The composition and distribution of the benthic meiofauna assemblages of the Egyptian coasts along the Red Sea are described in relation to abiotic variables. Sediment samples were collected seasonally from three stations chosen along the Red Sea to observe the meiofaunal community structure, its temporal distribution and vertical fluctuation in relation to environmental conditions of the Red Sea marine ecosystem. The temperature, salinity, pH, dissolved oxygen, and redox potential were measured at the time of collection. The water content of the sediments, total organic matters and chlorophyll $a$ values were determined, and sediment samples were subjected to granulometric analysis. A total of 10 meiofauna taxa were identified, with the meiofauna being primarily represented by nematodes (on annual average from 42% to 84%), harpacticoids, polychaetes and ostracodes; and the meiofauna abundances ranging from 41 to 167 ind./10 cm$^2$.

The meiofaunal population density fluctuated seasonally with a peak of 192.52 ind./10 cm$^2$ during summer at station II. The vertical zonation in the distribution of meiofaunal community was significantly correlated with interstitial water, chlorophyll $a$ and total organic matter values. The present study indicates the existence of the well diversified meiofaunal group which can serve as food for higher trophic levels in the Red Sea interstitial environment.

© 2015 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
their potential for rapid response to environmental changes is high (Fraschetti et al., 2006; Giere, 1993; Gyedu-Ababio and Baird, 2006; Harguinteguy et al., 2012). The marine meiofauna is often a very useful tool for biological monitoring since the community structure may be sensitive to both natural and anthropogenic environmental disturbances (Gyedu-Ababio and Baird, 2006; Mirto and Danovaro, 2004; Moreno et al., 2008; Harguinteguy et al., 2012). Moreover, the bees may function as natural filters responsible for the remineralization of substances, which then return to the sea as nutrients (Coull and Chandler, 2001). The interstitial system of the beaches, in particular the system protected by muddy sediments, is formed by long and intricate food chains of bacteria, unicellular algae and meiofauna at the first levels. Therefore, biological systems are dependent on the productivity of coastal areas (Higgins and Thiel, 1988; Leguernier et al., 2003).

The growth and diversity of meiofauna may be stimulated by feeding on bacteria, which could increase the recycling of nutrients into the ecosystem and thereby be expected to have a greater productivity (De Wit et al., 2001; De Troch et al., 2006). Moreover, the meiofauna can provide food for higher trophic levels, such as fish and marine invertebrates (Leduc and Probert, 2009). The spatial patterns of the structure of the meiofaunal community in sandy beaches of marine ecosystems may be associated with different environmental variables. Related to this, the sediment granulometry (Gómez Noguera and Hendricks, 1997; Barnes et al., 2008), the organic matter source in coastal sediments (Danovaro et al., 2002; Flach et al., 2002; Moreno et al., 2008; Ingels et al., 2009; Pusceddu et al., 2009), and oxic and anoxic conditions in the interstitial pore space (Mirto et al., 2000; Sutherland et al., 2007) have a fundamental role in the richness and abundance of the benthic meiofauna.

The criteria in the study of benthic meiofauna were established by Giere (1993) and these concepts have been recently applied for the Egyptian fauna of the Red Sea (Hanafy et al., 2011; Ahmed et al., 2011). However, none of the two studies took place on the vertical distribution of the meiofauna. This somewhat meager data suggest that there is a need for more information on meiofaunal community of the Egyptian coasts along the Red Sea and their temporal changes, weather stochastic, seasonal or long term to understand their trophic relation in the benthic ecosystem. This pioneer study was undertaken to provide answers to the basic question on what are different types of meiofaunal metazoans and their spatio-temporal variation in the Egyptian coasts of the Red Sea.

2. Materials and methods

Sediment samples for environmental parameters and meiofauna were collected from three stations of Gabal El-Zeit (site I), Safaga (site II) and Al-Qulaan (site III) (Fig. 1); with the help of a hand core of 4.5 cm inner diameter and 10 cm length situated approximately 350 m apart in the sea. The three stations were selected based on their proximity to mangrove. SAFaga (lat 26° 36′ 56″N, long 34° 00′ 43″E) and Al-Qulaan (lat 24° 21′ 28″N, long 35° 18′ 23″E) were closer to mangrove vegetation than Gabal El-Zeit (27° 48′ 10″N, long 33° 33′ 59″E). Samples for horizontal and vertical distribution were collected seasonally during 2012. Sampling was carried out where three replicate cores were collected at low tide by inserting the 10 cm length core into the sediment from each station. The core sediments were sub-sectioned at 2 cm interval for the study of vertical distribution of meiofauna, grain size analysis, and total organic matters. The percentage of silt/clay in the sediment was obtained by wet sieving using a 62 μm sieve to separate the fine and sand fractions, which were then dried at 80 °C and weighed (Harguinteguy et al., 2012).

Sediment samples containing meiofauna were preserved in 4% formalin and stained with Rose Bengal (Ansari et al., 2001). In the laboratory, these samples were elutriated of larger sand particles using a shake and decant procedure (Cross and Curran, 2000) and meiofauna were sorted by sieving through 0.50 and 0.062 mm mesh sizes sieves. The content of the 0.062 mm sieve was recovered and preserved in the fixative (Ditlevsen, 1911). Then, the fauna were identified to higher taxa and counted under a stereomicroscope (Higgins and Thiel, 1988), and dry weight biomass was obtained by multiplying a factor of 0.00045 with total number of taxa recorded on each sampling date and station (Ansari, 1989). The meiofaunal density was standardized to individuals per 10 cm². Identification of meiobenthic organisms were performed using the keys of Riedl (1969), Tarjan (1980), Norenburg (1988), Platt and Warwick (1988) and Huys et al. (1996).

Temperature was recorded with the help of a centigrade thermometer. Interstitial water was collected for the estimation of salinity and dissolved oxygen. For the estimation of salinity, method of Strickland and Parsons (1972) was followed. Oxygen concentration was estimated using an oxygen meter. The percentage of interstitial water of the sediment was measured regularly. Wet sediment from the fraction of core was weighed on a watch glass, dried at 100 °C to constant weight and re-weighed. Wet weight minus dry wet was interpreted as a rough estimate of the weight of the interstitial water from which the percent interstitial water was calculated (Tiétjen, 1969). Total organic matters of each sediment sample were determined according to Holme and McIntyre (1984). Sedimentary pigment determination was made according to Tiétjen (1968) to obtain estimates of chlorophyll a in the sediment.

Simple correlation coefficient (r) was used to find the relation between different environmental parameters and meiofaunal density. Data on meiofauna density obtained in the present study was subjected to the ANOVA analysis to understand whether there exist any significant correlations in the meiofaunal densities with depth.

3. Results

3.1. Physico-chemical conditions

Physico-chemical parameters and sediment characteristics of the three stations are shown in the (Table 1). The seawater temperature was observed to vary from a low of 17.5 °C during winter to 23.7 °C during summer. The variation in water salinity was from 40.6 psu in winter to 44.2 psu during summer. The dissolved oxygen content varied from 4.1 to 5.3 mg/l. The oxygen content showed an inverse relation with temperature and salinity during the present study. Fluctuations in pH around slightly alkaline values were generally limited and
varied between 7.6 and 8.3. The sediment was predominantly loose mud and had silt as the most dominant constitute with sand and clay in different proportions at station II and III, however the sediment collected from the station I differed completely and dominated by high values of sand. The average values of sand, silt and clay at station I were 79.64%, 11.84% and 8.51%, respectively. While at station II the values for the same constituents are 14.63%, 71.17%, and 9.69%, respectively and in station III these values were 35.16%, 52.09% and 12.74%, respectively.

The sedimentary organic matter, chlorophyll $a$ and interstitial water are illustrated in (Table 2). A well defined vertical profile was recorded for the interstitial water, total organic matter and chlorophyll $a$ concentration. The interstitial water content showed a decreasing trend from surface to a depth of 10 cm in the sediment. A difference of over 50% in the total organic matter values was observed in the top (0–4 cm) and bottom (4–10 cm) layer. The same trend of decreasing values with increasing depth was followed by chlorophyll $a$ and the interstitial water.

Figure 1 Location of sampling sites (with red colours) chosen for collecting meiofauna at the northern part of the Red Sea during the present study.
Total number of meiofauna varied from 17.87 to 56.10 ind./10 cm at station I and from 97.43 to 192.52 ind./10 cm² at station II. In the station III the meiofaunal population density varied between 106.82 and 139.6 ind./10 cm². The total biomass fluctuated between 0.008 and 0.0866 mg/10 cm² at stations I and II, respectively. The faunal density was lowest during winter and increased during summer at the three stations (Table 3). Four major meiofaunal groups were represented in the present study. Nematodes were the most dominant group with percentage contribution of 67%. Harpacticoid copepods were the second most abundant group; they contributed 12% of the total meiofaunal density. Polychaetes remained the third major group and contributed 10%, while ostracodes occupied the fourth level with percentage contribution of 4%. Oligochaetes and gnathostomulids occupied the fifth level with a percentage of 3% for each. Other taxa (Amphipoda, Cumacea, Isopoda and Nemertina) occurred in limited number and collectively averaged 1% of the total meiofauna.

On average about 79% of the total fauna was restricted to the top 0–4 cm layers and there was a consistent decrease in the number with increasing depth in the sediment. Out of the total number of meiofaunal population density in the 10 cm depth sediment core, only about 3% were present at the 8–10 cm layer and the remaining 97% in the top layers. There was a significant difference ($p < 0.01$) in the total number observed between 0–2 and 8–10 cm depth. Table 4 describes the values of total meiofaunal biomass, evenness, Shannon–Weaver index and species richness at the three locations.

### Table 1 Physico-chemical and sedimentary properties at the three stations chosen along the northern part of the Red Sea during the present study.

| Site and parameter | Season       | Spring | Summer | Autumn | Winter |
|-------------------|--------------|--------|--------|--------|--------|
| **Gabal El-Zeit**  | **Water**    |        |        |        |        |
| Temperature (°C)  | 20.9         | 21.7   | 19.6   | 17.5   |        |
| Salinity (psu)    | 41.5         | 43.3   | 42.0   | 41.8   |        |
| pH                | 8.2          | 8.3    | 8.1    | 8.0    |        |
| Dissolved oxygen (mg/l) | 5.2  | 5.0    | 5.1    | 5.3    |        |
| **Sediment**      |              |        |        |        |        |
| Sand (%)          | 87.42        | 70.74  | 77.5   | 82.9   |        |
| Silt (%)          | 11.28        | 12.28  | 14.2   | 9.62   |        |
| Clay (%)          | 1.30         | 16.98  | 8.3    | 7.48   |        |
| Redox (mv)        | 49.7         | 46.6   | 45.8   | 48.5   |        |
| Total organic matters (mg/g) | 3.94 | 8.5    | 5.06   | 5.63   |        |
| **Safaga**        | **Water**    |        |        |        |        |
| Temperature (°C)  | 21.8         | 23.7   | 22.2   | 20.0   |        |
| Salinity (psu)    | 42.4         | 44.2   | 41.8   | 40.6   |        |
| pH                | 7.7          | 7.9    | 7.7    | 7.6    |        |
| Dissolved oxygen (mg/l) | 4.6  | 4.1    | 4.3    | 4.8    |        |
| **Sediment**      |              |        |        |        |        |
| Sand (%)          | 13.28        | 17.64  | 11.40  | 16.20  |        |
| Silt (%)          | 77.62        | 66.93  | 82.44  | 57.7   |        |
| Clay (%)          | 9.1          | 15.43  | 6.16   | 8.1    |        |
| Redox (mv)        | 110.8        | 120.5  | 130.2  | 120.6  |        |
| Total organic matters (mg/g) | 5.27 | 9.87   | 3.4    | 5.13   |        |
| **Al-Qulaan**     | **Water**    |        |        |        |        |
| Temperature (°C)  | 22.3         | 23.6   | 21.8   | 21.3   |        |
| Salinity (psu)    | 43.6         | 44.0   | 42.8   | 41.6   |        |
| pH                | 7.9          | 8.1    | 7.7    | 7.8    |        |
| Dissolved oxygen (mg/l) | 4.9  | 4.5    | 4.7    | 5.1    |        |
| **Sediment**      |              |        |        |        |        |
| Sand (%)          | 33.25        | 37.75  | 33.40  | 36.26  |        |
| Silt (%)          | 55.45        | 46.55  | 56.44  | 49.94  |        |
| Clay (%)          | 11.30        | 15.70  | 10.16  | 13.8   |        |
| Redox (mv)        | 273          | 284    | 258    | 247    |        |
| Total organic matters (mg/g) | 7.87 | 9.4    | 7.37   | 5.0    |        |

4. Discussion

The meiofauna composition was quite similar among the three sites chosen for the present study, however, its densities varied significantly among them. During the present study, the meiofauna showed considerable fluctuation in the total population density, which coincided with parallel changes in specific
environmental parameters. The total density of meiofauna attained its highest values of 192.52 ind./10 cm$^2$ at Safaga (site II) during summer and its lowest values of 17.78 ind./10 cm$^2$ at Gabel El Zeit (site I) during winter. The sedimentary environment in station II was different compared to station I (i.e. higher organic content, higher chlorophyll $a$ values and smaller grain size. The highest densities of meiofauna coincided with the highest percent of silt (82.44%) & clay (15.43%); highest total organic matters (9.89 mg/g); and highest chlorophyll $a$ (1.1 l g/g sed.) recorded at station II. Similar observations were recorded in the NW Shelf of Cuba (Armenteros et al., 2009), Mediterranean marine system (Moreno et al., 2008), coasts of South Africa (McLachlan et al., 1981, sandy beaches of Spain (Rodrı́guez et al., 2003). Besides physico-chemical sediment differences, another important factor that may influence the meiofaunal density is the fluctuation in the density of the most dominant group. During the present study, Nematoda was the most dominant group which constituted more than 60% of the total meiofauna. Similar results on the temporal variation with nematode’s dominancy in meiofaunal communities have been reported from different geographical regions (Rodrı́guez et al., 2003; Moreno et al., 2008; Landers et al., 2012; Harguinteguy et al., 2012; Meleno et al., 2013).

The total density observed in the present study was similar to those reported from other shallow regions of the northern Red Sea and ranged between 100 and 130 ind./10 cm$^2$ (Hanafy et al., 2011), and also was very close to that of recorded by Hulings (1975) in sandy beaches along the coasts of Jordan with a higher population density of 223 ind./10 cm$^2$ and lower values of 44 ind./10 cm$^2$. However, estimates of meiofaunal densities in other coastal regions (for example: sandy beaches of the Nuevo Gulf, Argentina; Harguinteguy et al., 2012) were extremely very higher (1500–6500 ind./10 cm$^2$) than the present study. These differences could be related to the oligotrophic conditions prevailing in the Red Sea.

In the current study, site III (Al Qulaan) was found to be the most diversified site among the three sites chosen for this study as it contains higher number of nematode and copepod taxa. This is mainly due to the location of this site within Wadi El Gemal protectorate area which contains the most productive habitats of mangroves and seagrass meadows. Increased diversity in seagrass meadows has been reported for meiofaunal nematodes (Ndaro and Olafsson, 1999) and copepods (Nicholls, 1944; Noordt, 1964; Hicks, 1986). Possible explanations are more food availability, sediment stability, protection from predators, and habitat complexity in the mangal and seagrass meadows (Orth and Heck, 1984).

On the other hand, over 50% of the population density of all meiofaunal taxa occurred in the upper layer of 0–4 cm depth and then these densities were sharply progressively decreased with increasing depth in the sediment (Table 2).

**Table 2** Vertical distribution of meiofauna, organic matter, chlorophyll $a$, interstitial water in the sediment collected from the northern part of the Red Sea during the present study.

| Parameter                        | Core depth (m) | 0-2 cm | 2-4 cm | 4-6 cm | 6-8 cm | 8-10 cm |
|----------------------------------|---------------|--------|--------|--------|--------|---------|
| Density (ind./10 cm$^2$)         |               | 109    | 59     | 27     | 11     | 6       |
| Total organic matter (mg/g)     |               | 6.36   | 5.64   | 4.31   | 2.41   | 1.92    |
| Chlorophyll $a$ (µg/g sed.)     |               | 0.87   | 0.43   | 0.34   | 0.21   | 0.11    |
| Interstitial water (%)           |               | 34     | 32     | 27     | 21     | 19      |

**Table 3** Total population density (ind./10 cm$^2$ sed.) and biomass (mgC/10 cm$^2$ sed.) of meiofauna at the three stations during the present study.

| Season    | Gabal El-Zeit | Safaga | Al-Qulaan |
|-----------|---------------|--------|-----------|
| Density   | Biomass       | Density | Biomass | Density | Biomass |
| Spring    | 56.10         | 0.0252 | 184.62   | 0.0831 | 138.82 | 0.0625 |
| Summer    | 44.08         | 0.0198 | 192.52   | 0.0866 | 139.6  | 0.0628 |
| Autumn    | 34.77         | 0.008  | 189.6    | 0.0853 | 106.82 | 0.0480 |
| Winter    | 17.87         | 0.0156 | 97.43    | 0.0438 | 109.37 | 0.0492 |

**Table 4** Average values of diversity indices of meiofauna in the Red Sea at the three different sites chosen for the present study.

| Diversity index | Site          | Gabal El-Zeit | Safaga | Al-Qulaan |
|-----------------|---------------|---------------|--------|-----------|
| Number of species|               | 13            | 17     | 31        |
| Population density (ind./10 cm$^2$) |   | 41            | 167    | 141       |
| Biomass (mgC/10 cm$^2$) |     | 0.018         | 0.075  | 0.063     |
| Eveness ($E$)    |               | 0.91          | 0.84   | 0.92      |
| Shannon-weaver index ($H$) | | 2.53          | 2.63   | 2.86      |
| Species richness ($D$) | | 3.6           | 3.6    | 4.0       |
Significant vertical decrease in meiofaunal densities as being recorded in the present study have also been reported in many other studies (Ansari et al., 1980; Cantelmo, 1978; Ndaro and Olafsson, 1999). In the present study, nematodes were the only group present in the entire core and dominated the fauna. A number of nematode species are known to withstand near anaerobic condition in the sediment (Wieser, 1975) and this may explain the regular occurrence of this group in the deeper layer of the sediments of the present study. Generally, those parameters which control macrofauna are also responsible for the distribution and abundance of meiofauna. Food availability and oxygen are considered important factors responsible for the vertical distribution of meiofauna. Moreover, sediment chlorophyll provides information on the primary productivity in the sediment and considered to be an important parameter for the distribution of meiofauna in the marine benthic habitat (Lee et al., 1977; Coull and Bell, 1979).

Significant vertical decrease in the meiofaunal density was positively correlated with sediment chlorophyll $a$ ($r = 0.81$; $p < 0.01$), interstitial water ($r = 0.74$; $p < 0.01$) and organic matter ($r = 72$; $p < 0.01$). These factors proved limiting in shallow coastal areas as they form important sources of food and energy supply (Coull and Bell, 1979; McIntyre, 1969). There has been much debate on the ultimate fate of meiobenthos in the ecosystem. The pathways from meiofauna could be linked to macrofauna, nektons and nutrient regeneration (Coull, 1973). It is because majority of meiofauna in the interstitial environment of the Red Sea occur in the top few centimeters of sediment where they are easily accessible to predators including fishes. This hypothesis was supported by many other investigators (Sudarshan and Neelakantan, 1986). The nematodes seem to play the role of conveyor belt and therefore the meiofauna of Red Sea could be considered important as food for higher trophic levels.

In conclusion, a total of 10 meiofaunal taxa were identified at the interstitial habitat of the Red Sea, with meiofauna community being primarily dominated by nematodes, harpacticoid copepods, polychaetes and ostracodes. The meiofaunal density is influenced by a set of physico-chemical factors of the sediment as well as by the presence of the biogenic structures. The more food availability of mangroves and seagrass meadows, their sediment stability, protection from predators, and their habitat complexity increase the density of meiofaunal community in the Red Sea sediment. Over 50% of the density of all meiofaunal taxa occurred in the upper layer of 0–4 cm depth and progressively decreased with increasing depth in the Red Sea sediment.

Acknowledgement

The authors extend their sincere appreciation to the Deanship of Scientific Research at King Saud University – Saudi Arabia for funding this work through Research Group number (RG-1436-242).

References

Ahmed, A., Mohammed, D., Hanafy, M., 2011. Distribution and species composition of the littoral interstitial free living nematodes in the northern Red sea, Egypt. J. Aquat. Biol. Fish 15 (2), 159–177.

Ansari, Z.A., 1989. Ecology of Meiobenthos in Two Estuaries of Goa (Ph.D. thesis). University of Bombay.

Ansari, Z.A., Parulekar, A.H., Jagtap, T.G., 1980. Distribution of sublittoral meiobenthos of Goa Coast. Hydrobiologia 74, 209–214.

Ansari, A., Rimonkar, C.U., Sangodkar, U.M.X., 2001. Population fluctuation and vertical distribution of meiofauna in a tropical mudflat at Mandovi estuary, west coast of India. Indian J. Mar. Sci. 30 (4), 237–245.

Armenteros, M., Creagh, B., González-Sansón, G., 2009. Distribution patterns of the meiofauna in coral reefs from the NW Shelf of Cuba. Rev. Invest. 30 (1), 37–43.

Austen, M.C., McEvoy, A.J., Warwick, R.M., 1994. The specificity of meiobenthic community responses to different pollutants: results from microcosm experiments. Mar. Pollut. Bull. 28, 557–563.

Barnes, N., Bamber, R., Moncrieff, C., Sheader, M., Ferrero, T., 2008. Meiofauna in closed coastal saline lagoons in the United Kingdom: structure and biodiversity of nematode assemblage. Estuar. Coast. Shelf Sci. 79, 328–340.

Cantelmo, F.R., 1978. The Ecology of Sublittoral Meiobena in a Shallow Marine Environment (Ph.D. thesis). University of New York.

Coull, B.C., 1973. Estuarine meiofauna: a review: trophic relationship and microbial interactions. In: Harold, Stevenson, Colwell, R.R. (Eds.). In: Estuarine Microbial Ecology. University of South Carolina Press, Columbia, pp. 499–512.

Coull, B.C., Bell, S.S., 1979. Perspective of marine meiofauna ecology. In: Livingston, R.J. (Ed.). In: Ecological Processes in Coastal and Marine System. Plenum Publishing Corporation, pp. 189–216.

Coull, B.C., Chandler, G.T., 2001. Benthos (meiobenthos). In: Steele, Austen, M.C., McEvoy, A.J., Warwick, R.M., 1994. The specificity of artificial reefs on the surrounding infauna: analysis of meiofauna. ICES J. Mar. Sci. 59, S356–S362.

De Troch, M., Van Gansbeke, D., Vinex, M., 2006. Resource availability and meiofauna in sediment of tropical seagrass beds: local versus global trends. Mar. Environ. Res. 61, 59–73.

De Wit, R., Stal, L.J., Lamstein, B.A., Herbert, R.A., Van Gennderen, H., Viaroli, P., Cecherevi, V.U., Rodriguezvalera, F., Bartoli, M., Giordani, G., 2001. Robust: the role of buffering capacities in establishing coastal lagoon ecosystems. Cont. Shelf Res. 21, 2021–2041.

Ditlevsen, J., 1911. Danish free-living nematode. Videnskabelige Meddelelser fra Dansk naturhistorisk Forening 63, 213–256.

Flach, E., Muthumbi, A., Heip, C., 2002. Meiobenthos and macrofauna community structure in relation to sediment composition at the intertidal habitat of the Red Sea. Meddelelser fra Dansk naturhistorisk Forening 94, 293–320.

Fraschetti, S., Gambi, C., Giangrande, A., Musco, L., Tertiary, A., 2002. Influence of artificial reefs on the surrounding infauna: analysis of meiofauna. ICES J. Mar. Sci. 59, S356–S362.

Giere, O., 1993. Meiobenthology. Springer, Berlin, p. 328.

Gómez Noguera, S., Hendrickx, M., 1997. Distribution and abundance of meiofauna in a subtropical coastal lagoon in the South-eastern Gulf of California, Mexico. Mar. Pollut. Bull. 34, 582–587.

Gyedu-Ababio, T., Baird, D., 2006. Response of meiofauna and nematode communities to increased levels of contaminants in a laboratory microcosm experiment. Ecotoxicol. Environ. Saf. 63, 443–450.

Hanafy, M.H., Mohammed, D.A., Ahmad, A.E., 2011. Seasonal distribution of the littoral interstitial meiofauna in the northern Red Sea, Egypt. Egypt. J. Aquat. Biol. Fish 15 (2), 35–51.

Harguindey, C.A., Coefré, M.N., De Ward, C.T.P., 2012. Change in the meiofauna community structure of sandy beaches of the Nuevo

464 H.A. El-Serehy et al.
Meiofauna in the Red Sea interstitial environment

Gulf (Chubut, Argentina). Pap. Avulsos de Zool. (SAO Paulo) 52 (34), 411–422.

Hicks, G.R.F., 1986. Distribution and behaviour of meiofaunal copepods inside and outside seagrass beds. Mar. Ecol. Prog. Ser. 31, 159–170.

Higgins, P.P., Thiel, H., 1988. Introduction to the Study of Meiofauna. Smithsonian Institution Press, Washington, D.C., p. 488.

Holme, N.A., McIntyre, A.D., 1984. Methods for the Study of Marine Benthos, second ed. Blackwell, Oxford, p. 387.

Hulings, N.C., 1975. Spatial and quantitative distribution of sand beach meiofauna in the northern Gulf of Aqaba. Rapp. Comm. Int. Mer Medit. 23, 163–181.

Huys, R., Gee, J.M., Moore, C.G., Hamond, R., 1996. Marine and brackish water harpacticoid copepods. Part I. In: Barnes, R.S.K., Crothers, J.H. (Eds.), . In: Synopses of the British Fauna No. 51. Field Studies Council, Shrewsbury, p. 352.

Ingels, J., Kiriakoulakis, K., Wolff, G.A., Vanreusel, A., 2009. Nematode diversity and its relation to the quantity and quality of sedimentary organic matter in the deep Nazaré Canyon, Western Iberian Margin. Deep Sea Res. Part I 56, 1521–1539.

Landers, S.C., Romano III, F.A., Stewart, P.M., Ramroop, S., 2012. A multi-year survey of meiofaunal abundance from the northern Gulf of Mexico continental shelf and slope. Gulf Mexico Sci. 1 (2), 20–29.

Leduc, J., Probert, P.K., 2009. The effect of bacterivorous nematodes on detritus incorporation by macrofaunal detritivores: a study using stable isotope and fatty acid analyses. J. Exp. Mar. Biol. Ecol. 371, 130–139.

Lee, J.J., Tietjen, J.H., Mastropalo, C., Rubin, H., 1977. Food quality and heterogenous spatial distribution of meiofauna. Helgo. Wiss. Meeresunters. 30, 272–279.

Leguerrier, D., Niquil, N., Boileau, N., Rzeznik, J., Pierreguy Sauriau, P.-G., Le Moine, O., Bacher, C., 2003. Numerical analysis of the food web of an intertidal mudflat ecosystem on the Atlantic coast of France. Mar. Ecol. Prog. Ser. 246, 17–37.

McIntyre, A.D., 1969. The ecology of marine meiobenthos. Biol. Rev. 44, 245–290.

McLachlan, A., Wooldridge, T., Dye, A.H., 1981. The ecology of sandy beaches in Southern Africa. S. Afr. J. Zool. 16, 219–231.

Meleno, H.C., Alvir, A.A., Tara, A.R., Ted Mikko, A.A., Vincent Nino, C.V., Enrique, G.A., Jarryn, L.M., Margie, V.P., 2013. Marine meiofauna in Songuelan Lagoon, Songuelan, Dausi, Bohol Philippines. J. Entomol. Zool. Stud. 1 (3), 47–51.

Mirto, S., Danovaro, R., 2004. Meiofaunal colonization on artificial substrates: a tool for biomonitoring the environmental quality on coastal marine systems. Mar. Pollut. Bull. 48, 919–926.

Mirto, S., La Rosa, T., Danovaro, R., Mazzola, A., 2000. Microbial and meiofaunal response to intensive Mussel-farm bio-deposition in coastal sediments of the Western Mediterranean. Mar. Pollut. Bull. 40, 244–252.

Moreno, M., Ferrero, T.J., Gallizia, I., Vezzulli, L., Albertelli, G., Fabiano, M., 2008. An assessment of the spatial heterogeneity of environmental disturbance within an enclosed harbor through analysis of meiofauna and nematode assemblages. Estuar. Coast. Shelf Sci. 77, 565–576.

Ndaro, S.G.M., Olafsson, E., 1999. Soft-bottom fauna with emphasis on nematode assemblage structure in a tropical intertidal lagoon in Zanzibar, eastern Africa. I. Spatial variability. Hydrobiologia 405, 133–148.

Nicholls, A.G., 1944. Littoral Copepoda from the Red Sea. Ann. Mag. Nat. Hist. 11, 487–503.

Noodt, W., 1964. Copepoda Harpacticoida aus dem littoral des Roten Meeres. Kieler Meeresforsch. 20, 128–154.

Norenburg, J.L., 1988. Remarks on marine interstitial nemertines and key to the species. Hydrobiologia 156, 87–92.

Orth, R.J., Heck, K.L., 1984. Faunal communities in sea grass beds: a review of the influence of plant structure and prey characteristics on predator–prey relationships. Estuaries 7, 339–350.

Platt, H.M., Warwick, R.M., 1988. Free living marine nematodes. Part II. British Chromadorids. In: Kermack, D.M., Barnes, R.S.K. (Eds.), . In: Synopses of the British Fauna No. 28. E.J. Brill/Dr. Backhuys, Leiden, p. 502.

Pusceddu, A., Gambi, C., Bianchelli, S., Danovaro, R., 2009. Organic matter composition, metazoan meiofauna and nematode biodiversity in Mediterranean deep sea sediments. Deep Sea Res. Part II 56, 755–762.

Riedl, R.J., 1969. Gnathostomulid from America. Science 163, 445–452.

Rodriguez, J., Lastra, M., López, J., 2003. Meiofauna distribution along a gradient of sandy beaches in northern Spain. Estuarine, Coastal Shelf Sci. 58, 63–69.

Strickland, J.D.H., Parsons, T.R., 1972. A Practical Handbook of Sea Water Analysis. Fish Res. Bd Canada, p. 310. Bull. No. 167.

Sudarshan, R., Neelakantan, B., 1986. Meiobenthic production in Karwar Bay, India. In: Thompson, M.R., Sarojani, R., Nagabhushanam, R. (Eds.), . In: Biology of Benthic Organisms. Techniques and Methods as Applied to Indian Ocean. Oxford & IBH Pub, New Delhi, pp. 135–162.

Sutherland, T.F., Levings, C.D., Petersen, S.A., Poon, P., Piercey, B., 2007. The use of meiofauna as an indicator of benthic organic enrichment associated with salmonid aquaculture. Mar. Pollut. Bull. 54, 1249–1261.

Tarjan, A.C., 1980. Illustrated Guide to the Marine Nematodes. IFAS, Univ. Florida, Gainesville, p. 135.

Tietjen, J.H., 1968. Chlorophyll and phaeopigments in estuarine sediments. Limnol. Oceanogr. 13, 189–192.

Tietjen, J.H., 1969. The ecology of shallow water meiofauna in two New England estuaries. Oecologia (Berl.) 2, 251–291.

Wieser, W., 1975. The meiofauna as a tool in the study of habitat heterogeneity ecophysiological aspects, a review. Cah. Biol. Mar. 16, 664–670.