Zooplankton and meiobenthos diversity at the intertidal sandy shores of Jizan and Farasan coastal areas of Red Sea

Hassien M. Alnashiri
Department of Biology, Faculty of Science, Jazan University, Jizan, Saudi Arabia

Abstract
Distinctive studies were conducted for the identification of meiobenthos and zooplankton at Farasan Islands and Jizan sandy shores. The present work compares the meiobenthos and zooplankton communities at Alhsas sandy shore at Farasan Islands and As-Suways sandy shore at Jizan. Population density, species richness and Shannon-Weiner diversity index were determined for meiobenthos and zooplankton inhabiting both the studied sites. Water criteria; surface water temperature, pH and conductivity were determined for each investigated site. Eleven zooplankton species were defined at Alhsas sandy shore Farasan, nine species were identified at the littoral zone at As-Suways sandy shore, Jizan. Ten meiobenthos species were defined at Alhsas site, Farasan. Only eight meiobenthos species were defined at the intertidal zone of As-Suways site, Jizan. The results were discussed to highlight the effect of water criteria on the spatial distribution of zooplankton and meiobenthos at the investigated sites.

1. Introduction
Meiobenthos are tiny microscopic organisms that spend all their life span at the same inhabitant site. They are important elements at the marine food web (Lee and Stokes, 2006). They inhabit about 5–10 cm depth below the soil surface. Their size is below 0.063 mm. They are referred to as microbenthic fauna. Benthic fauna that are higher than 1 mm are known as macro-fauna (Higgins and Thiel, 1988; Lee and Stokes, 2006). They are used as bioindicators for the health of marine ecosystem (Rombouts et al. 2013).

Meiofauna are extremely diverse heterotrophic benthic animals. Due to the higher turnover rates, short life cycle and absence of planktonic larvae in addition to their sensitivity to environmental changes, meiofauna were considered useful in assessing environmental instabilities (Kennedy and Jacoby, 1999). Sediments harbor benthic fauna of different sizes distributed at the surface part or within the sediments. They are adapted to their survival habitat being attached with their anchoring organs to sediment grains or the sediment surface (Lee and Stokes, 2006). Zooplanktons are planktonic organisms have weak locomotor organs and inhabit intertidal, subtidal zones and open water. They have important ecological role as a source of energy link between primary producers and intermediate or top of food chain in the marine ecosystem (Grzelak and Kotwicki, 2012). They were characterized by dual migration phenomenon following their main food source, the phytoplanktons to the water surface by day and down the water surface at night to depths up to 300 m (Castro and Huber, 2012).

Zooplanktons are the food source of many fish and the pelagic macroinvertebrates in the food web. Their population density are affected by the surrounding environmental changes in the aquatic ecosystem. Several authors used zooplankton as bioindicators for the quality of water criteria. Fewer studies have reported about the identification and spatial distribution of zooplankton at Jizan and Farasan coastal areas. The present work deals with the identification of zooplankton inhabiting intertidal zone of the sandy shore of As-Suways coastal area, Jizan, the Red Sea coast of Saudi Arabia and the Alhsas, Farasan, located towards the eastern side of Jizan. Jizan coast is comparatively stagnant part of Red Sea and receives turbid by anthropogenic activities and rainwater runoff from several valleys in the region; whereas Red Sea coasts Farasan island is pure and endowed with water currents and coral reefs.

Production and hosting by Elsevier
relationship between water criteria and the spatial distribution of zooplanktons was examined.

2. Materials and methods

Two locations in the Southern of Red Sea were selected for the present study; As-Suways, Jizan (16°49’24.5"N 42°37’48.0"E) and Beach Alhsas, Farasan Island (16°44’52.7"N 42°04’23.0"E) (Fig. 1).

2.1. Water criteria

Physical characteristics - surface water temperature, conductivity were measured. Salinity and pH was determined as chemical water criteria. Hanna digital electronic instruments were used to measure the selected water criteria. The samples were collected from 2016 to 2019.

2.2. Zooplankton

350 μ plankton net was used to collect zooplanktons from the intertidal zone of the selected coastal areas. Collected zooplankton samples were fixed in formalin and stained with 5% Rosebengal.

2.3. Population density

Plankton samples were transferred into 9 ml petri-dishes and examined under Zeiss research microscope. Zooplankton examination was performed in 9 cm Petri-dish under Zeiss research microscope. Identification of zooplankton was done according to Lee and Stokes (2006) and Hickman et al. (2014). Three replicate samples were counted for each zooplankton group. Mean values and standard deviation were calculated.

Species richness was calculated according to Tuomisto (2010) as the number of detected zooplankton groups. Relative abundance was determined as a percentage of mean of each planktonic group to the total abundance of zooplankton species.

2.4. Biodiversity

Shannon-Weiner diversity index formula was applied to assess the variability and richness of zooplankton at selected study sites (Shannon, 1951)

\[ H' = - \sum_{i=1}^{S} p_i \log p_i \]

\( R^2 \) is the relative abundance of each recorded zooplankton group.

2.5. Meiobenthos

Meiobenthos were collected from As-Suways coast at Jizan area and Alhsas coast at Farasan Island. Metallic cylindrical core was used to collect meiobenthos samples at 10 cm depth from the intertidal zone at the selected studied sites. Sediment samples were sieved with 0.1 mm size sieve, preserved with 7% formaldehyde and stained with 5% Rosebengal. Meiobenthos were examined under research microscope according to Lee and Stokes (2006) and Hickman et al., (2011).

Abundance of defined meiofauna groups was detected and compared at the studied sites. Three replicates were examined for each site. Relative abundance, Species richness and Shannon-Wiener diversity index were calculated.

2.6. Statistical analysis:

Regression analysis using SPSS program was conducted between water criteria and abundance of zooplankton at the selected sites. The effect of water criteria on distribution of meiofauna at Jizan sandy shore As-Suways and Farasan sandy shore, Alhsas were estimated by regression analysis.

3. 3. Results

3.1. Water criteria determination

Table 1 showed physical and chemical water criteria at the intertidal zone of the sandy shore As-Suways coast, Jizan and Alhsas, Farasan. Higher value of salinity was shown for the intertidal zone of Alhsas, Farasan. Higher value was shown for conductivity of As-Suways coastal area.

3.2. Biodiversity of zooplankton

Population density of defined zooplankton at the intertidal zone of Alhsas area, Farasan was demonstrated at Table 2. Species richness was 11. Based on mean abundance (Fig. 2), zooplankton can be arranged as follows: Ciliates > Copepods > Nematods > Rotifers > Meliola > Nauplius larva > Gnathostomulida > Medusa > Kinorhynca > Mysis larva > Insect larva. Ciliates represented the most abundant zooplankton inhabiting the littoral zone of Alhsas at Farasan. Insect larva were the least abundant ones (see Fig. 3).

Zooplankton abundance at the intertidal zone of As-Suways sandy shore, Jizan was shown at Table 3. Species richness was 9. Zooplankton can be arranged in the following order based on their population densities (Fig. 2). Ciliates > Copepods > Nauplius larvae > Mysis larvae > Nematods > Gnathostomulida > Water fleas > Veliger larvae > Insect larvae (see Table 4).

Ciliates were the abundant zooplankton at the intertidal zone of As-Suways sandy shore at Jizan. Insect larvae were the least abundant zooplankton. Calculated Shannon-Weiner diversity index was 0.88 for Zooplankton defined at Alhsas and 0.769 at As-Suways sandy shore.

Table 1
Mean ± SD of water criteria determined seasonally at location sites.

| Location    | Water temperature | Salinity | pH | Conductivity |
|-------------|-------------------|---------|----|-------------|
| As-Suways   | 31.68 ± 4.649     | 35.25 ± 3.426 | 7.58 ± 0.296 | 61.26 ± 2.17 |
| Alhsas      | 30.25 ± 4.026     | 39 ± 1.309  | 7.26 ± 0.296 | 59 ± 0.296  |
3.3. Meiobenthos spatial distribution

Ciliates, foraminiferans, nematodes, copepods, Nauplius larvae, oligochaetes, bryozoans, rotifers, insect larva, water fleas, gastropod larvae, gnathostomulida, mysis larvae and polychaetes were identified at the studied sites in the present study (Fig. 4). Species richness was 10. Ciliates were the most abundant meiofauna, while bryozoans were the least abundant.

Meiobenthos inhabiting Alhsas shore at Farasan can be arranged based on their relative abundance (Fig. 5) as follows:

Table 2
Mean population density of Zooplankton, relative abundance and Shannon-Weiner diversity index at Alhsas, Farasan.

| Zooplankton group | Mean abundance | Relative abundance (%) | Pi log Pi | Classification |
|-------------------|----------------|------------------------|-----------|---------------|
| Ciliates          | 132 + 13.038   | 20.74                  | 0.13      | Ciliophora    |
| Meliola           | 52.5 ± 9.574   | 8.25                   | 0.08      | foraminifera  |
| Nematodes         | 96 ± 10        | 15.09                  | 0.12      | Nematoda      |
| Copepods          | 130 ± 26.457   | 20.43                  | 0.13      | Crustacea     |
| Nauplius larva    | 46.67 ± 15.275 | 7.33                   | 0.08      | Crustacea     |
| Insect larva      | 10 ± 7.32      | 1.57                   | 0.03      | Insect        |
| Gnathostomulida   | 43.33 ± 15.275 | 6.81                   | 0.08      | Gnathostomulida |
| Rotifers          | 53.33 ± 15.27  | 8.38                   | 0.09      | Rotifer       |
| Kinorhyncha       | 22.5 ± 17.078  | 3.53                   | 0.04      | Kinorhyncha   |
| Medusa            | 36.67 ± 40.414 | 5.76                   | 0.07      | Cnidaria      |
| Mysis larva       | 13.33 ± 11.547 | 2.09                   | 0.03      | Crustacea     |
| **Total**         | **636.33**     |                       |           |               |
| **Diversity index** | **0.88**        |                        |           |               |

Fig. 2. Percentage composition of zooplankton inhabiting the intertidal zone of Alhsas, Farasan.

Fig. 3. Percentage composition of zooplanktons inhabiting littoral zone of As-Suways, Jizan.
Nematodes > Oligochaetes > Copepods > Foraminiferans > Nauplius larvae > water fleas > Rotifers > Insect larvae > Bryozoans.

Based on the relative abundance data (Table 5 and Fig. 6). Meiobenthos living at the intertidal zone area of As-Suways sandy shore, Jizan can be ranked as follows: Ciliates > Nematodes > Polychaetes > Copepods > Gastropod larvae > Gnathostomulida > Water fleas > Mysis larvae (see Fig. 7).

Ciliates were the most abundant meiobenthos, while myisis larvae recorded the least abundant. Species richness was 8. Shannon-Weiner diversity index was 1.014 at the intertidal zone of Alhsas and 0.812 at As-Suways sandy shore.

3.4. Effects of water criteria on distribution of zooplankton and meiofauna

The effect of water criteria on the population density of zooplankton or meiofauna was investigated through the study of the possible regression relationship. Salinity had significant effect on spatial distribution of nematodes ($r^2 = 0.96$, $P < 0.01$). Water temperature and salinity showed significant effect on copepod distribution ($r^2 = 0.72$&$0.68$ respectively, $P < 0.05$). Significant effect of pH on gnathostomulida, ($r^2 = 0.88$, $P < 0.01$). Conductivity and pH had significant effect on Nauplius larva distribution ($r^2 = 0.79$)

Table 3
Zooplankton population density (mean ± SD) at the intertidal zone of As-Suways, Jizan.

| Benthic group          | Mean ± SD       | Relative Abundance pi | pi log pi | Classification |
|------------------------|-----------------|-----------------------|-----------|----------------|
| Copepods               | 110 ± 15.81     | 0.139                 | 0.119     | Crustacea      |
| Nematodes              | 66.7 ± 15.      | 0.084                 | 0.09      | Nematoda       |
| Veliger larvae         | 50 ± 30         | 0.063                 | 0.07      | Mollusca       |
| Myisis larvae          | 85 ± 17.32      | 0.104                 | 0.1       | Crustacea      |
| Ciliates               | 213.3 ± 40.4    | 0.269                 | 0.15      | Ciliophora     |
| Gnathostomulida        | 63.3 ± 15.27    | 0.08                  | 0.08      | Gnathostomulida|
| Water fleas            | 60 ± 26.46      | 0.076                 | 0.07      | Crustacea      |
| Insect larvae          | 46.7 ± 20.81    | 0.059                 | 0.11      | Hexapoda       |
| Nauplius larvae        | 96.7 ± 15.27    | 0.122                 | 0.11      | Crustacea      |
| Total                  | 791.79          |                       |           |                |
| Shannon-Weiner diversity index $H'$ | 0.769

Table 4
Mean population density of Meiobenthos, relative abundance and Shannon-Weiner diversity index at Alhsas, Farasan.

| Benthic group          | Mean abundance | Relative abundance (Pi) | Pi log Pi | Classification |
|------------------------|----------------|-------------------------|-----------|----------------|
| Ciliates               | 160 ± 26.457   | 0.21                    | -0.142    | Ciliophora     |
| Foraminifersans        | 80 ± 10        | 0.105                   | -0.18     | Rhizopoda      |
| Nematodes              | 140 ± 30.055   | 0.184                   | -0.135    | Nematoda       |
| Copepods               | 93.3 ± 15.275  | 0.123                   | -0.112    | Crustacea      |
| Nauplius larvae        | 46.667 ± 15.27 | 0.061                   | -0.074    | Crustacea      |
| Oligochaetes           | 110 ± 20       | 0.114                   | -0.096    | Annelida       |
| Bryozoans              | 26.67 ± 15.27  | 0.035                   | -0.051    | Bryozoa        |
| Rotifers               | 33.3 ± 15.27   | 0.044                   | -0.081    | Rotifer        |
| Insect larvae          | 30 ± 10        | 0.039                   | -0.055    | Hexapoda       |
| Water fleas            | 40 ± 10        | 0.053                   | -0.068    | Crustacea      |
| Total                  | 759.997        |                         |           |                |
| Shannon diversity index $H'$ | 1.014

Fig. 4. Spatial distribution of zooplankton at the intertidal zone of Alhsas, Farasan and As-Suways, Jizan.
Spatial distribution of mysis larvae were significantly affected by conductivity ($r^2 = 0.77$, $P < 0.05$) and pH ($r^2 = 0.66$, $P < 0.05$).

4. Discussion

Zooplankton have essential value as intermediate link in the food chain. They are the main food source for fish and other aquatic animals (Lee and Stokes, 2006). Calanoid and Euphausiid zooplankton were reported as the important zooplankton in the red sea (AbdAllah et al. 2018). Farasan report (AbuZinada et al., 2001) stated the presence of ciliates, nematode and copepod as dominant zooplankton in the surface seawater. The present studies agree with this study and showed the presence of all these groups at the intertidal zone of As-Suways sandy shore and Alhsas. Several studies reported copepod as a common holoplankton at the inter-

**Table 5**

| Meiobenthos abundance at As-Suways, Jizan. |
|-------------------------------------------|
| Mean ± SD | Relative Abundance pi | Pi logpi | Classification |
|-----------|------------------------|----------|----------------|
| Ciliates  | 149 ± 16.73            | 22.9     | 0.146          | Ciliophora     |
| Copepods  | 80 ± 11.55             | 12.3     | 0.112          | Crustacea      |
| Polychaetes| 114 ± 35.78            | 17.5     | 0.132          | Annelida       |
| Nematodes | 147.5 ± 20.6           | 22.7     | 0.146          | Nematoda       |
| Gastropod larvae | 66.7 ± 25.17 | 10.2 | 0.099 | Mollusca |
| Gnathostomulida | 56 ± 18.16 | 8.6 | 0.091 | Gnathostomulida |
| Mysis larvae | 13.27 ± 5.1 | 2.04 | 0.034 | Crustacea |
| Water fleas | 23.7 ± 6.2 | 3.64 | 0.052 | Crustacea |
| Total     | 650.17                 |          | 0.812         |

Shannon-Weiner diversity index (H)

**Fig. 5.** Meiobenthos relative abundance at the intertidal zone of Alhsas, Farasan.

**Fig. 6.** Meiobenthos relative abundance inhabiting intertidal zone As-Suways, Jizan.
tidal zone of marine habitats. Baksh (1994) reported copepods and amphipods among the food content of bream fish Nemipterus japonicus. These studies agree with the results of current study where copepods were the most dominant metazoan zooplankton.

Benthic invertebrates are almost permanent inhabitants of sediments at marine habitats. Their spatial distribution and abundance reflect the health status of marine ecosystem (Rombouts et al., 2013). Meiobenthos were reported as important element in the marine food web. Also, they were studied as possible bioindicators for good water quality (Boufahja et al. 2016). Some factors can affect colonization of meiofauna such as predation, salinity or human impact.

Farasan report (2000) stated the presence of meiofauna at Farasan Island. Ciliates, nauplius larvae, nematodes, gastropod larvae, foraminifera and gnathostomulida were identified in the present work. This result agrees with previous works for meiothentos at intertidal zone. Mokievsky (2009) recorded nematodes, foraminifers and copepods at large Aral, Sea sediments. Yamamuro (2000) recorded nematodes at sediments of eutrophic estuarine lagoons with varying salinity and found that salinity level affects biomass and size of meiothenthos. The present study showed high relative abundance of nematodes at collected meiofauna from mangrove (18.4%) or sandy shore (22.7%) habitats. This result indicated good water criteria at both studied sites. The finding agrees with previous studies (Olafsson, 1997; Kotwicki et al. 2005; Olga et al. 2008; Liu, 2009; Armenteros et al. 2009; Tang et al. 2012).

For mangrove habitat, average meiofauna (759.79 ind.10 cm$^{-2}$) was at the range recorded by Vanhove et al. (1992) in Avicennia marina sediments, Gazi Bay, Kenya. Data of the present work are at the range of the total density recorded by other studies (Dye, 1983 at south Africa, Hodda and Nicholas, 1985 at southeast Australia and Vanhove et al. 1992 at Kenya). Ciliates recorded the highest density at sandy shore and muddy shore sediments. The results are in accordance with Dye (1983a; 1983b) in Southern African mangrove estuary and contradicts with the finding of Harguinteguy et al. (2012) in sites of Neuvo gulf, Argentina that ciliophores were the third abundant meiofauna group following nematodes and gastrotroches.

A difference in the population density was significantly found between the common meiofauna; nematodes, ciliates recorded at sandy and muddy shore habitats. This might be attributed to granulometric composition, the physical nature of sediment granules and the oxygen penetration into sediments’ layers (Olga and Julia, 2006; Tang et al. 2012). Pollution due to industrial and sewage treatment effluents, suspended matter due to the marine reclamation activities and the heavy metal and oil pollution by the fishing activities were found to be destructive to the meiothenthos population (Alnashiri et al. 2018). The difference at granule size of sandy and clay muddy sediments in addition to sediment oxygen content might also explain the lower diversity index of meiothenthos (0.812) and zooplankton (0.769) at As-Suways sandy shore habitat compared to those of Alhhas.

Future studies are in need about the meiofauna in different types of marine habitats at Jizan coastal areas to detect the seasonal abundance of meiobenthic fauna and to determine the factors that affect their prevalence and distribution at Jizan coastal areas.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**References**

AbdAllah, A.T., Ghazwani, A.A., Alififi, M.H. 2018. Biodiversity of zooplankton at some mangrove habitats at Jizan coastal areas. Life. Sci. 15, 61–65.

Abuzinada, A.H., Robinson, E.R., Nader, I.A., Wetaid, Y.I., 2001. First Saudi Arabian National Report on the Convention on Biological Diversity. National Commission for Wildlife Conservation and Development.

Armenteros, M., Ruiz-Abierno, A., Fernandez-Gaetes, R., Perez-Gracia, J.A. Diaz-Asencio, L., Vinca, M. and Decraemer, W., 2009. Biodiversity of free living marine nematodes in a tropical bay Cienfuegos, Caribbean Sea. Estrar. Coast. Shell6:85, 179-189.

BAKHSH, A.B., 1996. The biology of thread bream, Nemipterus japonicus (Bloch) from the Jizan Region of the Red Sea. Mar. Sci.-Ceased lssuerg 17 (1), 1–2.

Boufahja, F., Semprucci, F., Beyrem, H., 2016. An experimental protocol to select nematode species from an entire community using progressive sedimentary enrichment. Ecol. Indic. 60 (292–30), 9.

Castro, P., Huber, M.E., 2012. Biologia marinha. AMGH Editora.

Dye, A.H., 1983a. Vertical and Horizontal distribution of meiofauna in mangrove sediments in Transkei, Southern Africa. Estrar. Coast. Shell Sci. 16, 591–598.

Dye, A.H., 1983b. Composition and seasonal fluctuation on meiofauna in a southern African mangrove estuary. Mar. Bio. 73, 165–177.

Grzelak, K., Kotwicki, L. 2012. Meiofaunal distribution in Hornsund fjord, Spitzbergen. Polar Biol. 35 (2), 269–280.
