meiofauna and nematodes densities (individuals/10 cm^2) at Kirepwe, Dabaso, and Mayonda (Kenya)

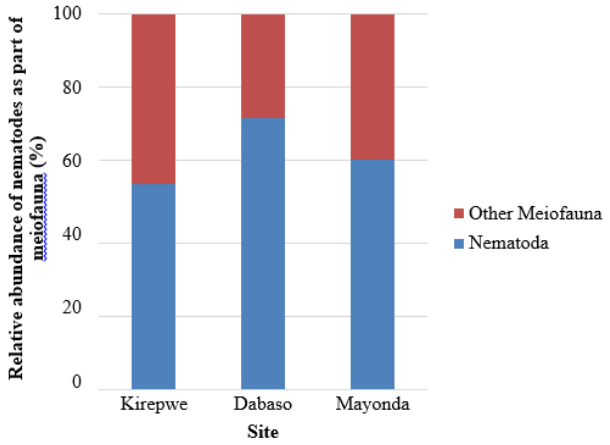

Figure 6. Relative abundance of nematodes and other meiofauna taxa (%) at Kirepwe, Dabaso, and Mayonda (Kenya)

Table 1. Distribution of nematode genera across the sites in Mida Creek, Kenya

Genera	Kirepwe		Dabaso				Mayonda					Mean
	QC	QD	QC	QD	QE	QF	QC	QD	QE	QF	QG	
Spirinia	19.8	28.5	7.8	41.1	12.9	43.4	16.3	30.7	2.6	2.7	0.7	18.8
Terschellingia	9.7	22.4	46.5	5.1	21.6	19.1	19.3	3.6	1.0	0.0	0.0	13.5
Pheronus	0.0	0.0	1.7	0.0	0.0	0.0	0.7	0.3	12.9	4.1	49.6	6.3
Daptonema	8.9	11.5	1.9	5.1	3.8	0.5	18.6	12.2	3.6	0.0	0.0	6.0
Dorylaimid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	46.6	4.3	5.0
Viscosia	2.5	0.1	1.7	1.5	0.0	0.0	9.0	29.9	4.6	0.0	0.7	4.6
Pontonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.5	0.0	3.9
Paracomesoma	1.8	0.0	0.0	24.9	6.2	7.5	0.7	0.0	0.0	0.0	0.0	3.7
Synonchium	0.2	0.0	0.8	0.0	0.3	0.0	0.0	0.0	7.7	0.0	29.1	3.5
Dorylaimopsis	0.5	14.7	0.0	2.5	11.6	7.2	0.0	0.0	0.0	0.0	0.0	3.3
Haliplectus	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	28.4	0.0	7.1	3.3
Dichromadora	14.1	1.4	1.9	0.0	0.8	0.3	12.3	0.8	3.1	0.0	0.0	3.2
Paracanthonchus	0.8	0.0	0.3	0.0	0.0	0.0	4.3	19.8	2.6	0.0	0.7	2.6
Gomphionema	6.9	2.7	0.0	7.1	0.3	1.8	7.0	1.0	0.0	0.0	0.0	2.4
Chromadorita	10.7	2.3	0.0	0.0	2.2	1.3	0.3	0.3	7.2	0.0	0.7	2.3
Marylynnia	2.7	4.1	0.0	0.0	4.9	12.4	0.0	0.0	0.0	0.0	0.0	2.2
Longicyatholaimus	0.3	0.0	0.0	0.0	20.8	0.0	0.3	0.0	0.0	0.0	0.0	1.9
Stylotheristus	0.0	0.1	0.3	1.5	6.7	1.8	3.3	1.0	0.0	0.0	0.0	1.3
Spilophorella	1.0	0.8	5.3	0.0	0.5	0.3	5.3	0.0	0.0	0.0	0.7	1.3
Megadesmolaimus	0.0	0.0	12.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.2

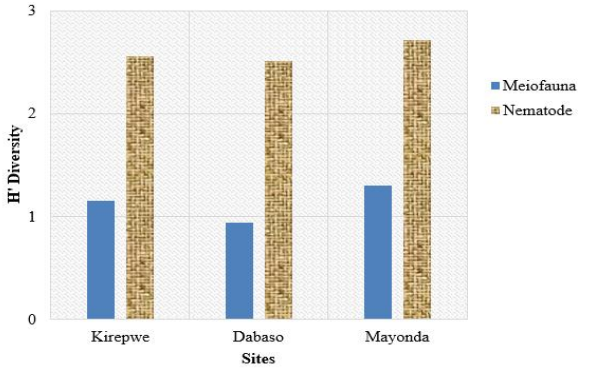

Figure 7. Diversity index H' of meiofauna and nematodes at Kirepwe, Dabaso, and Mayonda (Kenya)

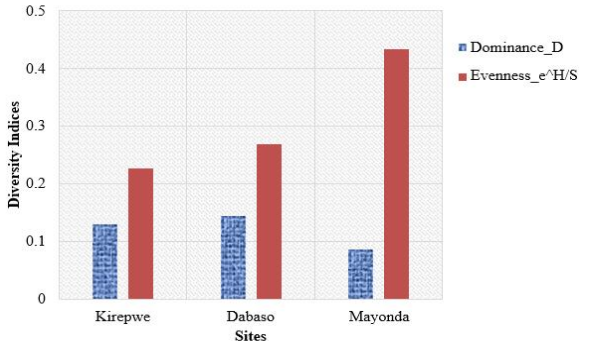

Figure 8. Nematode dominance and evenness at Kirepwe, Dabaso, and Mayonda (Kenya)

On the other hand, the nematode community showed generally low similarity in samples from thedifferent sites and quadrats. The above dendrogram shows that the nematode community at the quadrat in Mayonda QF, QE, and QG were all clustered together, which showed that these quadrats had a higher nematode community similarity.

Furthermore, the Dabaso QD nematode community was clustered together with Mayonda QC and QD. Which also showed that these quadrats had a higher nematode community similarity. On the other hand, Dabaso QC, QE, and QF were clustered with Kirepwe QC and QD, showing these quadrats had a higher nematode community similarity. However, Kirepwe QC and QD were clustered together, showing a high nematode similarity within the quadrats. It is important to note that the Mayonda QC and QD nematode community is closely related to that of Dabaso QD. Despite the overall similarity of the nematode community in the three studied sites, there was apparent segregation of the Mayonda nematode community from the nematode communities at Dabaso and Kirepwe.

Discussion

Sediment organic matter and sediment grain size

Mangroves forest contributes a large percentage of organic matter to the sediment through the litterin the marine ecosystem (Odum and Heald 1972; Alongi 1990). In addition, these mangrove forests play an important role in holding and compacting the sediments. That, in turn, helps protect the shoreline against all kinds of erosion (both wind and waves) (Odum and Heald 1972; Alongi 1990). Mayonda had the least amount of the mean sediment organic matter, and one-way ANOVA indicated that silt was significantly different across all sites. That could be attributedto the low proportion of silt. Tyson (2012), in his book on sedimentary organic matter, and Secrieru and Oaie (2009), reported that sediment organic matter is influenced by grain size distribution in an area. They also suggested that a small proportion of finer particles promotes a lower percentage of sediment organic matter, as seen at Mayonda compared to Kirepwe and Dabaso.

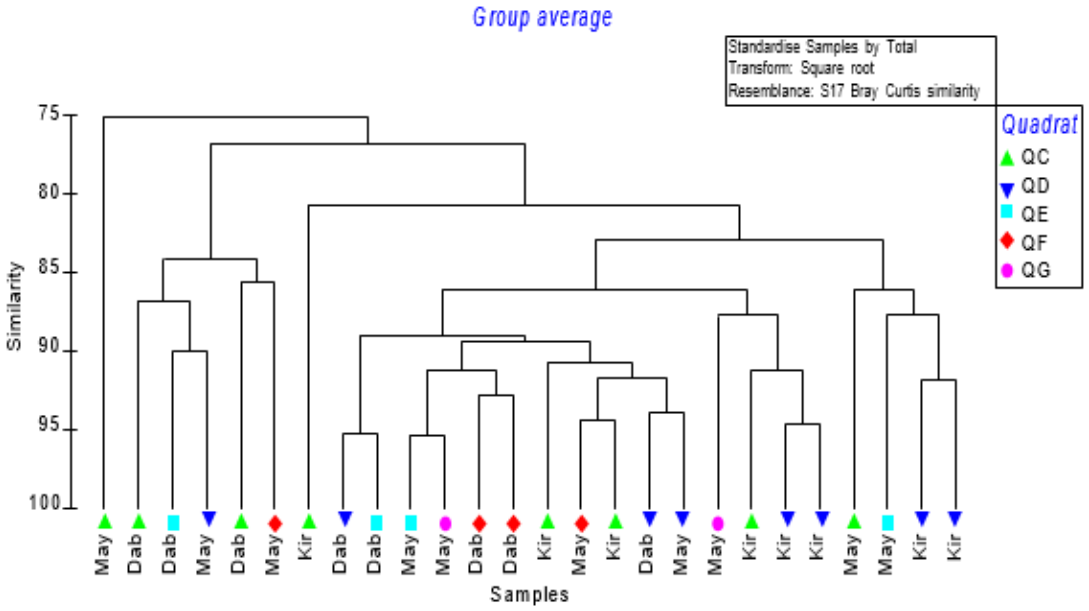

Figure 9. Dendrogram showing the cluster analysis for meiofauna at Mida Creek, Kenya

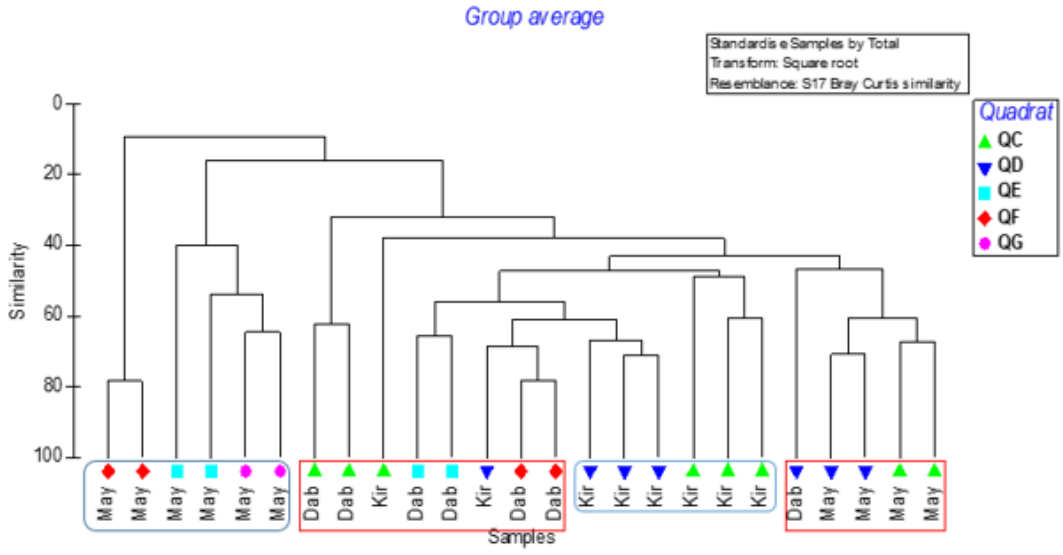

Figure 10. Dendrogram showing the cluster analysis for nematodes in Mida Creek, Kenya

There was a lot of sediment disturbance caused by the fisherfolk at Mayonda. The disturbances were caused by the ever digging and churning of the sediment. The main aim was to capture the large polychaetes, which contributed greatly to the disintegration of sediments through mechanical breakdown (Secrieru and Oaie 2009; and Tyson 2012). Odum and Heald (1972) and Alongi (1990) reported the importance of mangrove forest cover along the coastline. They reported that mangrove forest cover helps sediment organic matter formation through leaf fall, and mangrove protects the sediments by compacting and holding soil sediments together. In Mayonda, silt and very fine sand were easily eroded since the sediments were exposed to the agents of erosion due to little mangrove cover compared to Dabaso and Kirepwe. Apart from the low silt amounts that hindered the decomposition of organic matter at Mayonda, the little mangrove forest cover also contributed greatly to the low sediment organic matter. Secrieru and Oaie (2009) and Tyson (2012) reported that sediment organic matter is influenced by the distribution of grain sizes found in an area when they noted that a small proportion of finer particles promotes a lower percentage of sediment organic matter. This study confirms that silt in Mayonda was significantly different from other sites that play a key role in the decomposition and presence of sediment organic matter in an area (Secrieru and Oaie, 2009; Tyson, 2012). Wieser (1953) noted that genera such as *Spirinia* and *Terschellingia* are higher in concentration in areas with high sediment organic matter. That can be used to infer that Mayonda had the least concentration of sediment organic matter due to the drastic drop of existing genera such as *Spirinia* and *Terschellingia*, which are non-selective feeders, and selective feeders of sediment organic matter, respectively. Wieser (1953) and Moens and Vincx (1997) also noted that a drop in selective and non-selective feeders gives room to an increase of other opportunistic and scavengers genera such as *Viscosia, Pontonema, Synochium*, and *Pheronus*.

In Kirepwe, the mean sediment organic matter was less than that of Dabaso. It was evident that the forest cover at Dabaso was higher than the cover at Kirepwe, which is a major source of sediment organic matter through leaf fall (Odum and Heald 1972 and Alongi 1990). In addition, the same phenomenon of grain size by Secrieru and Oaie (2009) and Tyson (2012) comfortably explains the difference in the mean sediment organic matter present in both areas of Kirepwe and Dabaso. The lower mean sediment organic matter at Kirepwe can be attributed to the high proportion of fine and medium sand compared to Dabaso. High silt at Dabaso, compared to Kirepwe, can be used to explain the difference in mean sediment organic matter. Fine and medium sand does not promote sediment organic matter compared to silt and very fine sand, as documented by Secrieru and Oaie 2009; Tyson 2012. Heip et al. (1985) documented that nematode genera such as *Daptonema* and *Chromadorita* are mostly found on sandy beaches. Due to the presence of *Daptonema* at Kirepwe, this is evident that the area was sandier than Dabaso.

Furthermore, there was a high concentration of *Terschellingia* at Kirepwe. Alongi (1987) recorded that *Terschellingia* survives better in the mangrove forest because it can feed not only on the sediment organic matter since it is a selective deposit feeder but also does well in mangrove-derived tannin. He also documented that tannin from mangroves is more in sandy areas because it binds more easily with sand than fine sand and very fine sand, as observed at Kirepwe; that evidence is sufficient to show that there was more fine and medium sand at Kirepwe compared to Dabaso leading to the low sediment organic matter.

Gheskiere et al. (2005) and Maria et al. (2012) reported that high amounts of silt with fewer disturbances promote a high amount of sediment organic matter. Therefore, the high mean sediment organic matter in both Kirepwe and Dabaso can be attributed to the fewer sediment disturbances happening in the area compared to Mayonda. At the same

time, high amounts of sediment organic matter favor the presence of nematodes due to great amounts of food (Wieser 1953).

Less amount of silt and sediment disturbances caused by fisherfolk contributed greatly to the low sediment organic matter experienced at Mayonda. Tyson (2012) observed that sediment organic matter is influenced by the distribution of grain sizes found in an area when he noted that asmall proportion of finer particles promotes a lower percentage of sediment organic matter. In addition, Giere (2009) observed that low proportions of silt, very fine sand, and fine sand, as experienced in Mayonda, favor the existence of other meiofaunal groups. Moreover, these groups will include Oligochaeta, Polychaeta, Copepoda, Thermobanacea, Gnathostomulida, Cladocera, Turbellaria, Arachnida, Ostracoda, tanaidacea, cnidarian, Insecta, and Rotifera, which is clearly demonstrated at Mayonda where different meiofaunal taxa are thriving more across the quadrats as compared to Dabaso and Kirepwe. Therefore, as observed in this study, sediment disturbances experienced at Mayonda affect the decomposition of organic matter, affecting the distribution of nematode genera. Furthermore, sediment grain sizessuch as silt play a major role in sediment organic matter decomposition, with which the sediment organic matter also influences the distribution and existence of nematode and other meiofaunal taxa.

Meiofauna density

Medium sand was higher in proportion at Mayonda than at Dabaso and Kirepwe. Giere (2009) documented that low silt, very fine sand, and fine sand, with high proportions of medium sand, favor the survival of other meiofaunal groups. This information can explain the high meiofaunal density at Mayonda since the site had lower finer sands and greater proportions of medium sand sizes compared to Dabaso and Kirepwe, which caused the high meiofaunal density. However, we cannot use the meiofauna in general to give a conclusive and concrete reason that it is due to the sediment disturbances happening at Mayonda that caused the high meiofaunal densities.

Nematode density

The study showed no significant difference in the population densities of nematodes between Kirepwe, Dabaso, and Mayonda. Gheskiere et al. (2005) on meiofauna as a descriptor of tourism-induced changes at sandy beaches. Maria et al. (2012) on the relationship between sandy beach nematodes and environmental characteristics in two Brazilian sandy beaches. These researchers all documented that high amounts of silt and fine sands caused a high sediment organic matter with less disturbance. These conditions enhance high nematode density because of the high food content provided by the availability of high sediment organic matter. This phenomenonis replicated in Dabaso since the site had high amounts of silt, very fine sand, and high sediment organic matter with less disturbance leading to high food content. As a result, the area supported the nematode population comfortably, leading to high densities. Kirepwe had the least nematode density, although it had fewer disturbances with low sediment organic matter content than Mayonda. This rear phenomenon can be researched further to explain these results.

The silt and very fine sand were relatively higher in proportion in all the sites favoring nematode existence and survival. A similar study done by Renaud-Debyser (1963) concluded that the nematode assemblages reach up to a depth of 50cm. Therefore, the high amounts of silt and very fine sand played a major role in the high-density occurrence of the nematodes (Gheskiere et al. 2005; Maria et al. 2012), which was supported too, by Secrieru and Oaie (2009) and Tyson (2012). Therefore, this phenomenon can be related to the high nematode density at Dabaso. Furthermore, silt, very fine sand, and fine sand were high in proportion at Dabaso and Kirepwe, causing the high nematode densities as compared to Mayonda, which had low silt, very fine sand, and fine sand proportion.

Relative abundance of nematode within the meiofauna

Research by Giere (2009) indicates that a high proportion of medium sand promotes the survival of other meiofaunal groups. That can explain the high meiofaunal relative abundance at Kirepwe compared to Dabaso and Mayonda. Such meiofaunal taxa include oligochaeta, cladocera, insecta, rotifera, copepoda, polychaeta, thermobanaceae, turbellaria, ostracoda, and tanaidacea. Similar results of an increase in medium sand caused an increase in other meiofaunaltaxa (Maria et al. 2012).

The relative abundance of nematode taxon compared to other meiofauna taxa was very high in all sites. These findings were similar to research by Giere (2009), who recorded that the nematode community dominates any area in relative abundance. Moreover, they are always among the first living organisms to colonize any area, which can be attributed to the presence and availability of silt, very fine sand, and fine sand that promotes the decomposition of organic matter, which is food to the nematodes (Secrieru and Oaie 2009; Tyson 2012).

Despite nematode dominating all sites in relative abundance compared to other meiofaunal taxa, Dabaso had the highest proportions of silt that enhanced high sediment organic matter, which promoted the survival and existence of a high relative abundance of the nematode as compared to Kirepwe and Mayonda. Moens and Vincx (1997) and Moens et al. (2013) indicated that high sediment organic matter favors nematode colonization and specialization due to the availability of food and well-physical conditions (Gheskiere et al. 2005; Maria et al. (2012). That can still explain the high relative abundance of nematode and Dabaso compared to Kirepwe and Mayonda.

On the other hand, Mayonda had little proportions of silt, very fine sand, and fine sand compared to Dabaso and Kirepwe, which caused a decrease in sediment organic matter decomposition, which usually affects nematode abundance. In addition, Mayonda was the site that experienced a lot of sediment disturbances from the fishfolker through digging and churning. Therefore, it was expected that relative nematode abundance should be much less than in Kirepwe. Still, the relative abundance of

nematodes in Mayonda (59%) was higher than in Kirepwe (56%). These can be attributed to the continuous sediment disturbances at Mayonda, which do not allow nematode species specialization. Instead, those give room for more opportunistic and hardy nematode genera that can survive heavy sediment disturbances very well to migrate and occupy the area. Such nematode genera include *Viscosia, Pontonema, Synochium, Haliplectus,* and *Pheronus,* as stated by Moens and Vincx (1997). These genera played a key role in pushing the relative abundance of nematodes at Mayonda compared to Kirepwe and Dabaso.

Distribution of nematode taxa at Mida Creek

Feeding in marine nematodes plays an important role in their distribution (Wieser 1953). Wieser (1953) came up with 4 trophic groups: first, the selective deposit feeder, mainly characterizedby having a small buccal cavity with no tooth. A few examples are *Tershellingia, Paracanthochus, Bathylaimus, and Haliplectus,* among others. The second trophic group is non-selective deposit feeders. Their major characteristic is that they possess a large buccal cavity but without teeth. Some non-selective deposit feeders include *Spirinia, Daptonema, Sabatiera, and Theristu*s. The third trophic feeder is the epistratum feeder, which feeds on diatoms. Some examples include *Gomphionema, Marylynnia, Dichromadora, Chromadorita, Spilophorella, Longicytholaimus, and Stylotheristu*s. The final trophic group is the omnivore-predator. Their major characteristic is the possession of a rather big strong tooth. They include *Synochium, Pheronus, Viscosia, Pontonema, and Paracomesoma*. However, this group is not understood much. Moens and Vincx (1997) reported that *Viscosia* and *Pontonema* could be described as scavenger predators because of their ability to feed on dead foraminiferans.

From this study, One-way ANOVA indicated that the nematode distribution across the quadrats was not significantly different across the sites. However, *Spirinia, Terschellingia,* and *Daptonema* were widely distributed across all the sites though reduced in numbers in some quadrats of Mayondabecause such genera are greatly affected by heavy sediment disturbances. The sediment disturbance affects their feeding grounds since they are all deposit feeders, impacting their distribution. As explained before, sediment disturbance greatly affects sediment organic matter decomposition and deposition, which is the deposit feeders' main food source. Such sediment disturbances were more pronounced at Mayonda than at Kirepwe and Dabaso. The disturbances caused a reduced sediment organic matter concentration, affecting the distribution of deposit feeders at Mayonda: *Synochium, Pheronus, Viscosia, Pontonema, Viscosia,* and *Pontonema* increased in number due to their opportunistic characteristics.

Terschellingia is a selective deposit feeder, whereas *Daptonema* and *Spirinia* are non-selective feeders feeding mostly on deposited foods such as organic matter (Wieser 1953; Moens and Vincx1997; Schratzberger et al. 2006). In addition, these genera dominate every habitat (Alongi 1990).*Spirinia* was more in quadrats D, located at the start of the mudflat region across all sites, while Terschellingia was more in quadrats C, where mangrove cover was across all sites. Alongi (1987) documented that *Terschellingia* survives better in the mangrove forest because it could feed not only on the organic matter since it is a deposit feeder but also does well in mangrove-derived tannin. On the other hand, *Spirinia* was more in the quadrats located at the mudflats, which is because the mudflats have substantial sediment organic matter deposits best suited for survival (Alongi 1987). In addition, *Spirinia* is a non-selective deposit feeder; hence it is not deprived of its feeds (Alongi 1987). However, with the disturbances happening at Mayonda, both *Spirinia* and *Terschellingia* drastically reduced, especially towards the mudflats. Furthermore, polychaetes survive best in the mudflats where frequent sea water is coming in and moving out (Heip et al. 1985), giving Mayonda a good ground for polychaetes to thrive. The digging of the polychaetes towards the mudflat of Mayonda by the fisherfolk caused a drastic drop in both *Spirinia* and *Terschellingia* due to the reduced sediment organic matter, which is food for such nematodes.

Heip et al. (1985) noted that genera such as *Daptonema* and *Chromadorita* (Epistrate feeder) are found on sandy beaches. *Daptonema* and *Chromadorita* were more in Kirepwe, and this is because fine sand and medium sand were higher in Kirepwe as compared to Dabaso and Mayonda. More of *Terschellingia* was present in Kirepwe as compared to other sites. Alongi (1987) recorded that *Terschellingia* survives better in the mangrove forest because it could feed not only on the organic matter since it is a deposit feeder but also does well in mangrove-derived tannin. He also documented that tannin from mangroves is more in sandier areas because it binds more easily with sand than fine sandand very fine sand, as observed at Kirepwe.

Despite *Spirinia* and *Terschellingia* being widely distributed across all the sites, in Mayonda, the genera were low in distribution. Those are due to the physical disturbances that destroy their feeding habitat (Alongi 1990). They are non-selective and selective deposit feeders, respectively. The frequent disturbances prevented them from having a specific niche while taxa such as *Viscosia, Pontonema, Synochium,* and *Pheronus* increased in number (Moens and Vincx 1997). In addition, the sediment disturbance interfered with the decomposition of sediment organic matter, which is the main source of food for *Spirinia* and *Terschellingia,* causing a drastic drop at Mayonda as comparedto Kirepwe and Dabaso.

Terschellingia, Daptonema, and *Spirinia* are the genera among the nematode assemblages that are best known to occur in muddy and organically rich sediments (Schratzberger et al. 2006), just like in Dabaso and Kirepwe. These genera are not only found in undisturbed areas that allow the utilization of the dissolved sediment organic matter content by the specific genera of nematodes. They can also adapt and change during disturbances (Vanreusel 1990;), which explains why these three genera were found in Mayonda despite the serious sediment disturbances in small numbers.

Pheronus, Viscosia, Pontonema, and Synonchium were highly distributed in Mayonda, which is attributed to their predatory feeding habit (Moens and Vincx 1997). They are

also termed opportunistic nematodes that colonize disturbed areas just because other nematode genera cannot thrive in areas such as Mayonda (Moens and Vincx 1997). It is important to note that *Pontonema* was able to thrive at Mayonda better due to its ability to scavenge for its food. From the general observation, these predators were more concentrated in the quadrats of Mayonda, where oligochaetes were concentrated. These can be used to postulate a relation between such oligochaetesand predatory marine nematodes though further research to prove this can be conducted. *Sabatieria*was not present in Mayonda despite its ability to tolerate both hypoxic and anoxic conditions. Fromthe research findings by Jensen (1987) and Fonseca et al. (2018), *Sabatieria* and *Dorylaimopsis* thrive best under reduced sediments, as found in Kirepwe and Dabaso.

Diversity of meiofauna and nematode

Frequent moderate disturbance of sediments reduces dominance and increases evenness and diversity of nematodes Giere (2009). Communities that are diverse biologically most likely contain resilient species. That is made possible by the ability of these species to adapt to the changing environment because they have a higher chance of getting traits that help them survive (Yachi and Loreau 1999). The meiofauna diversity H' did not differ significantly across all the sites. However, Mayonda had a slightly higher meiofaunal diversity than Kirepwe and Dabaso. That was because the site had very little silt, similar to fine sand and fine sand from the results. This promoted the existence of other meiofaunal taxa such as Oligochaeta, Polychaeta, Copepoda, Thermobanaceae, Gnathostomulida, Cladocera, Turbellaria, Arachnida, Ostracoda, Tanaidacea, Cnidaria, Insecta, and Rotiferas documented by Giere (2009). As mentioned, sediment disturbances at Mayonda caused the meiofauna taxa not to occupy a specificniche; hence new taxa colonizing the area pushed the meiofauna diversity up (Moens and Vincx 1997).

Furthermore, in the meiofaunal group, Nematoda, Oligochaeta, and Copepoda will always recolonize an area after disturbances. However, the Nematoda taxon recolonization is faster and more immediate (Ingole et al. 2000) because nematodes quickly adapt to any disturbance over a very short period (Sherman and Coull 1980). Thus, after the fisherfolk's physical sediment disturbance at Mayonda by fisherfolk, nematodes recolonized the area almost immediately, pushing the meiofaunal diversity up as compared to Kirepwe and Dabaso. That is because nematodes recolonize the disturbed area almost immediately and fast. They also have the ability to easily adapt to changes in the environment due to their hardy nature as organisms suggesting that they can be used as indicator organisms in recolonization experiments (Ingole et al. 2000). Therefore, Oligochaeta and Copepoda recolonized the disturbed area by pushing the meiofaunal diversity up (Moens and Vincx 1997).

Mayonda had the least number of nematode individuals while Kirepwe had the highest, whereas Mayonda recorded the highest nematode diversity, followed by Kirepwe while Dabaso had the lowest. The nematode diversity in Dabaso and Kirepwe differed significantly from that of Mayonda. Yachi and Loreau (1999) concluded from their research that increasing diversity confers a greater chance of destabilizing the system. That is because there is a limit to the number of individuals packed in a particular community, confirming that as the number of community species increases, the average community population decreases. That means that the smaller the population size is, the higher the chances of extinction and species richness levels.

Therefore, from the data at Mayonda, diversity is high, which, as Yachi and Loreau (1999) explain, can cause species extinction due to the ever-increasing disturbances caused by fisherfolk, which can also be attributed to the difference in the intensity of sediment disturbances that affected the sediment organic matter in an area. Grain size proportion also played a big role in the nematode diversity. A lesser proportion of finer particles enhances a lesser percentage of sediment organic matter. The same phenomenon of sediment disturbances affecting the concentration of sediment organic matter (Secrieru and Oaie 2009; Tyson 2012) in comfortably explains the difference in the mean total sediment organic matter that affects the presence of nematodes in Mayonda. Moreover, Mayonda had the least proportion of finer sand that played a major role in the slow decomposition and presence of the mean total sediment organic matter in the area. That gave Mayonda a unique nematode diversity. Netto et al. (1999) noted that sediment stability is a very important variable in controlling nematode diversity and abundance at the studied sites, which is replicated at Kirpwe, Dabaso, and Mayonda.

Moreover, the low diversity observed in Dabaso and Kirepwe was due to nematode species specialization. At the same time, Mayonda had the highest diversity due to a lack of nematode species specialization, which caused a rise of opportunistic nematode species that came to colonize the areabecause of the sediment disturbances that occurred (Moens et al., 2013). That is because frequent sediment disturbances do not allow nematodes to occupy a specific niche. Those because, as the nematodestry to occupy a niche in the environment, there is sediment disturbance that causes others to migrateor die while providing room for predatory species to colonize the area (Moens and Vincx 1997; Moens et al. 2013), pushing the nematode diversity up as recorded in Mayonda.

Dabaso diversity and abundance of nematodes were slightly lower than Kirepwe's nematode species diversity and abundance. Those can be attributed to the fact that all kind of nematodes inhabits Kirepwe, that is, selective and non-selective deposit feeders (*Spirinia* and *Terschellingia*), predators (*Pheronus, Viscosia, Pontonema, and Synonchium*) to species that can also survive extreme *(Daptonema)* physical disturbances, epistratum feeders (*Chromadorita, Marylynnia, Dorylaimopsis, Dichromadora, Gompionema,* and *Longicytholaimus*) (Jensen 1987). Therefore, a unique specialization did not exist. On the other hand, various studies show that nematode abundance varies greatly among habitats, free-living nematodes in the marine environment (Heip et al.

1985). This variability is caused by the complex interactions among biotic and abiotic factors such as food and disturbances. For instance, Heip et al. (1985) reported that muddy estuarine sediments are characterized by high densities of more than 3,000 individuals/10cm^2 and a few dominant species per sample.

The results of the diversity indices of nematode showed significant differences among the three sites; Dabaso, Mayonda, and Kirepwe. According to the Shannon diversity index and Simpson's diversity index, Mayonda had higher species diversity (richness) than Dabaso and Kirepwe. That was brought majorly about by the frequent sediment disturbances at Mayonda, hindering species specialization and giving rise to more opportunistic species. In addition, sediment disturbance brought the differences in sediment texture of sampling sites that played an important role in influencing the diversity and distribution pattern of these nematodes, as indicated by Bertness et al. (2001) and Nabavi et al. (2008). The high diversity reduces dominance in anyecosystem; hence, species dominance at Mayonda was hindered since no species can come up strongly to dominate the area with frequent physical sediment disturbances. Low dominance automatically leads to the high evenness of nematodes, which is seen in Mayonda compared to Dabaso and Kirepwe; therefore, nematodes cannot be allowed to occupy a specific niche (Bertness et al. 2001; Nabavi et al. 2008).

Meiofauna and nematode community assemblage

Despite having different Physico-chemical parameters, Kirepwe, Dabaso, and Mayonda meiofaunal community assemblage did have a high percentage similarity from the cluster analysis. Furthermore, despite Mayonda experiencing a lot of sediment disturbance by the fisherfolk, from the community cluster analysis, the meiofaunal community did not differ from Dabaso and Kirepwe. Which shows that the meiofaunal community from the studied sites cannot be used as bio-indicators because they do not bring out a clear difference between them.

On the other hand, the nematode community assemblage at Kirepwe and Dabaso had a close similarity to each other compared to that of Mayonda nematode community assemblages. That can be attributed to the physical disturbances caused by the fisherfolk during the harvesting of polychaetes, sediment sizes, sediment organic matter decomposition, and feeding habits of the nematodes. Digging out of the polychaete causes a shift of the nematode community through death and migration away or into the area (Shine 2005; Anasari et al. 2012).

Dabaso and Kirepwe had substantial amounts of sediment organic matter content compared to Mayonda, which recorded the least amounts of the mean sediment organic matter. Odum and Heald (1972) and Alongi's (1990) indicated that mangroves forest contribute a large percentage of organic matter to the sediment through litter fall in the marine ecosystem. The low sediment organic matter at Mayonda could be attributed to the existence of very little mangrove forest cover. This sediment organic matter concentration promotes the survival of different nematode genera, as seen in Kirepwe and Dabaso. Apart from the low sediment organic matter caused by the little mangrove cover, Mayonda had low silt and very fine sand concentration, which play a key role in sediment organic matter decomposition, as reported by (Giere 2009).

Furthermore, the sediment disturbances greatly affected the decomposition of the organic matter, as Arntz et al. (1994) indicated, which is also seen at Mayonda. These factors played a major role in contributing to the low sediment organic matter at Mayonda. The low sediment organic matter simultaneously caused a drastic drop in the selective and non-selective deposit feeders such as *Spirinia* and *Terschellingia.* In contrast, more opportunistic genera such as *Viscosia, Pontonema, Synochium,* and *Pheronus* increased in number (Moens and Vincx 1997).

A similar study by Francisco et al. (2012) noted that frequent physical disturbances affect the decomposition of matter to sediment organic matter. This disturbance caused Mayonda to have a very little occurrence of sediment organic matter. As mentioned, sediment organic matter is a major food source for the nematodes (Arntz et al. 1994). That meant that sediment organic matter is critical in the distribution of nematode communities (Shine 2005; Anasari et al. 2012), just as observed during this study in all sites. Apart from sediment disturbance and sediment organic matter, grain size also affects the community structure of nematodes. Giere (2009) indicated that very small amounts of silt, very fine sand, and fine sand hinder the decomposition of organic matter. Mayonda had very small proportions of silt, very fine sand, and fine sand as compared to Kirepwe and Dabaso, which caused the nematodes community assemblage in Mayonda to differ from that of Dabaso and Kirepwe greatly. That was because of the continuous physical sediment disturbances at Mayonda that caused epistratum, selective and non-selective feeders such as *Spirinia, Terschellingia, Paracanthochus, Bathylaimus, and Haliplectus,* among others, to decrease in number. In contrast, more predatory feeders such as *Viscosia, Synochium, Pheronus, and Pontenema* increased.

Due to the mechanical weathering of soil sediments, more sand was recorded in Mayonda. In contrast, silt and very fine sand were eroded due to sediment disturbance and the little mangrove forest (root to compact and the soil sediments together) available. Therefore, *Paracanthocus* and *Chromadorita* increased in number due to their ability to survive in areas with sandier conditions (Alongi 1997), while *Sabateria* and *Dorylaimopsis* were absent (Jensen 1987; Moens and Vincx 1997; and Fonseca et al. 2018) as observed during their studies, which was also observed in Mayonda. At the same time, Dorylaimid, a plant parasite nematode, was widely distributed at Mayonda, which needs further research to explain these findings.

Spirinia, Terschellingia, and *Daptonema* were widely distributed across all the sites, though not observed in some quadrats of Mayonda. These nematode genera are all deposit feeders. *Terschellingia* is a selective deposit feeder, whereas *Daptonema* and *Spirinia* are non-selective feeders feeding mostly on deposited foods such as organic matter (Wieser 1953; Moens and Vincx 1997; Schratzberger et al.

2006). They also dominate every habitat (Alongi 1990). Spirinia was more in quadrats D, located at the start of the mudflat region across all sites, while *Terschellingia* was more in quadrats C, where the mangrove was across all sites. Alongi (1987) documented that *Terschellingia* survives better in the mangrove forest because itcould feed not only on the sediment organic matter since it is a deposit feeder but also does well in mangrove-derived tannin. *Spirinia* was more in the quadrats located at the mudflats. That is because the mudflats have substantial sediment organic matter deposits best for their survival, as reported by theresearch done by Alongi (1987). In addition, Alongi (1987) reported that *Spirinia* is a non-selective deposit feeder; hence it is not deprived of its feeds. However, with the sediment disturbances happening at Mayonda, both *Spirinia* and *Terschellingia* drastically reduced, especially towards the mudflats. That is because the sediment disturbance hindered organic matter decomposition caused by digging out the polychaetes at the mudflat of Mayonda, which played a majorrole in the drastic drop of both *Spirinia* and *Terschellingia.* After all, they have been deprived of their food.

Heip et al. (1985) documented that genera such as *Daptonema* and *Chromadorita* (Epistrate feeder) are found on sandy beaches. *Daptonema* and *Chromadorita* were more in Kirepwe, and this is because fine sand and medium sand were higher in Kirepwe as compared to Dabaso and Mayonda. Therefore, more Terschellingia were present in Kirepwe compared to other sites. Alongi (1987) noted that *Terschellingia* survives better in the mangrove forest because it could feed not only on the organic matter since it is a deposit feeder but also does well in mangrove-derived tannin. Alongi (1987) recorded that tannin from mangroves is more in sandier areas because it binds more easily with sand than fine sand and very fine sand, as observed at Kirepwe.

Spirinia, *Terschellingia*, and *Daptonema* were not distributed in some quadrats of Mayonda compared to Dabaso and Kirepwe. That is because the genera are among the nematode assemblages best known to occur in muddy and organically rich sediments (Schratzberger et al. 2006). Furthermore, these genera are not only found in undisturbed sediments in high numbers due to the availability of sediment organic matter, which acts as food, but they can also adapt and change during disturbances (Vanreusel 1990). Their ability to quickly adapt to a change in environment can be used to explain why these three genera were found in Mayonda despite the serious sediment disturbances.Therefore, the reduced number of such genera at Mayonda, compared to Kirepwe and Dabaso, played an important role in relaying information about the nematode community during the community analysis.

Pheronus, *Pontonema*, and *Viscosia* were restricted to a single quadrat of Dabaso (QC) while widely distributed in Mayonda, which was because of the predatory nature that enabled themto colonize disturbed areas (Moens and Vincx 1997). These genera contributed greatly to relaying important information about the nematode community assemblage during the community analysis between the three sites (Kirepwe, Dabaso, and Mayonda). *Dorylaimopsis*, *Marylynnia*, *Sabatiera*, and *Pontonema* were absent at Mayonda completely. *Dorylaimopsis*, *Sabatiera*, and *Pontonema* did not survive in Mayonda mainly because of the different proportions of the grain size. Such genera thrive best in areas with a high proportion of silt and very fine sand (Jensen 1987; Fonseca et al. 2018), as seen in Kirepwe and Dabaso.

Marylynnia is an epistratum feeder not seen in Mayonda alone (Wieser 1959). Giere (2009) confirmed that frequent physical sediment disturbances cause a shift in the nematode community from epistratum and deposit feeding to predatory feeding. That can explain why there were more predators at Mayonda compared to Kirepwe and Dabaso. During the community analysis, the presence of more predators and the absence of some epistratum, such as Marylynnia in Mayonda, caused the difference in the nematode community. Therefore, compared to the meiofauna from the studied sites, the nematodes can be used as bio-indicators of sediment disturbance to create a clear distinction between sites.

Despite *Spirinia* and *Terschellingia* being widely distributed in all the sites, in Mayonda, the genera had a low distribution. That is because of the physical sediment disturbances that destroy their feeding habitat (Alongi 1990). They are non-selective and selective deposit feeders, respectively. Therefore, the frequent disturbances prevented them from having a specific niche. At the same time, genera such as *Pheronus*, *Viscosia*, *Pontonema*, and *Synonchium* were widely distributed in Mayonda, which is attributed to their predatory feeding habit (Moens and Vincx 1997). They also noted that these nematodes are term opportunistic nematodes that colonize sediment disturbed areas just because other nematode genera cannot thrive in sediment disturbed areas such as Mayonda. It is important to note that *Pontonema* was able to thrive at Mayonda better due to its ability to scavenge for its food. *Sabatieria*, on the other hand, was not present in Mayonda despite its ability to tolerate both hypoxic and anoxic conditions. That is because *Sabatieria* and *Dorylaimopsis* thrive best under a high proportion of finer sediments size such as silt and very fine sand (Jensen 1987; Fonseca et al. 2018), as recorded in Kirepwe and Dabaso.

REFRENCES

Alongi DM. 1987. Population structure and trophic composition of the free-living nematodes inhabiting carbonate sands of Davies Reef, Great Barrier Reef, Australia. Aust J Mar Freshw Res 37: 609-619. DOI: 10.1071/MF9860609.

Alongi DM. 1990. Community dynamics of free-living nematodes in some tropical mangroveand sandflat habitats. Bull Mater Sci 46 (2): 358-373.

Arntz WE, Brey T, Gallardo VA. 1994. Antarctic zoobenthos. Oceanogr Mar Biol Annu Rev 32: 241-304.

Bertness MD, Gaines SD, Hay ME. 2001. Marine Community Ecology. Sinauer Associates, Massachusetts.

Dahdouh-Guebas F, Giuggioli M, Oluoch A, Vannini M, Cannicci S. 1999. Feeding habits of non-ocypodid crabs from two mangrove forests in Kenya. Bull Mar Sci 64 (2): 291-297.

Dahdouh-Guebas F, Mathenge C, Kairo JG, Koedam N. 2000. Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial users. Econom Bot *54* (4): 513-527. DOI: 10.1007/BF02866549.

Eggleston DB, Elis WE, Etherington LL, Dahlgren CP, Posey MH. 1999. Organismresponses to habitat fragmentation and diversity: H abitat colonization by estuarine macrofauna. J Exp Mar Biol Ecol 236 (1): 107-132. DOI: 10.1016/S0022-0981(98)00192-0.

Finch MS, Hydes DJ, Clayson CH, Weigl B, Dakin J, Gwilliam P. 1998. A low power ultra violetspectrophotometer for measurement of nitrate in seawater: Introduction, calibration and initial sea trails. Anal Chim Acta 377: 167-177. DOI: 10.1016/S0003-2670(98)00616-3.

Fonseca G, Fontaneto D, Di Domenico M. 2018. Addressing biodiversity shortfalls inmeiofauna. J Exp Mar Biol Ecol 502: 26-38. DOI: 10.1016/j.jembe.2017.05.007.

Funch P, Kristensen MR. 2002. Coda: The micrognathozoa-A new class or phylum of freshwater meiofauna? Freshw Meiofauna: Biol Ecol 337-348.

Gheskiere T, Vincx M, Urban Malinga B, Rossano C, Scapini F, Degraer S. 2005. Nematodes from wave dominated sandy beaches: diversity, zonation, patterns and testing isocommunities' concept. Estuar Coast Shelf Sci 62: 365-375. DOI: 10.1016/j.ecss.2004.09.024.

Giere O. 2009. Meiobenthology: The Microscopic Fauna in Aquatic Sediments. 2ndEdition. Springer-Verlag, Berlin.

Graf G. 1989. Benthic-pelagic coupling in a deep-sea benthic community. Nature 341 (6241): 437-439. DOI: 10.1038/341437a0.

Grant J. 1981. Sediment transport and disturbance on an intertidal sandflat: infaunal distribution and recolonization. Mar Ecol Prog Ser 6: 249-255. DOI: 10.3354/meps006249.

Hadi TA, Hafizt M, Hadiyanto, Budiyanto A, Siringoringo RM.2018. Shallow water sponges along the south coast of Java, Indonesia. Biodiversitas 19: 535-543. DOI: 10.13057/biodiv/d190223.

Heip C, Vincx M, Vranken G. 1985. The Ecology of Marine Nematodes. Aberdeen University Press, Scotland.

Ingole BS, Ansari ZA, Rathod V, Rodrigues N. 2000. Response of meiofauna to immediate benthic disturbance in the Central Indian Ocean Basin. Maret Georesour Geotechnol 18 (3): 263-272. DOI: 10.1080/10641190051092957.

IUCN. 2015. IUCN Red List of Threatened Species. Version 2015. [accessed 3 January 2018].

Jensen P. 1987. Feeding ecology of free-living aquatic nematodes. Mar Ecol Prog Ser 35 (1953): 187-196. DOI: 10.3354/meps035187.

Johnson CN, Michael G. 2009. Ecological consequences of Late Quaternary extinctions of megafauna. Proc R Soc Lond B Biol Sci 276: 2509-2519. DOI: 10.1098/rspb.2008.1921.

Kairo JG, Dahdouh-Guebas F, Gwada PO, Ochieng C, Koedam N. 2002. Regeneration status of mangrove forests in Mida Creek, Kenya: A compromised or secured future? Ambio 31 (7/8): 562-568. DOI: 10.1579/0044-7447-31.7.562.

Kennedy AD. 1990. Marine reserve management in developing nations: Mida Creek—a case study from East Africa. Ocean Coast Manag 14 (2): 105-132. DOI: 10.1016/0951-8312(90)90049-N.

Lalli C, Parsons TR. 1997. Biological Oceanography: An Introduction. Elsevier. DOI: 10.1016/B978-0-7506-3384-0.X5056-7.

Maria TF, Vanaverbeke J, Esteves AM, De Troch M, Vanreusel A. 2012. The importance of biological interactions for the vertical distribution of nematodes in a temperate ultra-dissipative sandy beach. Estuar Coas Shelf Sci 97: 114-126. DOI: 10.1016/j.ecss.2011.11.030.

Moens T, Braeckman U, Derycke S, Fonseca G, Gallucci F, Gingold R, Guilini K, Ingels J, Leduc D, Vanaverbeke J, Van Colen C, Vanreusel A, Vincx M. 2013. Ecology of free-living marine nematodes. Nematoda 1 (1): 1-6. DOI: 10.1515/9783110274257.109.

Moens T, Vincx M. 1997. Observations on the feeding ecology of estuarine nematodes. J Mar Biol Assoc UK 77 (1): 211-227. DOI: 10.1017/S0025315400033889.

Nabavi SMB, Yavari V, Kochanian P, Shokat P, Sabzkabayi G, Molla A, Ashrakiyan N. 2008. Meiofauna of mangrove in the Naiband protected area (Persian Gulf)-a preliminary report. Natl Acad Sci Lett 31 (7-8): 233-239.

Nascimento FJA. 2010. Trophic Ecology of Meiofauna: Response to Sedimentation of Phytoplankton Blooms in the Baltic Sea. [Thesis]. Stockholm University, Swedish.

Netto SA, Attrill MJ, Warwick RM. 1999. The effect of a natural water-movement related disturbance on the structure of meiofauna and macrofauna communities in the intertidal sand flat of Rocas Atoll (NE, Brazil). J Sea Res 42 (4): 291-302. DOI: 10.1016/S1385-1101(99)00033-7.

Ochieng CA, Erftemeijer PLA. 2003. The seagrasses of Kenya and Tanzania. In: EP Green, Short FT (Eds). World Atlas of Seagrasses. University of California Press, Berkeley, USA.

Odum WE, Heald EJ. 1972. Trophic analysis of an estuarine mangrove community. Bull Mar Sci 22: 671-738.

Platt HM, Warwick RM. 1988. Freeliving marine nematodes: Part II. British Chromadorida. Synopses of the British Fauna No. 38. EJ Brill, Dr. W. Backhuys for the LinneanSociety of London and the Estuarine and Brackish-water Sciences Association.

Renaud-Debyser J. (1963). Ecological research on interstitial sand fauna: Arcachon Basin, Bimini Island, Bahamas. Arago laboratory 12 (2): 11-17.

Schratzberger M, Warr K, Rogers SI. 2006. Patterns of nematode populations in the southwestern North Sea and their link to other components of the benthic fauna. J Sea Res 55 (2): 113-127. DOI: 10.1016/j.seares.2005.07.002.

Secrieru D, Oaie G. 2009. The Relation between the Grain Size Composition of the Sediments from the NW Black Sea and their Total Organic Carbon (TOC) Content. Geo-Eco-Marina 15: 5-11.

Sherman KM, Coull BC. 1980. The response of meiofauna to sediment disturbance. J Exp Mar Biol Ecol 46 (1): 59-71. DOI: 10.1016/0022-0981(80)90091-X.

Shine J. 2005. A Summary of Results if IOC-BIG Benthic-TOC Study. In Indicators of Stress in the Marine Benthos, UNESCO, Intergovernmental Oceanographic Commission Workshop Report No. 195.

Tyson RV. 2012. Sedimentary Organic Matter: Organic Facies And Palynofacies. Springer Science and Business Media, Berlin.

UNEP. 2006. Coastal and Marine Environments.Africa Environment Outlook 2. Our Environment, Our Wealth. 155-195.

Vanreusel A. 1990. Ecology of the free-living marine nematodes from the Voordelta (Southern Bight of the North Sea). 1. Species composition and structure of the nematode communities. Cahiers de Biologie Marine 31: 439-462.

Wieser W. 1953. The relationship between oral cavity shape, diet, and abundance of free-living marine nematodes. An ecological-morphological study. Arkiv for Zoologi 4: 439-484.

Wilson JR. 1990. Competition and predation in marinesoft-sediment communities. Ann Rev Ecol Syst 21: 221-241. DOI: 10.1146/annurev.es.21.110190.001253.

Yachi S, Loreau M. 1999. Biodiversity and ecosystem functioning in a fluctuating environment: The insurance hypothesis. Proc Natl Acad Sci USA 96: 1463-1468. DOI: 10.1073/pnas.96.4.1463.