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Some Traits of Meiofauna in the Surf Region of the Southern Mediterranean Sea Coast

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ABSTRACT: *During the winter and summer of 2019, eight study sites in eastern Libya were used to establish meiofauna diversity in the Southern Mediterranean Sea's near-shore sandy bottom surf region. The physicochemical characteristics of surface water at the study sites were mostly similar. Seventeen taxa of floatable meiofauna (extracted from sediment samples by floatation) were identified, sixteen during winter and ten during summer: By number of individuals per taxon, Nematoda and Foraminifera were the most abundant taxa. The other available taxa were Rhabdocoela, Xanacoelomorpha, Gastrotrichs, Polychaeta, Kinorhyncha, and Urodasys. Four non-floatable meiofauna taxa were encountered (Foraminifera, Mussel, Gastropod, and Ostracoda). This low diversity of floatable and non-floatable meiofauna was possibly due to the strong wave action prevailing in the region and the adjacent deleterious anthropogenic activities. Meiofaunal diversity was higher in winter than in summer, possibly due to the higher dissolved phosphorus concentration during this season. The causes of the between-site differences in meiofaunal diversity are unclear, but differences in adjacent coastal anthropogenic activities might had more impact than differences in the prevailing physicochemical traits of the interstitial habitat. New practical techniques for collecting and identifying the smaller meiofauna are needed.*

KEYWORDS: meiofauna, surf region Mediterranean Sea, southern, Libya

INTRODUCTION

Pelagic organisms inhabit the water column in all aquatic ecosystems. With very few exceptions, they are either tiny planktonic drifters or massive swimmers like fish, whales, turtles, and cephalopods. The benthos are the organisms that dwells on the bottom. Epifauna, infauna, and meiofauna are the three types of benthos that dwell on the bottom's surface, below its surface, and between its sediment grains, respectively. Meiofauna (interstitial organisms) are little creatures with sizes between 500 and 0.045 mm. Microbenthos are infauna that are smaller than 0.045 mm, and macrobenthos are those that are greater than 500 mm. Meiofauna are tiny invertebrates that live permanently or intermittently between or are attached to soil grains in all aquatic environments (marine and fresh) at all latitudes and depths.

Meiofauna are particularly abundant in the top 5 to 10 cm of the substratum and diminish below. They are also abundant in shallow coastal waters but less so farther out to sea. Zonation is common. Diversity among species and individuals is typically high; they frequently exist in very high abundance and biomass, sometimes in millions per square meter. The main factors that govern their abundance are the granulometry of the substratum, physicochemical traits of the water just above the substratum especially inorganic nutrients, dissolved oxygen concentration, temperature, and salinity, organic load of the substratum, waves and currents, and pollution.

Because of their widespread distribution and high variety throughout all aquatic environments, meiofauna support nutrient cycling and provide food for higher trophic levels (Higgins and Thiel, 1988; Robertson *et al*., 2000; Libes, 2009). Latitudes often have no great impact on the horizontal distribution of meiofauna. Subsurface-substrata environments are more longitudinally and latitudinally stable than surface-substrata environments as they are governed by fewer and more stable parameters.

The majority of invertebrate taxa are represented in meiofauna, the primary ones being nematodes, copepods, oligochaetes, terbillarians, and protozoans consecutively (Libes, 2009).

Meiofauna have acquired many adaptations for interstitial life. They are minute animals, typically mobile, with elongated, vermiform, or flat bodies that enable them to easily orient themselves between sand grains (Palmer and Strayer, 1996; Robertson *et al*., 2000). The body is reinforced with an epidermal cuticle, spicules and spines, and adhesive glands with which they can cling to soil particles (Libes, 2009). The organs are simple, some of which are omitted. Gonads are solitary; they are dioecious or hermaphrodite and frequently fertilized by copulation. Direct or indirect development occurs via benthic (most commonly) or pelagic larvae, and parental care in one form or another is common (Hulings and Gray, 1971; Brown, 2001). All feeding modes are pursuit (Gomoiu, 1971; and Traunspurger and Majdi, 2018).

The current study aimed to identify key characteristics of meiofauna in the southern Mediterranean Sea near-shore coastal water (surf region) as represented by 8 study sites on Libya's eastern coast during the winter and summer of 2019.

METHODS

The study sites

The study sites were: 1- Alhaneah, 2- Twat AlGwarib, 3- Alhamama, 4- near the desalination plant of Susa, 5- Susa harbor, 6 and 7- between Susa and Ras Hilal (Two stations: St. 1 and St. 2), and 8- Ras Hilal, on the eastern coast of Libya (Fig. 1).

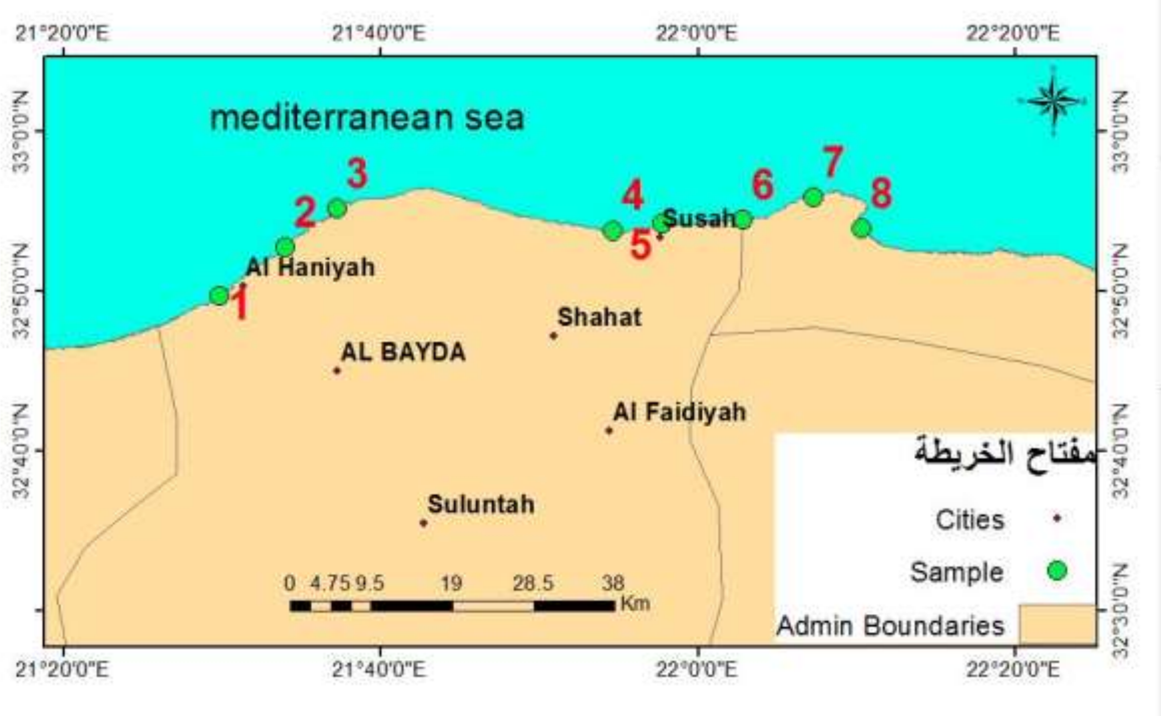

Figure 1. The study sites (8 sub sites).

Collecting surface water and bottom substratum samples

Near-shore (surf region) surface water samples were collected in acid washed and distilled water rinsed glass containers from each of the 8 study sites once in winter and once in summer of 2019 for establishing its physico-chemical traits (salinity, temperature, pH and dissolved oxygen). These samples were also used by another study (Alfurjani *et al*., 2022 a) for establishing the major and trace elements constituents of the water of the study sites,

Simultaneously with collecting the water samples, bottom sediments samples were taken from the upper 10 cm of the nearshore submerged substratum of each study site with a core and a shovel, and used for extracting contained meiofauna. These samples were also used by other studies for establishing the "soil" granulometry, bulk and real density, porosity and organic matter content (Alfurjani *et al*., 2022 b), and concentrations of contained major and trace elements of the sediments (Alfurjani *et al*., 2022 c).

Extraction of the meiofauna

Each collected sediment sample was mixed gently thoroughly and then a sub sample of 75gm was taken from it and treated as follows:

The sub sample was placed in a measuring cylinder; $MgCl_2$ 3.5 % solution was added to anesthetize contained meiofauna so as to force them to loosen their grip on the sand particles. Water was added, the cylinder was shaken vigorously to suspend the sediment particles and the meiofauna, few seconds were allowed to enable the sediment particles, but not the meiofauna, to settle at the bottom of the cylinder, then quickly the water (which now contained most of the floating meiofauna) was pour in a beaker by decantation. This process was repeated several times to insure maximum extraction of meiofauna from the subsample. The meiofauna were then extracted from the water present in the beaker by three techniques based on Wells, 1971; Holme, 1964; Dillon, 1964; and Gibson, 1967 as follows:

- **Settlement:** Here half the water present in the beaker was used. Drops of buffered formalin were added to the beaker to kill the meiofauna. The beaker was left still for 24 hours to allow the meiofauna to settle at the bottom. The water above the meiofauna was carefully siphoned out so that meiofauna were now contained only in 5ml of water
- **Flotation:** Here, the other half of the water that was present in the beaker was used. Sugar was added to the water in the beaker until near saturation was reached. This process increased the density of the water and force the contained meiofauna to float at the surface of the water within the beaker. After 12 hours, the water below the meiofauna was carefully siphoned out so that meiofauna were now contained only in 5ml of water
- **Filtration:** Water siphoned from the beakers by the above two techniques were filtered through a filter paper to trap meiofauna still present. **Identification of extracted meiofauna**
- **Floatable meiofauna:** Meiofauna extracted by the above three techniques were designated "floatable meiofauna" because flotation and decantation were used in all of them. Extracted meiofauna was identified under the microscope to the lowest possible taxa based on resources available in the net. For this purpose, 1 ml was taken from each of the 5ml and spread on glass slides and examined under the microscope The filter paper was then examined under the microscope.

Number of individuals per taxon per subsample per site per season were counted and presented as relative abundance units (0: absent, +: low abundance, ++: medium abundance, +++: high abundance) rather than absolute number of individuals per taxon.

Non-floatable meiofauna: The subsample (wet soil) left after the extraction of the meiofauna by the above methods still contained some shelled meiofauna that were too heavy to be collected by the above techniques which were based on floatation at one stage or the other (e.g. foraminifera, radiolarian, gastropods and bivalves). Therefore, the remained subsample was distributed on glass slides and examined under the microscope for identifying and counting contained meiofauna. These meiofauna were designated "non-floatable meiofauna". meiofauna abundance per taxon is presented in relative abundance units (0: absent, +: low abundance, ++: medium abundance, +++: high abundance). Identification was based on resources available in the net.

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RESULTS

A: The physico-chemical traits of surface water

Surface water temperatures of the 8 study sites were close (Fig. 2 and 3). The maximum was in summer at Susa harbor area (23.90 °C), and the minimum was in winter at Alhaneah (18.1 °C). Salinity ranged from a minimum of (33.15 ‰) in Susa harbor during winter to a maximum of (36.20 ‰) in Alhamama during summer. The pH ranged from a minimum of (7.1) in Alhaneah and Susa desalination plant site during summer to a maximum of (7.80) in Ras Hilal during winter. Dissolved oxygen (DO) was lowest at Desalination plant site (Susa) in summer (3.10 ppm) and highest at Susa-Ras Hilal "St. 2" in winter (5.90 ppm).

Significant correlation was observed between (DO) and salinity (r = 0.753 and 0.702 during winter and summer, respectively).

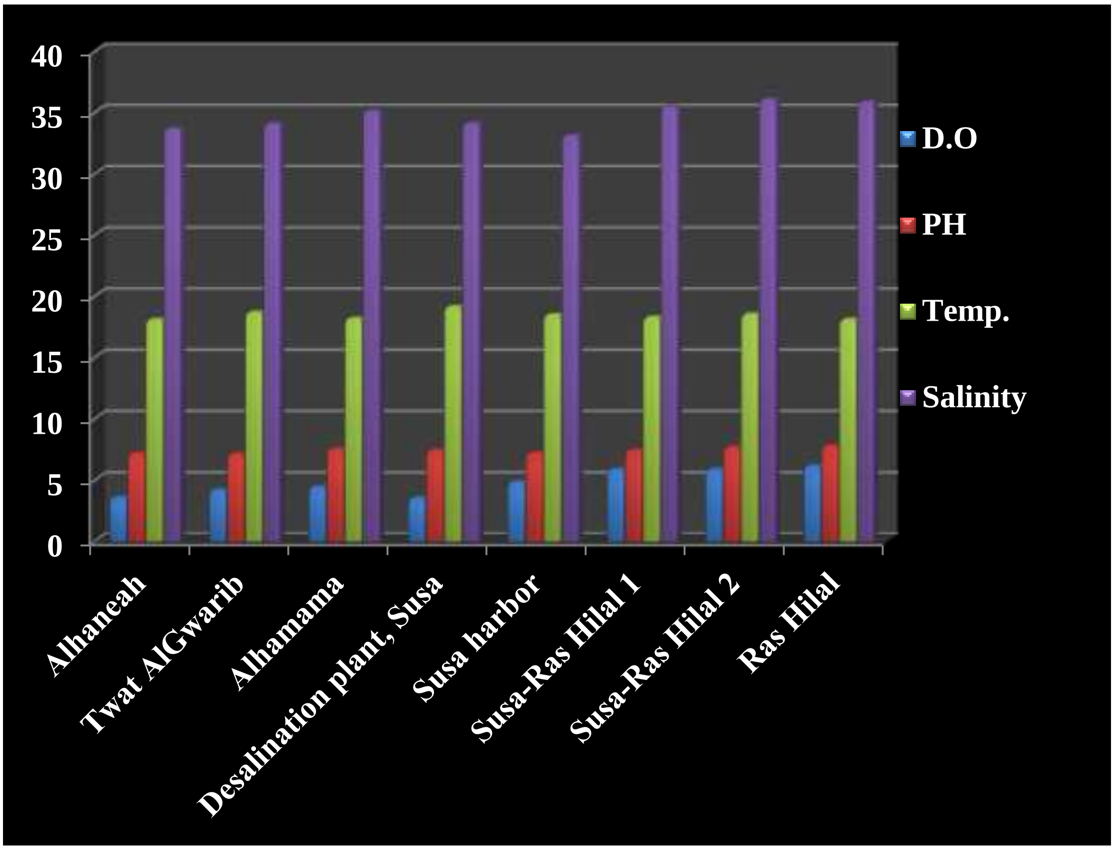

Figure 2: Values of physicochemical parameters of surface water of the studied sites during winter 2019.

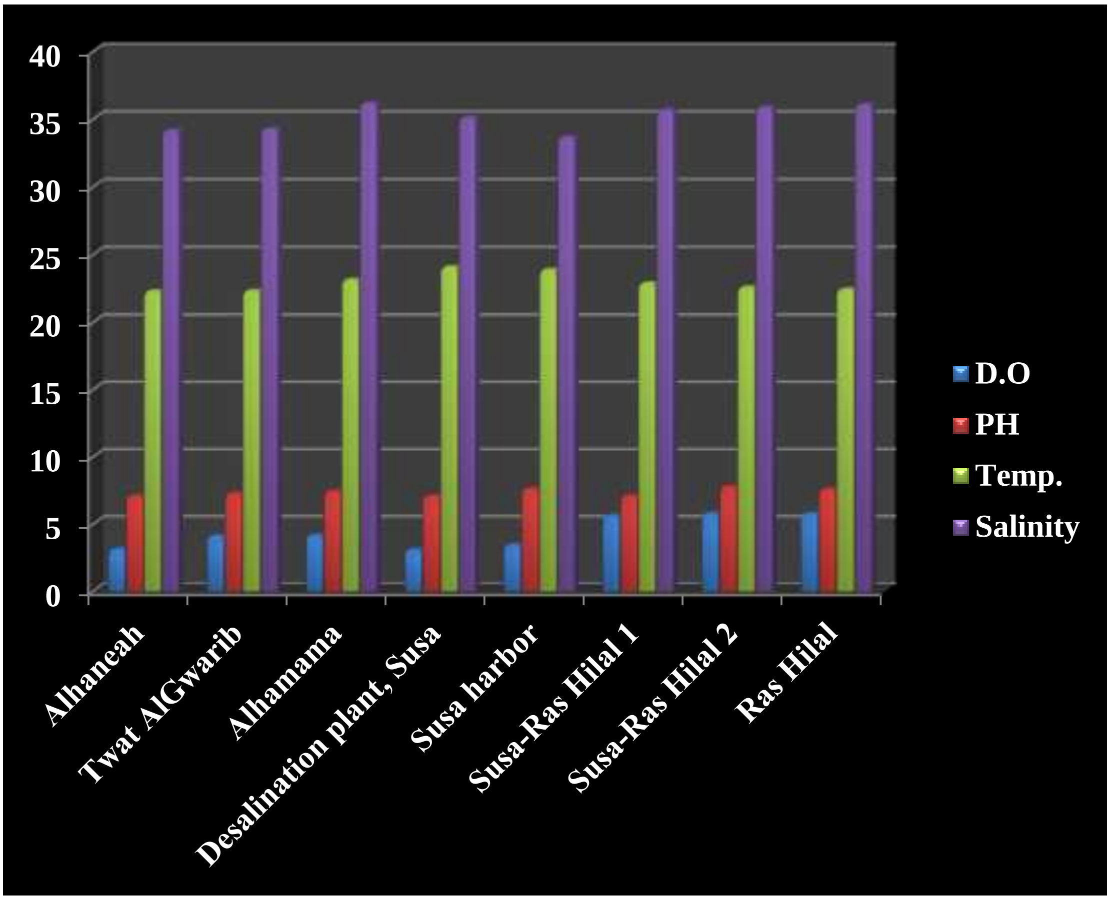

Figure 3: Values of physicochemical parameters of surface water of the studied sites during summer 2019.

B: The meiofauna:

1: The floatable meiofauna

a- Meiofauna taxa during winter:

Altogether, sixteen floatable meiofauna taxa were identified (to the lower possible taxon) in the near-shore submerged sediments of the study sites during winter (Table 1): Foraminifera, Turbellaria, Rhabdocoela, Nemertean, Rotifera, Xanacoelomorpha, Gastrotrichs, Nematoda, Tardigrada, Gastropoda, Oligochaeta, Polychaeta, Kinorhyncha, Copepoda, Ostracoda, Urodasys.

b- Based on number of taxon\site during winter

Alhaneah, was the poorest in meiofauna as only three taxa were present (Table 1): Foraminifera, Nematoda and Ostracoda. In Twat AlGwarib and Alhamama, four meiofanual taxa were recorded: Foraminifera, Nematoda, Gastropoda and Ostracoda in Twat AlGwarib, and Foraminifera, Nemertean, Nematoda, and Copepoda in

Alhamama. Susa-Ras Hilal St1, Susa-Ras Hilal St2 and Ras Hilal were the second richest with six taxa each, followed by Susa harbor, the richest, with 10 taxa.

c- Based on abundance of individuals per taxon during winter

The most abundant taxa were nematoda and foraminifera (Table 1). Rhabdocoela, Xanacoelomorpha, Gastrotrichs, Polychaeta, Kinorhyncha and Urodasys were the second abundant, followed by Rotifera and Gastropoda, then Nemertean, Tardigrada, Oligochaeta and Copepoda, and Ostracoda and Turbellaria recorded four and five stars.

Table 1: Relative abundance of floatable meiofauna in sediments of the study sites during winter 2019. 0: absent, +: low abundance, ++: medium abundance, +++: high abundance.

Stations / Taxa	Alhan-eah	Twat AlGwarib	Alham-ama	Desal. plant, Susa	Susa harbor	Susa-Ras Hilal 1	Susa-Ras Hilal 2	Ras Hilal	Relative abundance of individuals\ taxon
Foraminifera	+	+	+	+	+	+	+++	+	10
Turbellaria				+	+	+		+	4
Rhabdocoela				+					1
Nemertean			+		+		+		3
Rotifera					+			+	2
Xanacoelomorpha				+					1
Gastrotrichs				+					1
Nematoda	+	+	+++	+	+	+++	+	+	12
Tardigrada				+		+	+		3
Mussel									0
Gastropoda		+					+		2
Oligochaeta				+	+			+	3
Polychaeta					+				1
Kinorhyncha					+				1
Copepoda			+		+	++			4
Ostracoda	+	+			+	+	+		5
Urodasys								+	1
Number of taxa\site	3	4	6	8	10	9	8	6	54

d- Abundance of floatable meiofauna by grand number of taxa during summer

Altogether, ten meiofauna taxa were identified in the study sites during summer (Table 2).

e- Based on number of taxa per site during summer

The Desalination plant of Susa site was the poorest in meiofauna as only three taxa were observed (Table 2): Foraminifera, Nematoda and Mussel. In Alhaneah, Alhamama and Ras Hilal, four meiofanual taxa were recorded: Foraminifera, Nematoda, Gastropoda and Ostracoda in Alhaneah, and Foraminifera, Nematoda, Mussel and Ostracoda in Alhamama, and Foraminifera, Turbellaria, Nematoda, Oligochaeta and Gastropoda in Ras Hilal**.** Twat AlGwarib, Susa harbor and Susa-Ras Hilal 1 were the second richest. Susa-Ras Hilal 2 was the richest, with eight taxa.

f- Based on abundance of individuals per taxon during summer

By number of individuals per taxon, the most abundant taxa were foraminifera and nematoda (Table 2). The least abundant were Rhabdocoela, Nemertean, Rotifera, Xanacoelomorpha, Gastrotrichs, Oligochaeta and Urodasys. Tardigrada and Copepoda were second abundant, followed by Mussel, Polychaeta and Kinorhyncha, then Turbellaria. Gastropoda and Ostracoda were the most abundant.

Table 2: Relative abundance of floatable meiofauna in sediments of the study sites during summer 2019. 0: absent, +: low abundance, ++: medium abundance, +++: high abundance.

Station / Taxa	Alhan-eah	Twat AlGwarib	Alham-ama	Desal. plant, Susa	Susa harbor	Susa-Ras Hilal 1	Susa-Ras Hilal 2	Ras Hilal	Relative abundance of individuals\ taxon
Foraminifera	+	+	+	+	+	+	+	+	8
Turbellaria		+					+	+	3
Rhabdocoela									0
Nemertean									0
Rotifera									0
Xenacoelomorpha									0
Gastrotricha									0
Nematoda	+	+	+	+	+	+	+	+	8
Tardigrada					+				1
Mussel			+	+					2
Gastropoda	+				+	+	+	+	5
Oligochaeta									0
Polychaeta						+	+		2
kinorhyncha		+					+		2
Copepod							+		1
Ostracoda	+	+	+		+	+	+		6
Urodasys									0
Number of taxa\site	4	5	4	3	5	5	8	4	38

g- Winter/summer abundance of the meiofauna

Sixteen meiofauna taxa were encountered in the study sites in winter, and ten in summer. Equal summer/winter abundance by number of taxa per site was observed in

Alhaneah (Figure 4). Meiofauna was more abundant during summer than during winter in the Desalination Plant of Susa, Susa harbor, Susa-Ras Hilal 1 and Ras Hilal; the opposite trend was observed in the other sites.

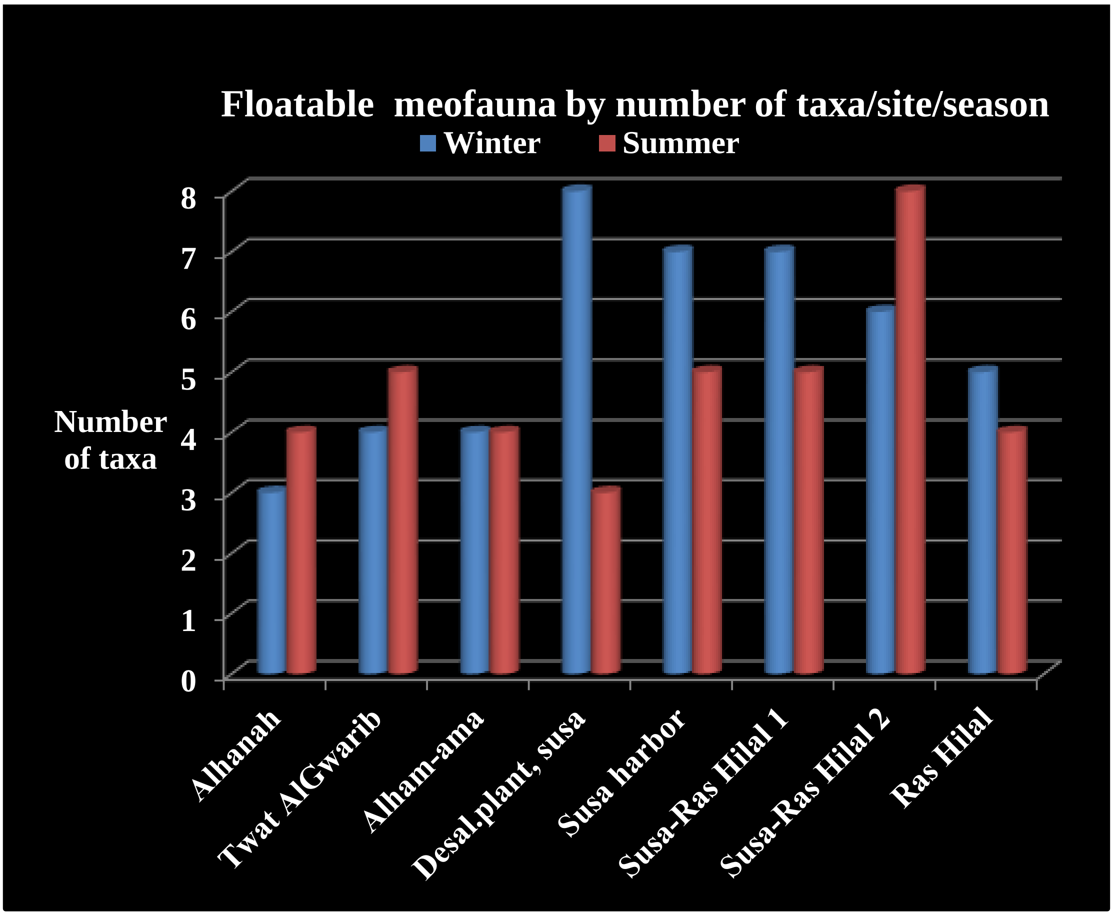

Figure 4: Relative abundance of floatable meiofauna by seasons and study sites.

2: Non-floatable meiofauna (foraminifera, radiolaria, gastropoda, mussels and ostracoda).

h- Abundance of non-floatable meiofauna during winter:

The desalination plant of Susa was the poorest in meiofauna as only one taxon was present (Table 3): Foraminifera. In Alhaneah, Susa-Ras Hilal 1 and Ras Hilal two meiofauna taxa were recorded: Foraminifera and Gastropoda respectively, followed by Alhamama, Susa harbor and Susa-Ras Hilal 1 with three taxa each. Twat AlGwarib was the richest, with four taxa.

Number wise, the most abundant taxa was foraminifera. Ostracoda was the second abundant, followed by Gastropoda. Mussel was the least abundant.

Table 3: Relative abundance of non-floatable meiofauna in sediments of the study sites during winter 2019.

Stations \ Taxa	Alhan-eah	Twat AlGwarib	Alham-ama	Desal. plant, Susa	Susa harbor	Susa-Ras Hilal 1	Susa-Ras Hilal 2	Ras Hilal	Relative abundance of individuals\ taxon
Foraminifera	+	+	+	+	+	+	+	+	8
Mussel		+							1
Gastropoda	+	+	+		+	+	+	+	7
Ostracoda		+	+		+		+		4
Abundance \ site	2	4	3	1	3	2	3	2	20

i- Abundance of non-floatable meiofauna during summer.

The most abundant taxon was foraminifera (Table 4). The least abundant was Mussel, followed by Gastropoda, then Ostracoda.

Susa-Ras Hilal 1 and Susa-Ras Hilal 2 were the poorest in meiofauna as only one taxon was present in each (Table 4): Foraminifera. In Alhaneah, Alham-ama and Susa harbor two meiofaunal taxa were recorded: Foraminifera and Ostracoda, followed by the Desalination plant of Susa and Ras Hilal, with 3 taxa each. Twat AlGwarib was the richest, with four taxa.

Table 4: Relative abundance of non-floatable meiofauna in sediments of the study sites during summer 2019.

Stations \ Taxa	Alhan-eah	Twat AlGwarib	Alham-ama	Desal. plant, Susa	Susa harbor	Susa-Ras Hilal 1	Susa-Ras Hilal 2	Ras Hilal	Relative abundance of individuals\ taxon
Foraminifera	+	+	+	+	+	+	+	+	8
Mussel		+							1
Gastropoda		+		+				+	3
Ostracoda	+	+	+	+	+			+	6
Abundance \ site	2	4	2	3	2	1	1	3	18

j- Relative abundance of non-floatable meiofauna by seasons and study site

Equal summer/winter abundance was observed in Alhaneah and Twat AlGwarib (Figure 5). Meiofauna was more abundant during summer than during winter in the Desalination Plant of Susa site and Ras Hilal, the opposite trend was observed in the other sites.

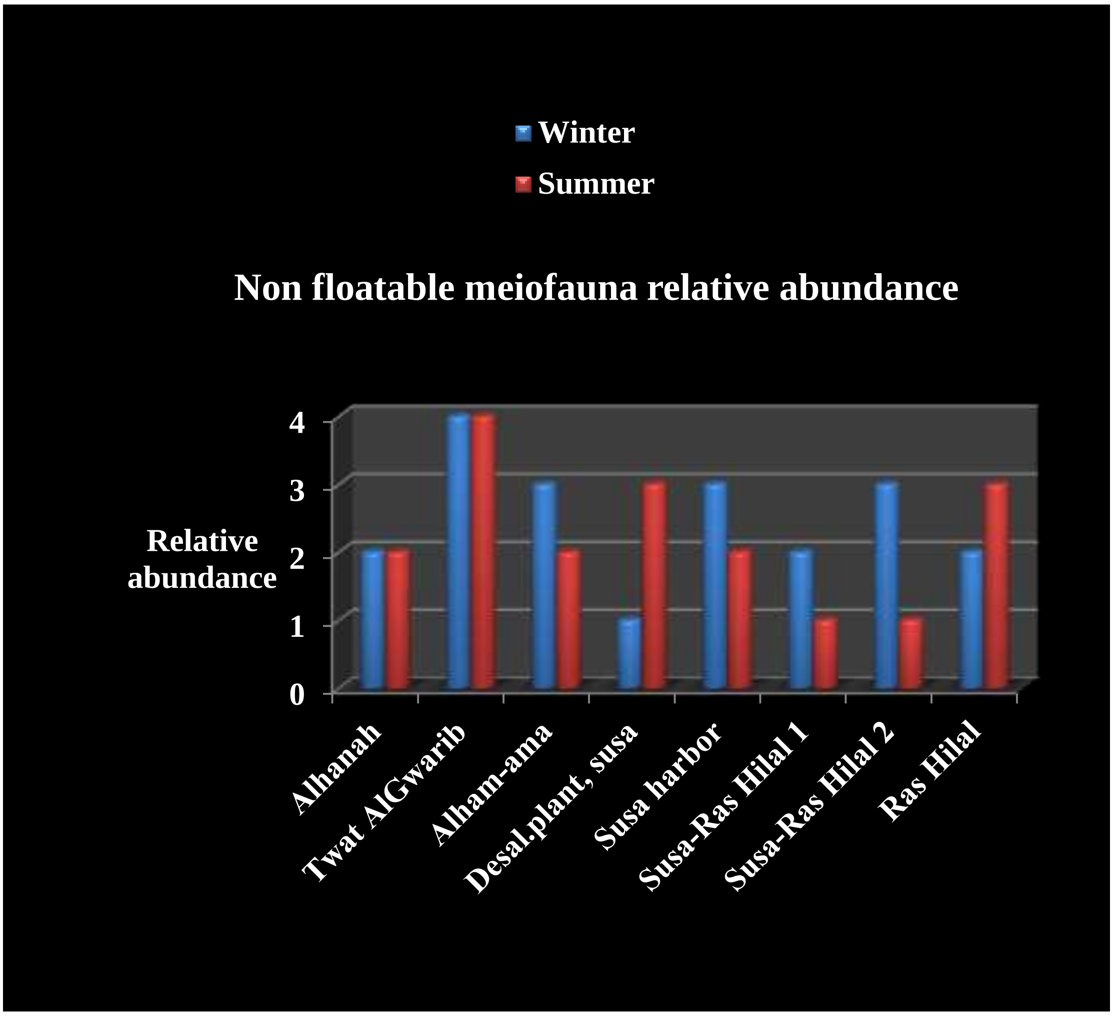

Figure 5: Relative abundance of non-floatable meiofauna by seasons and study site.

3: Effect of flotation:

Effect of flotation on meiofauna abundance was highly significant (Table 5 and Figure, 6). All together (average winter/summer abundance), there was more floatable meiofauna than non-floatable one.

Table 5: Statistical significance of effect of flotation and effect of season.

Flotation			Season		
Floatable	**Non floatable**	**Sig.**	**Winter**	**Summer**	**Sig.**
5.125±0.406[a]	2.375±0.239[b]	0.000	4.000±0.516[a]	3.500±0.447[a]	0.470

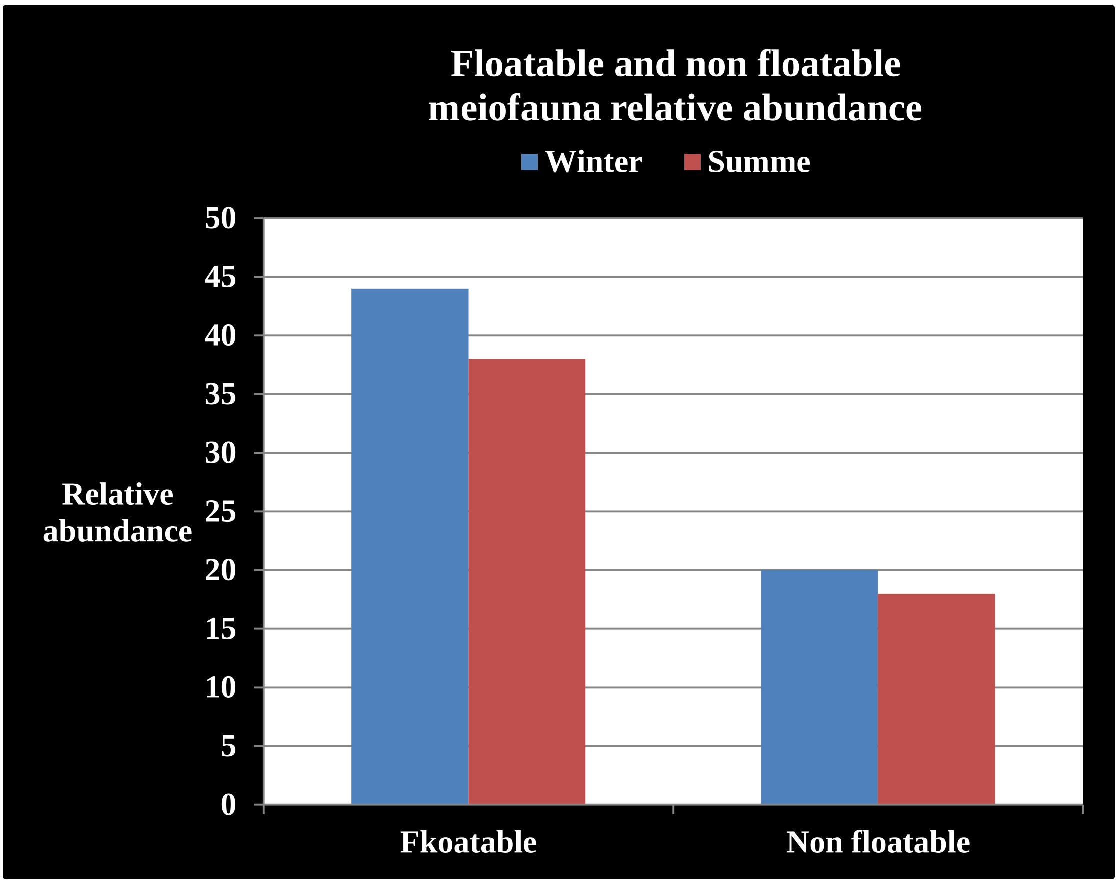

Figure 6: Relative density of floatable and non-floatable meiofauna by season.

4: Effect of seasons:

Season effect (winter vs. summer) on meiofaunal abundance was not statistically significant (Table 5 and Figure 6) however a dominant trend of increased meiofauna during summer was oserved.

DISCUSSION

Recently, many scientists advocated the use of meiofauna, rather than macrofauna, as a biological indicator in the assessment and monitoring of aquatic ecosystems because of their widespread occurrence, high species and individual diversity, large biomass, sensitivity to environmental degradation, and short life span. Meiofauna are "rr" selecting animals. The arguments against this trend reside in the difficulties of sampling and identification of the meiofauna (Coull, B. C. (1988).; Kennedy and Jacoby, 1999; Giere, 2009), the smaller meiofauna (0.045 mm) are difficult to isolate from collected sediment samples by the traditional techniques available today, a lot of bottom samples must be collected spatiotemporally and vertically (from the surface of the bottom substrata and downwards) to obtain a statistically representative distribution of present meiofauna. The difficulty of identifying the smaller meiofauna is obvious. These factors make comparing results from different studies very difficult. In the current study, 17 major taxa of floatable meiofauna and 4 major taxa of non-floatable meiofauna were identified, with nematodes and foraminiferans being the most abundant. On comparing abundance of meiofauna by taxon, site, or season, obtained in the current study it must be born in mind that the abundance was based relative units as no absolute numbers were obtained. Based on relative abundance by the number of individuals per taxon, foraminiferans and nematodes were the most abundant taxa. The other taxa were Rhabdocoela, Xanacoelomorpha, Gastrotrichs, Polychaeta, Kinorhyncha, Urodasys, Rotifera, Gastropoda, Nemertea, Tardigrada, Oligochaeta, Copepoda, Ostracoda, and Turbellaria. Meiofaunal diversity was higher in winter than in summer. Both the floatable and non-floatable meiofauna were more abundant in winter than in summer; this may be due to the higher concentration of total dissolved phosphorus in winter (Alfurjani *et al.*, 2022a; Appendix 1). The other winter/summer parameters by site, other than temperature, were comparable. Winter is the rainy season, during which rains wash away inorganic nutrients from surface of terrestrial soil into the adjacent sea. Total nitrogen concentrations in the study sites ranged from 4.23 to 8.05 ppm during the winter season; all sites had more or less similar concentrations (around 4 ppm) except Susa-Ras Hilal 1, which had the highest concentration (8.05 ppm, Alfurjani *et al.*, 2022a). The diversity of the non-floatable meiofauna obtained in the present study is possibly exaggerated because the shells of dead meiofauna may take a long time to wither away. These shells were included in the count. Balsamo *et al*. (www.intechopen.com) mentioned that as many as 24 of the 35 animal phyla have meiobenthic representatives that live in meiofauna, whether for all their lives or just temporarily. Taking this into consideration, one cannot say that the 17 floatable (16 in winter and 10 in summer) and the 4 non-floatable taxa encountered in the present study indicate high diversity since every phylum contains as many taxa as the terms of the individual studies decide. Meiofauna abundance by taxa, or by number of individuals, per site varied seasonally. Many studies have found that the shelled microorganisms Nematoda and Foraminifera are the most abundant and diverse in the oceans (Boucher and Lambshead, 1995; Giere, 2009).

Meiofauna diversity and distribution can be thought of as affected by two factors:

- Natural spatiotemporal parameters of the interstitial habitat.
- Degradation of the interstitial habitat due to anthropogenic causes.

It is often not possible to evaluate quantitatively the individual contribution of each of these factors. However, for coastal meiofauna, the anthropogenic factor may have the upper hand. In Libya, most of the population inhabits the coastal zone; as a result, anthropogenic activities including industry, agriculture, mining, dredging, and dumping introduce significant amounts of pollutants into the adjacent sea, causing major impacts on the marine ecosystems.

In the present study, the meiofauna was collected from the surf zone where the constant waves that prevail all year keep submerged sediments in continuous movement by lifting, relocating, and resettling. Under such conditions, sandy shores develop, and the interstitial habitat becomes continuously replenished with dissolved oxygen. Particle size fraction, bulk density, real (particle) density, and porosity of the submerged bottom substrata of the study sites were studied by Alfurjani *et al*. (2022b). The submerged substrata of all study sites were essentially sandy, with high porosity in the sites, ranging from 35.5 to 43.5 percent. That means the interstitial spaces of the bottom sediments of all the study sites were spacious enough to comfortably house the meiofauna. The waves reduce the organic load of the sediment by washing it out to sea. Alfurjani *et al*. (2022b) reported that the oxidized organic matter of the study sites' submerged sediments was very small, ranging from 0.08 % - 0.14 % with an all-sites average of 0.130.02 %. Organic matter provides food for bacteria and microorganisms that provide food for the meiofauna. Strong wave action may wash away a significant portion of the meiofauna to the open sea. The low organic load in the study sites, the physical action of the waves, and the adverse anthropogenic activities may have significantly contributed to the low meiofaunal diversity observed in the present study. The microscopic examination of the collected meiofauna did not reveal the presence of mutilated or damaged individuals, as might be expected under the violent and turbulent wave action that prevailed in the surf region and continuously reshaped the submerged substrata.

The study sites' surface water temperature, salinity, and pH were similar. It appears that differences in the physicochemical characteristics of the study sites were not the primary factor distinguishing meiofauna diversity in these sites, leaving more room for anthropogenic factors.

THE IMPLICATIONS FOR RESEARCH AND PRACTICE

This study concluded that surf zones of exposed sandy shore are poor in meiofauna. New studies are needed to establish whether this is a general trend for all similar shores or that it is localized to our study area (the study sites), and if so: why.

CONCLUSIONS

- According to the present study, meiofauna diversity in surf regions is low.
- Meiofauna diversity in the southern Mediterranean Sea surf regions is higher in winter than in summer, possibly due to higher concentrations of dissolved phosphorus in this season.
- Differences in meiofauna diversity by study site are possibly due more to anthropogenic activities than to differences in the natural physico-biochemical traits of the interstitial habitat.

RECOMMENDATIONS

- Future studies that could avail of new techniques and procedures for collecting, identifying, and counting small-size meiofauna are recommended. Practical techniques of this sort are not available at present.
- The absence of standard procedure makes comparing results of different studies very difficult.

CONFLICT OF INTEREST

No conflict of interest is claimed. The present study is part of an MSc thesis carried out at the University of Omar Al-Mukhtar, Libya.

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Appendix 1. The concentrations of Total phosphorus of water samples during winter and summer seasons (with permission from Alfurjani *et al*. (2022a)**.**