



Free-living nematodes in some mangrove sites on the southern Egyptian Red Sea coast with emphasis on their horizontal distribution.

Deyaaeddien A. Mohammad

Department of Marine Science, Faculty of Science, Suez Canal University, Egypt.

deyaa_ismail@yahoo.com

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ABSTRACT

The generic composition, abundance, and distribution of free-living nematodes along three mangrove sites in the southern Egyptian Red Sea coast were studied. Sediment samples were collected in April 2022 at three different tidal levels in each site. Densities of free-living nematodes varied among sites and tidal levels. The mangrove of El-Readaa site had the most abundant and diversified nematofauna and the mid-tidal level attained the highest densities and number of recorded genera. Nematofauna was represented by 25 genera belonging to 13 families, of them; Xyalidae, Desmodoridae and Linhomoeidae were the most abundant. *Terschellingia* and *Daptonema* were the common genera in fine sediment areas and their abundance increased from high water level towards the mangrove trees at the low tidal level. Genus *Spirinia* was common in the coarser sediments and showed an opposite distribution pattern. A strong correlation occurred between nematodes' abundance, feeding types and sediment characteristics. The abundance of the different nematodes was studied in relation to their feeding habits.

INTRODUCTION

Mangroves are among the most productive ecosystems found in the intertidal tropical and subtropicals regions and are largely restricted to latitudes between 30° north and 30° south (Kathiresan *et al.*, 1996; Ronnback, 1999). Their core distribution is in the tropical areas, which corresponds with rapid human activities and poses a huge threat on them (Oog, 1995). The coverage of mangroves has been estimated to be between 10 million hectares (Bunt, 1992) and 24 million hectares (Twilley *et al.*, 1996).

There are a number of ecological roles provided by this ecosystem. Maintain shoreline stability and water quality by controlling nutrient and sediment circulations (Twilley *et al.*, 1996; Semesi, 1998). They also provide a shelter for their neighboring communities from natural hazardous (Semesi 1998; Ronnback, 1999). Mangrove root parts offer microhabitats for vast groups of organisms (Robertson and Alongi, 1992) and act as nursery for fish and macro-invertebrate animals (Robertson and Alongi, 1992;

Semesi 1998, Ronnback, 1999; Laegdsgaard and Johnson, 2001). Mangroves also present a variety of diverse natural products for many uses, such as fuel material and tannins as well as incomes to the local communities through harvesting, hunting, and fish gathering operations (Ronnback, 1999).

Within the mangrove forest, an abundant variety of benthic assemblages are found (Olafsson, 1995). Meiofauna is numerically dominating the metazoan group particularly nematodes (Hodda and Nicholas, 1985) since they provide an important food source for higher trophic levels (Olafsson and Moore, 1990). The densities and composition of nematodes have been affected by complex factors; sediment texture, depth of sediment, common species and seasonality (Hogarth, 1990). The size of sediment grains is an important aspect when describing benthic habitats and directly controls the spatial situations, and indirectly affects the physico-chemical conditions of sediment (Giere, 2009).

Only two studies focused on the free-living nematodes of the Red Sea mangroves: Sabeel and Vanreusel (2015) in Sudan and Al-Sofyani and Al-Sherbiny (2018) in Saudi Arabia. This is the first study to describe the free-living nematodes of the Egyptian Red Sea mangroves to elucidate their generic composition and distribution patterns at the different tidal levels.

MATERIALS AND METHODS

Study area and sediments sampling:

In April 2022; three sites along the western coast of the Egyptian Red Sea were selected to represent the mangrove habitats; Site I, El-Readaa (24°19'25" N 35°20'31" E), Site II, Lahmy Bay (24°13'19" N 35°25'13" E) and Site III, Hertwaay (24°8'3.4" N 35°29'0.1" E) (Fig. 1). Site I contains a small stand of mangroves visible from the mainland. Some disturbance due to fishing activities and considerable litter are present. Site II a small stand of mangrove tree is found a couple of kilometers to the south of Hamata village on two sides of the shallow lagoon. Site III surrounds a large tidal inlet; several stands of mangroves are found. They are mostly short with a mean height of 1.5 m and occasional older trees of about 3.5 m. Landward, mangrove trees become increasingly stunted with signs of intense camel grazing such as damaged apices and dense coppiced branches. As a result of the grazing, the canopies are open and sediments are exposed to increase evaporation which has led to surface salinization. Recruitment is low but present. Litter and tar balls are abundant. Around the mangroves at this site, there were particularly well-developed salt marsh formations, consisting largely of *Arthrocnemum macrostachyum* and *Halopeplis perfoliata*.

In each site, three replicate sediment samples were taken from each of three tidal levels; high tidal marks (H.T.M.), mid tidal marks (M.T.M) and low tidal marks (L.T.M.) during spring tide by means of a hand metal cylindrical corer of 10 cm² (3.5 cm diameter, 10 cm high) for examination of nematodes and sediments characteristics. The YSI 650

multi-parameter instrument (YSI, Yellow Springs, OH, USA) was used to measure water temperature and salinity (expressed as total dissolved salts, TDS) in the field.

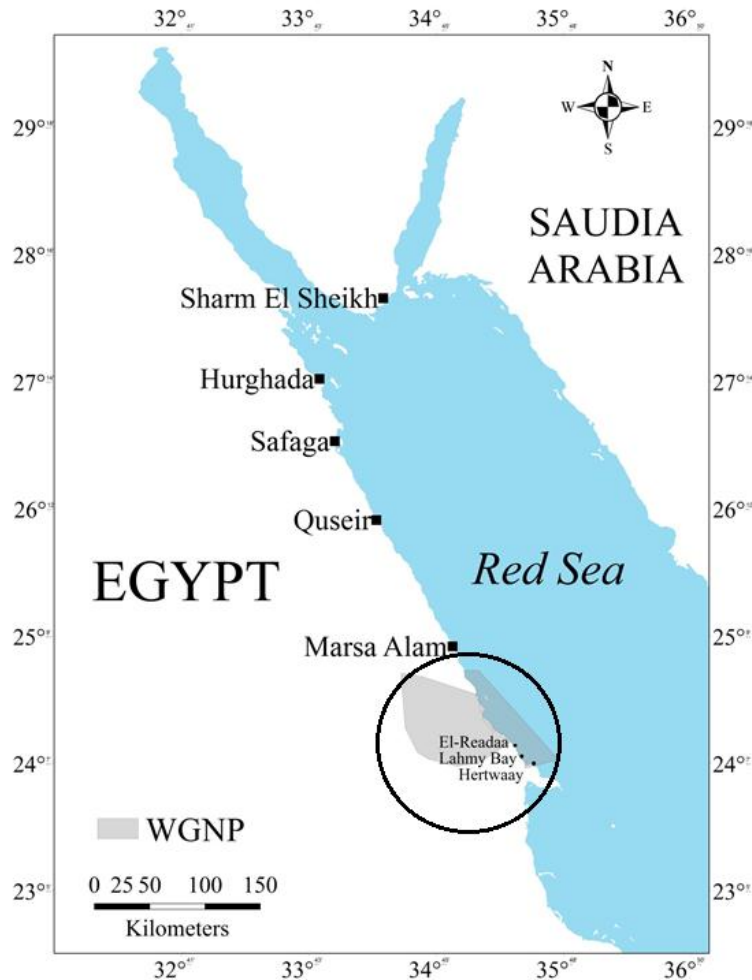


Fig. 1: A map of the Egyptian Red Sea coast showing the studied sites.

Sample Analysis:

Sediment samples collected for the investigation of nematodes were fixed in the field using 5% neutral formalin and placed in labeled plastic bottles and brought to the laboratory. They were immediately stained with 0.5 g/l Rose Bengal for 1 h then washed through sieves of 500 μm and 50 μm mesh size. All individuals retained on the 50 μm sieve were collected and counted under a stereomicroscope (Prior S 2000, magnification 100x). All nematodes were picked out and transferred to vials containing glycerol through two series of ethanol-glycerol solutions and mounted on glycerin slides (De Griesse, 1969). They were examined underneath a compound microscope (Carl Zeiss 1000x magnification) and identified to the genus level using the pictorial keys by Tarjan (1980); Platt and Warwick (1983); Plat and Warwick (1988) and Warwick *et al.*

(1998). Nematodes were categorized to three different feeding types according to the morphology of their buccal cavities (Wieser, 1953).

The other sediment samples were washed with tap water to remove salt, dried at 60°C for 24 h, then placed on top of a series of sieves of mesh sizes 1,000, 500, 250, 125, and 62 µm. The sediments that retained on top of each sieve were weighed then classified to different grain size categories according to the method of Holme and McIntyre (1984): silt-clay, very fine sand, fine sand, medium sand and coarse sand and gravel. Sediment sorting indices were determined according to Gray (1981).

For the determination of total organic matter in the sediment samples, 1 g of fine sediment for each one with sizes ranged between 125- 250 µm were taken and dried at 60 °C overnight in the laboratory. Total organic matter (TOM) was assessed as the percentage weight loss in the samples after combustion at 550 °C for 24 Hours (Jorgensen, 1977).

Data analysis:

To test for the spatial heterogeneity of sediment and abundance of nematode genera between sites and different tidal levels, one-way analysis of variance (ANOVA) with 95% confidence limits were performed. Pearson's Correlation Analysis was used to determine the relationships between the nematode abundance with the sediment characteristics. Analyses were carried out using the statistical software SPSS 18.0 (2002). To assess the structural diversity at each site, nematode diversity indices (Species richness (SR), evenness (Pielou index, J') and the Shannon-Wiener diversity index (H')) were calculated using PRIMER v6.0 software (Clarke and Gorley, 2006). All diversity indices were determined at nematode genus level.

RESULTS

1. Physico-chemical parameters and sediment characteristics

In the spatial study, water temperatures, TDS and sediment characteristics displayed little variations among sites. Sediments of site II and III exhibited higher silt/clay content percentages, total organic matter percentages (TOMs) and lower median grain size than site I. Sediments for all sites were classified as "well sorted" textures (Table 1). For horizontal study, the studied physico-chemical parameters and sediment characteristics increased from the high tidal marks (H.T.M.) areas to low tidal marks areas (L.T.M.) in terms of silt/clay percentages and TOMs% while water temperatures, TDS, Mz, sand percentages decreased seawards. The sediment sorting index for the areas of L.T.M was from moderately well sorted type while the other ones were from well sorted types (Table 2).

Table 1: Water temperature, salinity, silt and clay content %, sediment median grain size (Mz), total organic matter (TOMs) and sorting index at the investigated sites.

| Site | Temperature °C | TD S | Silt/clay % | Sand % | TOMs % | Mz(µm) | Sediment sorting |
|----------|----------------|------|-------------|--------|--------|--------|------------------|
| Site I | 24.6 | 42.8 | 48.5 | 51.5 | 4.4 | 275 | Well sorted |
| Site II | 24.5 | 42.5 | 51 | 49 | 5.8 | 220 | Well sorted |
| Site III | 24.5 | 42.5 | 50.8 | 49.2 | 5.5 | 210 | Well sorted |

Table 2: Water temperature, salinity, silt content %, sediment median grain size (Mz), total organic matter (TOMs) and sorting index at the investigated tidal levels.

| Tidal level | Temperature °C | TDS | Silt and clay % | Sand % | TOMs% | Mz (µm) | Sediment sorting |
|-------------|----------------|------|-----------------|--------|-------|---------|------------------------|
| H.M.T. | 25.2 | 43.5 | 42 | 58 | 2.3 | 325 | Well sorted |
| M.T.M. | 24.5 | 42.7 | 53 | 47 | 5.1 | 190 | Well sorted |
| L.T.M. | 24 | 42.4 | 57 | 43 | 8.8 | 147 | Moderately well sorted |

2. Nematofauna in the spatial study

A total of 13 families represented the nematofauna. Of them, 4 families accounted for 76.6% in terms of abundance namely, Xyalidae (22.4%), Desmodoridae (21.9%), Linhomoeidae (20.5%) and Oncholaimidae (11.9%). In terms of number of genera, Comesomidae was the most diversified family with 4 genera followed by Dosmodoridae, Leptolaimidae, Oncholaimidae and Xyalidae with 3 genera each (Table 3).

Nematoda abundance varied among sites, one way ANOVA showed significant variation among sites ($F = 89.27$, $P < 0.001$). The highest density value of nematodes was recorded in site I (316 ± 100 individual/10 cm²). Nematoda was represented by 25 genera. Of them 15 were recorded in all sites. *Terschellingia* and *Daptonema* exhibited the highest densities (Table 4). The abundance of the former ranged between 35 ± 21.7 and 55 ± 23.7 individual/10 cm² with a relative abundance of 18.5% while the latter showed a very close relative abundance value of 18.2% (Fig. 2). *Sprinia* ranked third; its densities ranged between 2.7 ± 1.3 and 55.3 ± 18.7 individual/10 cm² and a relative abundance of about 17% (Table 3 and Fig. 2). Site I had the highest values of number of genera, Shannon-Wiener indices and Species Richness while site III had the lowest apart from the Evenness value which was its highest (Table 5). Deposit feeding was the most common type in all sites (50%) of total nematodes and ranged between 41.1-60.5%. Epistrate feeding was ranked second followed by predator/omnivore feeding (Figs. 3 and 4).

Table 3: Total average count of families (expressed as No. of individual/10 cm²), Relative abundance and No. of recorded genera in the studied sites

| Family | Count | Relative abundance | No. of genera | % |
|-----------------------|---------------|--------------------|---------------|----|
| Cyatholaimidae | 2.7 | 0.39 | 1 | 4 |
| Monhysteridae | 3.3 | 0.48 | 1 | 4 |
| Tripyloididae | 4 | 0.58 | 1 | 4 |
| Haliplectidae | 4.73 | 0.68 | 1 | 4 |
| Ethmolaimidae | 6.7 | 0.96 | 1 | 4 |
| Microlaimidae | 13.7 | 1.97 | 1 | 4 |
| Chromadoridae | 23.7 | 3.41 | 1 | 4 |
| Leptolaimidae | 48.3 | 6.96 | 3 | 12 |
| Comesomidae: | 55.1 | 7.93 | 4 | 16 |
| Oncholaimidae | 82.5 | 11.88 | 3 | 12 |
| Linhomoeidae | 142.3 | 20.49 | 2 | 8 |
| Desmodoridae | 152 | 21.89 | 3 | 12 |
| Xyalidae | 155.4 | 22.38 | 3 | 12 |
| Total | 694.43 | | 25 | |

Table 4: Average genus count in the studied sites expressed as No. of individual/10 cm².

| Family | Genera | Site I (Mean±Standard deviation) | Site II (Mean±Standard deviation) | Site III (Mean±Standard deviation) |
|-----------------------|------------------------|--|---|--|
| Chromadoridae | <i>Ptycholaimellus</i> | 11.7±5.3 | 7±2.7 | 5±1.3 |
| Comesomidae: | <i>Dorylaimopsis</i> | 6.7±2.7 | - | - |
| | <i>Laimella</i> | 4.3±1.7 | - | 1.7±0.3 |
| | <i>Paracomesome</i> | 5.7±1.3 | 5±0.7 | 6.7±2.3 |
| | <i>Sabatieria</i> | 16.7±7.3 | 4±1.7 | 4.3±0.7 |
| Cyatholaimidae | <i>Pomponema</i> | 2.7±0.7 | - | - |
| Desmodoridae | <i>Desmodora</i> | 8.3±2.7 | 1.3±0.3 | 11.7±3.3 |
| | <i>Metachromadora</i> | 11.7±5.7 | 15±6.7 | 7.7±2.3 |
| | <i>Spirinia</i> | 55.3±18.7 | 38.3±15.3 | 2.7±1.3 |
| Ethmolaimidae | <i>Ethmolaimus</i> | 1.7±0.7 | 5±0.3 | - |
| Haliplectidae | <i>Haliplectus</i> | 2.7±1.3 | 0.33±1 | 1.7±0.3 |
| Leptolaimidae | <i>Camacolaimus</i> | 2±0.7 | - | - |
| | <i>Halaphanolaimus</i> | 16.7±5.3 | 1±0.3 | 13.3±4.7 |
| | <i>Leptolaimus</i> | 8±1 | 2.3±0.7 | 5±1.3 |
| Linhomoeidae | <i>Metalinhomoeus</i> | 5±1.3 | 2.3±0.7 | - |
| | <i>Terschellingia</i> | 55±23.7 | 45±28.3 | 35±21.7 |
| Microlaimidae | <i>Microlaimus</i> | 7±2.3 | 2.7±0.3 | 4±1 |
| Monhysteridae | <i>Diplolaimella</i> | 1±0.3 | 2.3±1 | - |
| Oncholaimidae | <i>Oncholaimellus</i> | 5±1.3 | 21.7±10.7 | 6.7±0.7 |
| | <i>Oncholaimus</i> | 10.7±4.3 | 17±3.7 | 5±3.3 |
| | <i>Viscosia</i> | 3.7±2.3 | 12.7±9.3 | - |
| Tripyloididae | <i>Tripyloides</i> | 4±1.7 | - | - |
| Xyalidae | <i>Daptonema</i> | 51.7±13 | 36.7±18.7 | 40.3±15.3 |
| | <i>Stylotheristus</i> | 3.3±1.7 | 2.7±0.3 | 6.7±1.7 |
| | <i>Theristus</i> | 14±3.7 | - | - |
| Total count | | 316±100 | 220.3±90 | 157.5±6 |

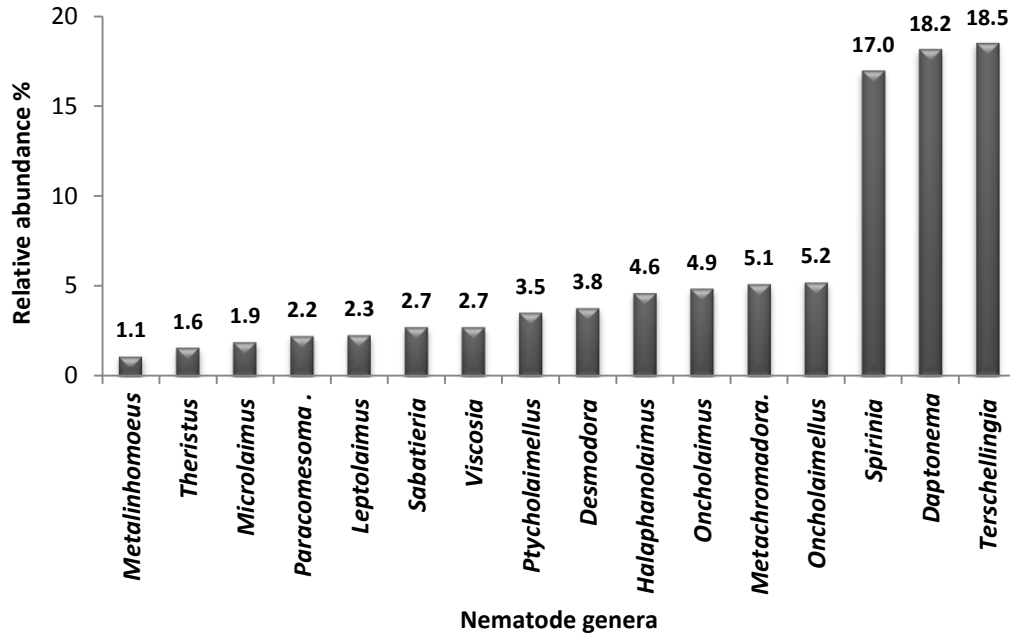


Fig. 2: Relative abundance of the common nematode genera in the studied sites (values are given in the top of each column).

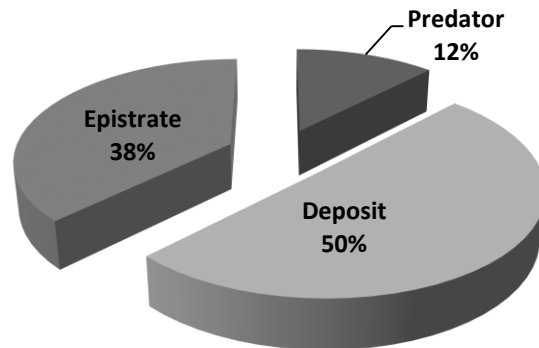


Fig. 3: Percentage of nematodes feeding types in the studied mangroves.

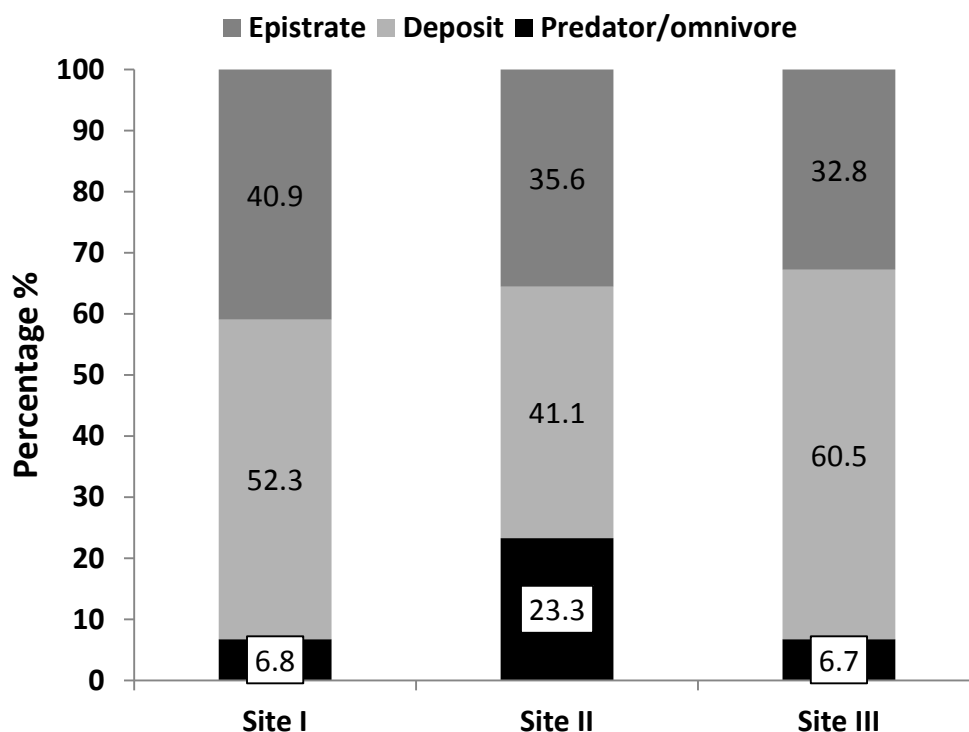


Fig. 4: Percentage of nematodes feeding types in the studied mangroves sites (values are given for each category).

Table 5: Total recorded genera of nematodes (S), total individual count expressed as No. of individual/ 10 cm² (N), Shannon- Wiener (H'), Species Richness (SR) and Evenness (J') at the studied sites.

| | Site I | Site II | Site III |
|-----------|--------|---------|----------|
| S | 25 | 19 | 16 |
| N | 316 | 220 | 157 |
| H' | 2.66 | 2.34 | 2.35 |
| SR | 3.5 | 2.8 | 2.4 |
| J' | 0.83 | 0.79 | 0.85 |

3. Nematofauna in the horizontal study

The abundance of nematodes varied on the horizontal basis. ANOVA test showed significant variation ($F_{14,46}$, $P < 0.01$). The highest density was recorded in the mid tidal mark (272 ± 73 individual/10 cm²) while a slight difference was between the densities of the high and low water marks (Table 6). *Terschellingia* attained the highest density (51.7 ± 12.7 individual/10 cm²) followed by *Daptonema* (46.7 ± 23.7 individual/10 cm²) in the mid tidal mark (Table 6). All diversity indices, density and number of genera were higher in the mid tidal levels than the other ones. Nematofauna in the low tidal level showed the lowest values (Table 7). Predator/omnivore feeding type was the least

common with a percentage ranged between 3.9 and 20.5%. Deposit and predator/omnivore feeding types increased seaward while Epistrate feeding showed opposite pattern with a highest percentage in the high tidal mark (Fig. 5).

Table 6: Abundance of nematode genera (expressed as No. of individuals/ 10 cm²) and feeding type in the studied tidal levels where H.T.M=High tide mark, M.T.M=Mid tide mark and L.T.M. =Low tide mark.

| Feeding Type | Genera | H.T.M | M.T.M. | L.T.M. |
|----------------------------------|------------------------|---------------------------|---------------------------|---------------------------|
| | | (Mean±Standard deviation) | (Mean±Standard deviation) | (Mean±Standard deviation) |
| Deposit feeding | <i>Daptonema</i> | 30±11.3 | 46.7±23.7 | 45.3±19.3 |
| | <i>Halaphanolaimus</i> | 13.3±7.3 | 12.7±5.7 | 3.3±0.7 |
| | <i>Leptolaimus</i> | 4.3±1.7 | 6.7±2.3 | 1±0.3 |
| | <i>Sabatieria</i> | 3.3±1.3 | 6±0.7 | 9±2.3 |
| | <i>Stylotheristus</i> | - | 5±1.7 | 0.7±0.3 |
| | <i>Terschellingia</i> | 33.3±7.7 | 51.7±12.7 | 39.3±14.3 |
| | <i>Theristus</i> | 3.7±1.3 | 6±0.7 | 0.3±0.3 |
| Epistrate feeding | <i>Camacolaimus</i> | 0.7±0.3 | 1.3±0.7 | - |
| | <i>Desmodora</i> | 9.3±2.7 | 10±3.3 | 6±1.3 |
| | <i>Diplolaimella</i> | 0.7±0.3 | 2.3±1.3 | 0.3±0.3 |
| | <i>Dorylaimopsis</i> | 2.7±0.7 | 5±2.3 | - |
| | <i>Ptycholaimellus</i> | 7.3±1.3 | 12.7±2.3 | 3.7±0.7 |
| | <i>Ethmolaimus</i> | 5.7±1 | 1±0.3 | - |
| | <i>Laimella</i> | - | 3.3± | - |
| | <i>Metachromadora</i> | 15±2.7 | 10±2.3 | 9.3±1.7 |
| | <i>Metalinhomoeus</i> | 4.3±1.3 | 2.3±1.7 | 0.7±0.3 |
| | <i>Microlaimus</i> | 7±2.7 | 4.3±1.3 | 1.3±0.7 |
| | <i>Paracomesoma</i> | 5±1.3 | 8.3±2.7 | 1.7±0.3 |
| | <i>Spirinia</i> | 45±12.7 | 36.7±14.3 | 32.7±11.7 |
| | <i>Tripyloides</i> | 2±0.3 | 2.7±1.3 | 0.3±0.3 |
| Predator/omnivore feeding | <i>Oncholaimellus</i> | 2.7±1.3 | 15±8.3 | 17.3±5.7 |
| | <i>Oncholaimus</i> | 3.3±0.7 | 10±4.3 | 19.3±10.7 |
| | <i>Viscosia</i> | 2.7±1 | 13.3±2.3 | 3.3±0.7 |
| | Total count | 201±45 | 272±73 | 196.7±62 |

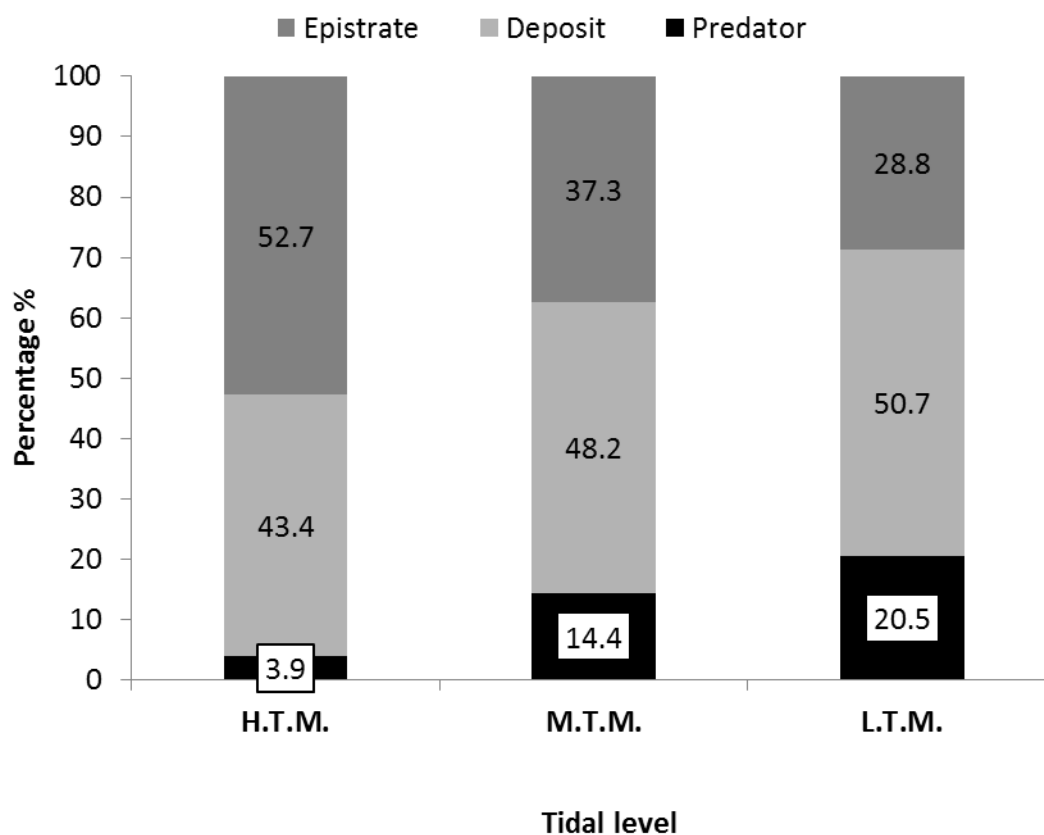


Fig. 5: Percentages of nematode feeding types at the studied tidal levels where H.T.M=High tidal mark, M.T.M=Mid tidal mark and L.T.M. =Low tide marks.

Table 7: Total recorded genera of nematodes (S), total individual count expressed as No. of individual/ 10 cm² (N), Shannon- Wiener (H'), Species Richness (SR) and Evenness (J') of the studied sites.

| | H.T.M | M.T.M. | L.T.M. |
|-----------|-------|--------|--------|
| S | 21 | 23 | 19 |
| N | 603 | 816 | 587 |
| H' | 2.23 | 2.64 | 2.2 |
| SR | 3.12 | 3.28 | 2.82 |
| J' | 0.73 | 0.84 | 0.75 |

In the spatial study, Pearson's correlation analysis showed strong significant values between all sediment parameters; silt content %, median grain size (Mz) and total organic matter (Table 8). The abundance and total number of genera of nematodes showed strong negative significant correlations with silt content and moderate ones with TOMs. In contrast, strong positive significant values with sand percentages and Mz were calculated. Epistrate feeding nematodes showed strong positive correlation with sand percentage ($r=0.89$, $P < 0.001$) while predator/omnivore feeders showed reasonable

positive significant correlation with silt content and TOMs and the negative ones were found with sand percentages and Mz.

For the different tidal marks, Pearson's correlation analysis showed strong significant values between all sediment parameters (Table 9). For nematodes, only the total number of genera showed a negative reasonable correlation with TOMs ($r=-0.57$, $P<0.027$). Deposit and predator/omnivore feeders showed strong positive significant correlations with silt and clay contents and TOMs. In contrast, epistrate feeders showed strong negative significant values with silt and clay percentages and TOMs while the strong positive significant correlations were calculated for their densities with sand contents and Mz (Table 9).

Table 8: Pearson's correlation coefficients between sediment parameters: silt content percentage %, Sand %, total organic matter (TOMs) and the median grain size (Mz), abundance of Nematoda, No. of recorded genera, predator/omnivores %, deposit feeders % and epistrate feeders % in the spatial study. ** Highly significant, *significant and NS non-significant.

| | Silt & clay | Sand % | TOMs | Mz |
|----------------------|----------------|----------------|----------------|---------------|
| Sand % | -0.99** | | | |
| TOMs | 0.95** | -0.95** | | |
| Mz | -0.97** | 0.97** | -0.88** | |
| Abundance | -0.91** | 0.92** | -0.79** | 0.98** |
| No. of genera | -0.92 | 0.92 | -0.79 | 0.98 |
| Predator/Omnivores % | 0.63* | -0.6* | 0.77** | -0.45* |
| Deposit feeder % | NS | NS | NS | NS |
| Epistrate feeder % | -0.89** | 0.89** | -0.75** | 0.97** |

Table 9: Pearson's correlation coefficients between sediment parameters: silt content percentage %, Sand %, total organic matter (TOMs) and the median grain size (Mz), abundance of Nematoda, No. of recorded genera, predator/omnivores %, deposit feeders % and epistrate feeders % in the different tidal levels. ** Highly significant, *significant and NS non-significant.

| | Silt & clay | Sand % | TOMs | Mz |
|----------------------|-------------|---------|---------|--------|
| Sand % | -0.9** | | | |
| TOMs | -0.94** | -0.94** | | |
| Mz | -0.99** | 0.99** | -0.93** | |
| Abundance | NS | NS | NS | NS |
| No. of genera | NS | NS | -0.57* | NS |
| Predator/Omnivores % | 0.99** | -0.99** | 0.97** | -0.99* |
| Deposit feeder % | 0.99** | -0.96** | 0.96** | -0.99* |
| Epistrate feeder % | -0.99** | 0.99** | -0.97** | 0.99** |

DISCUSSION

Densities of nematodes in the current study were within the range of other previous studies in mangrove regions around the world in general (their counts ranged between 35-280 in Bay of Bengal, India; **Ali *et al.*, 1983**; 62-411 in South Africa, **Dye 1983**; 113-451 in Australia, **Nicholas *et al.* 1991**; 374-885 in Malaysia, **Sasekumar, 1994**; 271-656 in Zanzibar, Africa, **Olafsson *et al.* 2000** and 196-811 in Brazil, **Netto and Galucci, 2003**).and in the Red Sea mangroves in particular (44-223 in Gulf of Aqaba, Jordan, **Hulings,1975**; 100-130 in Red Sea, Egypt, **Hanafy *et al.* 2011**; 343 in South Sinai, Egypt, **Pusceddu *et al.*, 2014**; 10-370 in Sudan; **Sabeel, 2015** and 72-1100 in Red Sea, Saudi Arabia, **Al-Sofiyani and El-Sherbiny, 2018**). The last study in the Red Sea mangroves found higher densities of nematodes in several sites along the Saudi Arabian coast of the Red Sea than other studied mangroves. They attributed that to the nature of which are within sites situated in protected or sheltered lagoons and near fish farm effluents. Furthermore, **Della Patrona *et al.* (2016)** in New Caledonia, southwest Pacific Ocean observed that the effluent-receiving mangrove usually displays a double count in the density and biomass of nematodes due to the availability of organic matter and other nutrients. **Alongi (1987a)** in Australia; **Olafsson (1995)** in Eastern Africa) stated that tidal oscillation has a negative impact on meiofaunal communities in terms of abundance and the sheltered ones are likely those areas where tidal currents have only

insignificant effects, which might be considered as possible reason of the higher abundance observed at these sites.

Water temperature, salinity, dissolved oxygen, redox potential, sediment characteristics and predator density are environmental factors that affected the diversity and abundance of meiobenthic organisms (Coull, 1999; Giere, 2009; Braeckman *et al.*, 2011). The present study revealed a significant correlation with the granulometry of sediment and the abundances of free-living nematodes. The significance of granulometric parameters for the determination of the spatial variability of meiofauna was studied in many areas (Alongi, 1987a, b; Ansari *et al.*, 1993; Thilagavathi *et al.*, 2011; Semprucci *et al.*, 2015; Al-Sofiyani and El-Sherbiny, 2018). The higher availability of space in the interstices of sand substrates permits organisms to use a several niches which increase their density and diversity (Dye, 1978; Coull, 1999; Mirto *et al.*, 2002). In addition, the sandy substrate provides a bigger scope for specialization in their feeding habits in terms of the occurrence of attached materials as well as many biogenic materials like fragments of mollusk shells (Coull and Bell, 1979; Rodriguez *et al.*, 2003; Gheskiere *et al.*, 2005). Although there are several parameters known to impact the variability of meiofauna, there are also quite a few studies that report the absence or lesser effect of several environmental factors on the distribution of them (Olafsson, 1995; Netto and Gallucci, 2003; Tolhurst *et al.*, 2010; Abdullah and Lee, 2017). Tolhurst *et al.* (2010) clearly pointed out that microhabitat (separate niches within the same mangrove ecosystem) or other factors such as recruitment, food, predation and competition have a more influence on the distribution of meiofauna than other environmental factors.

In the current study, nematodes were represented by 13 families and 25 genera, most of which were typical of intertidal sediments worldwide. The dominant families observed (Desmodoridae Linhomoeidae and Xyalidae) are considered to be common inhabitants of detritus-rich intertidal mangroves as that found in several mangroves (Hopper *et al.* 1973; Alongi 1990b; Nicholas *et al.* 1991; Olafsson 1995; Somerfield *et al.* 1998; Bhadury *et al.* 2015; Al-Sofiyani and El-Sherbiny, 2018). Low diversity of nematodes in comparisons with other temperate and tropical mangrove ecosystems, this relatively small number can be explained either by the restricted sampling time, that covered only a specific season or by the oligotrophic nature of the Red Sea (Almahasheer *et al.*, 2017), which is low in biodiversity. It has also been documented that tropical mangroves display basically lower diversity and abundance of meiofauna/nematodes compared to other temperate mangroves as a result of poor nutritional quality of mangrove-derived detritus (Tietjen and Alongi 1990; Alongi and Christoffersen, 1992), increased physical stress (Alongi, 1987a, b; Armenteros *et al.*, 2006), and high tannin content in mangrove sediments (Alongi, 1987c; Tietjen and Alongi, 1990; Abdullah and Lee, 2017). Although some of the sites were characterized by higher

densities, the nematode composition did not reveal any dominance pattern in different studied habitats.

The present study found the absence of any specific free living marine genus in each mangrove habitat. This obviously shows that the composition of nematodes in the Red Sea follows the same distribution pattern and does not appear to be impacted by different habitats. Desmodoridae and Xyalidae were the most abundant and diversified families, which is in accordance with several studies (**Bhadury et al., 2015** in The Indian west coast; **Nicholas et al., 1991** in Australia, **Olafsson, 1995** in Zanzibar, Eastern Africa; **Sabeel and Vanreusel, 2015** in Sudan, Red Sea and **Al-Sofiyani and El-Sherbiny, 2018** in Saudi Arabia, Red Sea) they reported similar patterns. In the present study, the dominance of certain nematode genera (*Daptonema*, *Spirinia* and *Terschellingia*) in mangrove sediments were observed, which is similar to the mangroves in the temperate latitudes of South America, Australia as well as tropical ones (**Hodda and Nicholas, 1985**; **Nicholas et al., 1991**; **Olafsson, 1995**; **Netto and Gallucci, 2003**; **Sabeel and Vanreusel, 2015**, **Al-Sofiyani and El-Sherbiny, 2018**).

Sandy substrates are known to favor epistrate and non-selective feeders feeding on benthic diatoms, protozoans, plant roots and bacteria (**Hodda and Nicholas, 1986**; **Jensen, 1987**; **Moens and Vincx, 1997**; **Netto and Gallucci, 2003**). This is evidenced by the significant positive correlation obtained for some genera such as *Spirinia* with the sand fraction. In the current study *Spirinia* genus was common that are in accordance with several studies (**Sasekumar, 1994** in Malaysia; **Olafsson, 1995** and **Olafsson et al., 2000** in Zanzibar, Africa; **Sabeel and Vanreusel, 2015** in Red Sea, Sudan; **Al-Sofiyani and El-Sherbiny, 2018** in Red Sea, Saudi Arabia).

Deposit feeders were common in sediments of fine nature, while epistrate feeders are predominant in coarser sediments. This finding is in accordance with **Heip et al. (1985)** and **Ansari et al. (2014)**. Strong significant correlations were found between sediment texture and the abundance of feeding types, Epistrate feeders dominated the high-water levels with coarse sediment nature and decreases seaward where the sediment texture was finer. Opposite pattern was found for deposit feeders which attained the highest occurrence in areas of low water mark. Similar findings were observed by many authors in other mangroves (**Dye, 1983**; **Alongi, 1987 and 1990**; **Alongi and Christofferen, 1992**; **Vanhove et al., 1992**; **Ansari and Parulekar, 1993**; **Olafsson, 1995**; **Chinnadurai and Fernando, 2006**; **Ansari et al., 2014**). In this study, the relative abundance of predator nematodes was high in the low water marks which are characterized by low oxygen levels and fine sediment nature. This finding agreed to that stated by **Fonseca et al. (2007)**, **Gallucci et al. (2008)** and **Vanreusel et al. (2010)** who elucidated that predator nematodes are having elongated body (i.e. *Oncholaimus*, *Oncholaimellus* and *Viscosia*) which may increase their mobility, permitting short excursions in the sediments with anoxic to the oxic ones. The sediment grain size is known to be the prime factor that determines the species composition and densities of

free living nematodes (Heip *et al.*, 1985; Steyaert *et al.*, 1999; Vanaverbeke *et al.*, 2002; Semprucci *et al.*, 2010; Fonseca *et al.*, 2014), as it significantly impacts the interstitial behavior and burrowing of benthic organisms (Vanaverbeke *et al.* 2011).

In the present study, the nematofauna was more abundant and diversified in the mid tidal level. The reason could be avoiding the unfavorable sediment conditions during low tide. Steyaert *et al.* (2001) reported that tides cause substantial alterations in sediment temperature, oxygen saturation level, and water content. These alterations produce horizontal distribution patterns and vertical stratification according to the tidal cycle. For thus, the mid tidal level zone is usually are more stable in all conditions between wave action and exposure and, therefore, shows higher in terms of abundance and diversity (Nicholas and Hodda 1999, Gheskiere *et al.*, 2004, Gingold *et al.*, 2010).

In the current study, the low tidal level zones were inhabited by lower density and diversity of nematodes than the other tidal levels. This pattern of distribution might be due to two factors; first is the presence of huge quantities of dead mangrove trees and fallen litters, which eventually leach colloidal compounds such as tannins that inhibit the growth of meiobenthic organisms (Alongi, 1987c; Tietjen and Alongi, 1990; Zhou *et al.*, 2001; Al-Sofiyani and El-Sherbiny, 2018). The amount of these compounds varied according to several ambient environmental factors such as water temperature, salinity and the residence time of water at these sheltered areas. The second factor is the predations that occur exclusively at this zone and is generated by the feeding actions of vast animals and can cause significant reductions in nematode densities. Similar interpretations were reported by Olafsson and Elmgren (1991); Dittmann (1996); Schratzberger and Warwick (1999); Danovaro *et al.* (2007).

CONCLUSION

The distribution of free-living nematodes in the mangrove ecosystems of the Egyptian western coast of the Red Sea is influenced by vast environmental factors. Sediment texture was directly and indirectly affecting their distributions in terms of generic compositions and types of feedings. The distribution of these organisms at different tidal levels was more complicated due to the wide variations in all conditions that provide specific microhabitats in each zone.

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