QATAR UNIVERSITY

COLLEGE OF ARTS AND SCIENCES

MEIOBENTHIC ASSEMBLAGES IN SOME INTERTIDAL AREAS AROUND QATAR, ARABIAN GULF

BY

DM G. ESTREMADURA

A Project Submitted to

the Faculty of the College of Arts and Sciences

in Partial Fulfillment of the Requirements for the Degree of

Masters of Science in Environmental Sciences

January 2021

COMMITTEE PAGE

The members of the Committee approve the Project of
DM Estremadura defended on 07/12/2020.

Dr. Jassim Al-Khayat
Thesis/Dissertation Supervisor

Dr. Abdulrahman Al-Muftah
Committee Member

Dr. Yousra Soliman
Committee Member

ABSTRACT

ESTREMADURA, DM G., Masters : January : 2021, Master of Science in Environmental Sciences

Title: Meiobenthic Assemblages in some Intertidal Areas around Qatar, Arabian Gulf

Supervisor of Project: Jassim Al-Khayat.

Sediment core samples were collected in 10 locations around intertidal areas of Qatar to acquire baseline information on meiobenthic density and composition. Temperature, salinity, and pH of interstitial waters were measured, *in situ*. Additional core samples were collected for nutrient and granulometry analysis. A total of 74 taxonomic groups belonging to 14 phyla were recorded. Total mean density was 120.89 ind/10cm^2, with a range 0.42 to 16.73 ind/10cm^2. High densities were recorded in Al Wakra 1 (rocky shore), Simaisma, Al Khor and Al Zubara. Furthermore, Al Zubara showed high species richness, expH' and evenness index. High nematode/copepod ratios were recorded in Fuwairit and Al Wakra 2 (mangrove area). Meiofaunal densities and composition were associated with sediment characteristics and total organic matter availability in the area. Further investigations should be done on meiofaunal community of Qatar to determine the effect of seasons and other anthropogenic activities on the community.

Keywords: Qatar, meiobenthos, meiofauna assemblage, intertidal zone, Arabian Gulf

ACKNOWLEDGMENTS

I would like to thank my colleagues in the Department of Biological and Environmental Science for the support, especially to my supervisor Dr. Jassim Al-Khayat, co-supervisor Dr. Abdulrahamn Al-Muftah, and panel member Dr. Yousra Soliman. I am also grateful to Mr. Abdul Ali Amoghadasi, Dr. Nayeem Mullungal, and Mr. Dean Estremadura for assistance during the field sampling. I would also like to thank the Environmental Science Center, especially Mr. Caesar Sorino and Ms. Amal Ismail for the assistance with nutrient and sediment analysis. Lastly, to my family and friends for the support and love.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Meiobenthos organisms are ecologically important because they serve as intermediate link in trophic marine ecosystem. They are involved in various benthic processes, e.g., biomineralization and nutrient regeneration enhancement. Furthermore, because of their close relationship with their environment, meiobenthos are considered bioindicators in detecting changes in the physical and chemical conditions of their environment. A few studies related to meiofauna have been conducted in waters of Kuwait and some parts of northern Arabian Gulf. However, here have been no studies on meiobenthic assemblages in Qatar waters.

In general, the Arabian Gulf is considered a fragile ecosystem because of its unique biodiversity. The increasing impacts of industrialization and other anthropogenic pressures in the country greatly affect the marine ecosystem and its associated organisms. Information from this study can be used for future assessment and characterization of the constantly-changing coastal intertidal waters of Qatar.

This is the first study on meiobenthos in the waters of Qatar. As an initial study, investigation will focus on the taxonomic composition of meiobenthic assemblage in various intertidal areas of the country. Moreover, the relationship between the pattern of assemblage and various physico-chemical properities of the sediment will be discussed. In the future, this study can be used as a tool in the assessment of water quality and pollution-related impacts on the marine ecosystem of Qatar.

1.1 Objectives

The aim of the study is to characterize the meiobenthic assemblage in the intertidal areas around Qatar. The specific objectives are as follows:

(1) To establish information on the taxonomic composition, distribution and abundance of meiobenthos in the intertidal waters of Qatar;

(2) To determine the differences in composition and abundance of meiobenthos between the upper and middle intertidal zones of the various locations; and

(3) To determine the effect of physico-chemical characteristics of the sediment on the pattern of meiobenthos assemblage.

CHAPTER 2: LITERATURE REVIEW

2.1 Qatar Waters and the Arabian Gulf

The State of Qatar is a small peninsula with a total land area of 11,000 km2 and a maritime coastline of more than 550 km. Characterized by hot and dry climate with low annual rainfall and nutrient availability, and high annual maximum temperature, Qatar is considered one of the most hostile environments on earth. Moreover, the waters surrounding Qatar is considered unique because of its high salinity and high temperature fluctuations due to limited exchange with the Indian Ocean (Brook et al., 2006). Despite these extreme conditions, certain marine organisms are still able to survive and thrive in the area. The marine environment of Qatar is reported to contain 955 species of marine organisms, which can be considered highly adapted to the aforementioned conditions of the ecosystem.

In the marine ecosystem of Qatar, studies were more focused on biodiversity and distribution of macrobenthic organisms in the area (e.g., Al-Khayat, 2005; Al-Khayat and Al-Khayat, 2000; Al-Ansi and Al-Khayat, 1999). No study has been conducted on meiobenthic community in any marine ecosystem of the country.

A few studies, however, were done in some areas of the Arabian Gulf, especially on the northeastern portion of the area. Dezfouli, et al. (2016) studied meiofauna community structure in the waters of Sajafi, Khuzestan, Iran, in order to investigate the health of the coastal ecosystem in the area. A total of 56 meiofaunal species were recorded with foraminifera as the most abundant group. Sahraean, et al. (2017) focused more on the biodiversity and community structure of free-living nematodes in the intertidal shores of Bandas Abbas, Hormuzgan, Iran, and determined the spatial pattern of nematodes in relation to local pollution.

2.2 Meiofauna Definition

Meiobenthos is defined as as a group of benthic metazoans with sizes smaller than the “macrobenthos” but larger than the “microbenthos” (i.e., most protozoa, diatoms and bacteria) (Mare, 1942). The standard mesh size used for meiobenthos is from 63 μm to 1mm but can be adjusted based on the requirements of the area (Giere, 2009).

Meiobenthos are comprised of diverse group of invertebrate organisms, belonging to various taxonomic groups having diverse morphology. Meiobenthic samples are usually dominated by nematodes and copepods, specifically harpacticoids. Other important groups include turbellarians, ostracods, gastrotrichs, rotifers, polychaetes and molluscs (Urban-Malinga, 2013). .

2.3 Importance of Meiobentic Studies

Assessment of the ecosystem oftentimes utilizes organisms that are either considered valuable or intrinsically valuable, i.e., performing important ecological functions, or because they are good indicators of changes in the environment. Oftentimes, macrobenthic invertebrates are used as indicators for community-based assessment studies due to high availability of taxonomic keys and sampling protocols for such group (Schratzberger, 2012).

On the other hand, meiofaunal organisms are extremely important in determining the effects of anthropogenic disturbance in marine sediments, specifically. Meiofauna are closely associated with the sediments. Their high diversity and important ecological functions make them more important than the macrobenthos as indicators in addressing questions on distribution patterns. Various ecological processes and trophic dynamics of the marine ecosystem are reported to influence this pattern of distribution (Coull and Chandler, 1992; Kennedy and Jacoby, 1999, Schratzberger et al., 2000). In addition, meiobenthic assemblages can be more advantageous in reflecting the overall health of the ecosystem than the most of macrobenthos because they occur ubiquitously and in high abundance. They also have high generation turnover and fast metabolic rates (Giere, 2009). Furthermore, nematodes are more appropriate bio-indicators for pollution-related ecosystem disturbance because they can sustain their populations in extreme physical conditions (Moreno et al., 2011).

2.4 Factors Affecting Patterns of Assemblage

Meiobenthos are always present in high densities in all types of sediments. They occur in different types of habitats from freshwater to marine ecosystem and from marine beaches to deepest waters. Usually, they are found in interstitial spaces between soft sand grains or burrowed in finer sediments. Through this habit, meiobenthos are able to displace sand particles and change sediment texture (Giere, 2009; Urban-Malinga, 2013).

Many studies revealed several factors that may affect the pattern of distribution of meiobenthic community distribution, in terms of abundance and biomass. According to Griere (2009), the main factor affecting the meiobenthic distribution pattern is grain size, which indirectly affects the physico-chemical characteristics of the sediment. Higgins and Thiel (1988) revealed that other factors such as tidal exposure, depth, season, nutrients and pollutants could also affect distribution patterns. Typically, highest populations were observed in intertidal muddy estuarine ecosystem. Horizontal distribution patterns, on the other hand, may be influenced by interaction with the abovementioned factors with biotic factors, e.g., food availability, predation and competition.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

A total of ten stations around Qatar were sampled during during the periods of February 2019 to January 2020. These stations include Mesaieed, Al-Wakra (two sites), Simaisma and Al-Khor, on the eastern coast, Fuwairit and Al-Ruwais, on the northern coast, and Dukhan, Umm Bab and Al-Zubara, on the western coast of Qatar (Figure 1). The sampling area in Al Wakra has the widest intertidal flat of around 150m. Al Wakra 1 is a slightly rocky flat while Al Wakra 2 is situated in an artificially-forested mangrove area. Al Zubara has also wide intertidal flat with moderate rocky features. Stations in Fuwairit and Mesaieed, on the other hand, have narrow intertidal zones at around 15m only. Fuwairit is a rocky beach while Mesaieed is located near the public beach area with sandy shore. Details of the sampling are shown previously in Appendix A.

Qatar coastline is made up of complex marine ecosystems. Stations represent different types of ecosystem based on their location. Most of the stations sampled, i.e., Umm Bab, Dukhan, Zubarah, Al Ruwais, Al Wakrah, are made up of rocky intertidal areas Al Wakra and Simaisma stations represent the mangrove-rich coastline and sandy shore is represented by Mesaieed and Fuwairit stations. The corniche area in Al Khor represents muddy flats with exposure to high terrestrial discharge. Details on the estimated size of intertidal area on each sampling station are shown in Appendix A.

3.2 Field Sampling

Sample collections were done in the intertidal areas of the abovementioned location during low tide. Samples were obtained on soft bottom areas of the particular location. Only the top 2cm of the sediment samples were used in this study. This depth is consistent with the method described by Holme and McIntyre (1984). A sediment corer with the dimensions of 10 cm long and 4.5 cm diameter was used. Samples were collected on both upper and middle intertidal zones of the selected area. Three replicates of sediment cores within a 1m x 1m quadrat were collected on each zone. Additional core samples were taken for the characterization of sediment and nutrient anallysis. Furthermore, other parameters, i.e., pH, temperature and salinity of the interstitial waters were recorded, *in situ*, using Jenway 370 handheld pH meter, a thermometer, and Vee gee STX-3 refractometer, respectively.

3.3 Biological Analysis

In this study, separation of meiobenthos from the sediment was done using the elutriation method as described by Holme and McIntyre (1984). This is considered an appropriate method for quantitative analysis of meiobenthos. The process uses the density difference between the meiobenthos and the sediment particles. The elutriation process was run for an hour for sandy sediments and two hours for silty to muddy sediments. The outflow will be filtered through a sieve with 63 um mesh size.

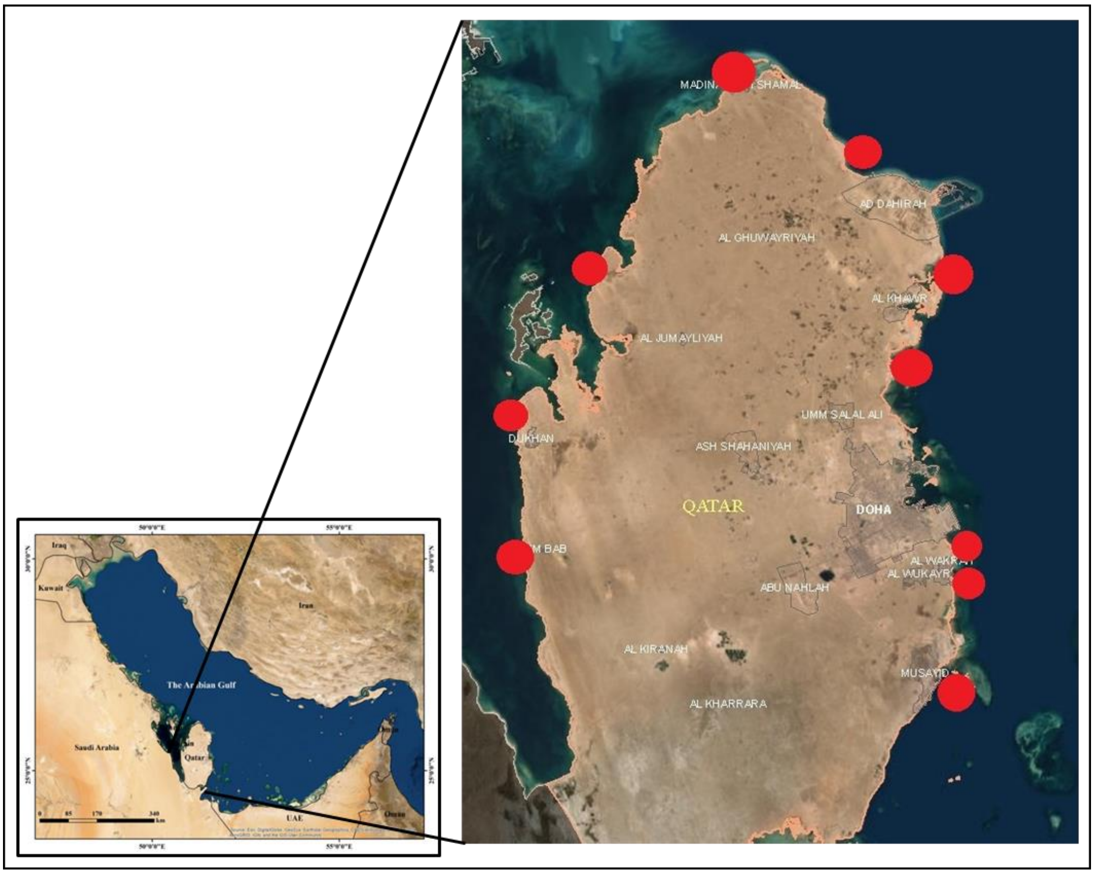

Figure 1. Qatar map showing the study area and sampling locations.

Sediment samples for meiobenthos were preserved in 4% formaldehyde-seawater solution with Rose Bengal dye. Samples intended for sediment analysis were brought to the lab and frozen for future analyses.

All samples collected in the sieve were transferred to a vial and preserved in formaldehyde for further analysis. Taxonomic identification of meiofaunal samples were done using Leica DM500 compound microscope and Motic SMZ-168 Series Stereomicroscope. Several references were used in the identification of various taxonomic groups. These include Fonseca and Bezerra (2014) and Giere (2009). Identification was done up to lowest taxonomic level as possible.

3.4 Granulometry

Grain size analysis was done using the Mastersizer 3000 laser diffraction particle size analyzer. Prior to analysis, sediment samples were air-dried and sieved in 2.0mm metal sieve. The analyzer measures the particle size and distribution in the sample by measuring the intensity of scattered light as the laser beam passes through the diffused particulate sample. Using water as the dispersant, the sample was run inside a Hydro LV which is equipped with in-line sonication to disrupt agglomerates and centrifugal pump to prevent sedimentation while undergoing analysis.

3.5 Chemical analysis

Chemical analyses of the sediment required prior preparation of sample for analysis. These include oven-drying the sample at 60oC overnight, breaking the weakly consolidated sediments in a mortar with rubber pestle and mixing and splitting the samples by coning and quartering method.

Total organic carbon and total organic nitrogen were determined using the Skalar Primacs Series SNC Analyzer. Various nitrogen forms, i.e., NO_3, NO_2, and NH_4 and PO_4 were determined using spectrophometry method, using Thermo Scientific Evolution 201 UV-Visible Spectrophotometer. Extractions of nutrients from sediments were done by acidification. Further analysis of extracted nutrients were conducted based on the methods described by Parson, et al. (1984). Carbonate content of the sediment was also measured by adding 10% HCl to a pre-weighed sample.

3.6 Data Analysis

Mean abundance (count) and density (count per cm^2) of each taxonomic group per zone per location were calculated. Various ecological indices were also calculated.

These include species richness, Shannon Index of diversity (H), entropy expH', and Pielous' Evenness (J). Moreover, nematode/copepod ratio, which has been proposed to be an essential information for pollution ecology studies (Warwick, 1981) was determined. Cluster analysis was conducted by correlation analysis with complete linkage using Minitab 19.2020.1. Taxonomic groups which appeared only in two stations were not included in the analysis. Furthermore, data were log transformed to limit the effect of less ubiquitous groups. The relationship between the pattern of meiofaunal distribution and the physico-chemical parameters were determined through Principal Component Analysis using the same Minitab.

CHAPTER 4: RESULTS

4.1 Physical Parameters

The temperature, salinity, and pH of interstitial waters are shown in Table 1. The mean temperature for all sampling stations is 22.7°C (± 2.8). Apparently, the pattern of temperature differences cannot be inferred from the information because sampling periods were done at different times of the day and year. Moreover, the upper and middle intertidal zones showed no significant difference in terms of temperature across all stations. The highest temperature was recorded in Al Wakra station at 26.6°C. Dukhan and Umm Bab also recorded high temperature during the time of sampling at 25.0°C. The lowest temperature was recorded in Al Khor station at 15.7°C. Generally, middle intertidal zones have higher temperatures than their corresponding upper intertidal zones.

Salinity values recorded during the sampling ranged from 42 to 56ppt with the average of 48.8 ppt. Highest salinity was recorded in Al Wakra 2 at 56ppt. All stations in the western coast, i.e., Dukhan, Umm Bab, Al Zubara and Al Ruwais, recorded high salinity values of greater than 50ppt. Lowest values were recorded in Al Khor and Simaisma at 42ppt and 43ppt, respectively. T-test revealed that there is no significant difference in salinity values between upper and middle intertidal zones. Nonetheless, upper intertidal zones showed high salinity readings compared with those in middle intertidal zones.

The recorded pH values for all stations ranged from 7.1 to 8.6 with a mean of 7.96 ± 0.36. The mangrove station in Al Wakra recorded the highest pH of 8.6. Similarly, the high pH of more than 8 were recorded in all stations on the western coast. Lower pH values were observed in Al Wakra 1, Al Khor, Al Ruwais and Simaisma.

Stations from the upper intertidal zones have generally high pH values compared with their corresponding intertidal locations.

Table 1. Physical Parameter Measurements on 10 Stations in the Intertidal Waters of Qatar (MIT = middle intertidal; UIT = upper intertidal)

No.	Location	Temperature (^{o}C)	Salinity (ppt)	pH	distance from beach (m)
1	Al Khor MIT	15.7	44	7.64	18
2	Al Khor UIT	16.4	42	7.71	4
3	Dukhan MIT	25.2	52	8.05	20
4	Dukhan UIT	23.3	53	8.14	6
5	Fuwairit MIT	24.7	44	8.07	20
6	Fuwairit UIT	24.1	44	8.03	5
7	Al Ruwais MIT	22.1	46	7.45	61
8	Al Ruwais UIT	21.4	52	7.84	30
9	Simaisma MIT	23.1	46	7.64	14
10	Simaisma UIT	23.4	43	7.58	7
11	Umm Bab MIT	25.2	52	8.05	23
12	Umm Bab UIT	23.3	53	8.14	6
13	Mesaieed MIT	20.4	49	8.31	12
14	Mesaieed UIT	20	49	8.32	5
15	Al Wakra1 MIT	26.6	46	7.1	150
16	Al Wakra1 UIT	25.6	47	8.6	89
17	Al Wakra2 MIT	24.5	53	7.9	160
18	Al Wakra2 UIT	24.5	56	8.4	65
19	Al Zubara MIT	22.2	52	8.1	160
20	Al Zubara UIT	22.4	53	8.13	19

4.2 Granulometry

All sediment samples collected were generally made up of sand based on grain size analysis (Tables 2 and 3). Simaisma contains fine sand with a mean Φ of 2.28 and 2.64 in the middle and upper intertidal zones, respectively. Sediments in Al Khor stations are also considered fine sand with a mean Φ of 2.48. The sediments in these two locations together with Al Wakra 2 were poorly sorted based on their sorting index. Stations with coarse sand include Dukhan, Mesaieed, Al Wakra 1 and Al Zubara. Moderate coarse sand, on the other hand, are found in Fuwairit, Al Ruwais, Umm Bab and Al Wakra 2 stations. Generally, silt and clay have no contribution to the overall sediment composition of the sampled areas. However, a high proportion of it is found in Al Khor (33.4%) and Simaisma (33.7%) stations. The rest of the stations have less than 10% to absent silt-clay in their composition.

4.3 Chemical Analysis

TOM values are reported in Table 4. TOM is highest in AL Ruwais stations with 6.5% and 3.6% in the middle and upper intertidal zones, respectively. Umm Bab also showed high percentage TOM at 2.4% (UIT) and 2.2% (MIT). Fuwairit and Mesaieed samples revealed very low amount of TOM.

Highest NO_2 was recorded in Mesaieed at 5.09 mg/kg of sediment. Al Zubara, Fuwairit, and Al Khor contain high amount of NO_2. The rest of the stations have very low NO_2 concentrations. Highest NO_3 concentration was recorded in Al Khor at 44.0 mg/kg of sediment. High concentrations were also recorded in Mesaieed and Al Zubara at 36.4 mg/kg and 33.5 mg/kg of sediment, respectively. Lower concentrations were reported in Dukhan at 19.6 mg/kg of sediment and in Al Wakra 1 at 18.1 mg/kg of sediment. Concentration of NH_4 was also highest in the upper intertidal zone of Al

Khor at 174.7 mg/kg of sediment. High concentrations were also recorded in Mesaieed and Al Zubara at 108.8 mg/kg and 97.2 mg/kg of sediment. Lower concentrations of 1.2 mg/kg to 2.2 mg/kg of sediment were recorded in Dukhan, Simaisma and Al Wakra 1 (Table 5).

The highest concentration of PO_4 was recorded in Fuwairit at 12.2 mg/kg of sediment. High concentrations were also present in both rocky zone and mangrove area of Al Wakra at 7.5 mg/kg and 8.0 mg/kg of sediment, Very low concentrations of less than 0.05 mg/kg of sediment were observed in Al Khor, Dukhan, and Mesaieed stations. Analysis of calcium carbonate content revealed that most sediment samples contain more than 60.0% carbonate. Fuwairit, Al Ruwais, Simaisma and Al Wakra 1 have more than 90.0% carbonate composition. Low carbonate content was recorded in Dukhan with 40.3% and Mesaieed with only 16.2% carbonate content.

Table 2. Grain Size Composition of Sediments Collected from 10 Stations in the Intertidal Areas of Qatar

No.	Location	% clay (<4μm)	% silt (4-63 μm)	fine sand (63 – 250 μm)	medium sand (250 – 500 μm)	coarse sand (500-2000μm)
1	AKR MIT	1.11	32.3	43.9	7.7	14.28
2	AKR UIT	0.77	21.9	20.6	16.6	36.47
3	DUK MIT		0.04	6.6	38.3	54.86
4	DUK UIT			1.9	32.9	65
5	FWR MIT			60.2	37.3	2.44
6	FWR UIT			53.1	29.2	14.57
7	RWS MIT			44.5	36.4	19.17
8	RWS UIT		1.43	49.9	32.4	16.31
9	SIM MIT	1.02	29.47	36.3	24.0	9.23
10	SIM UIT	1.32	32.39	48.2	14.7	3.42
11	UMB MIT		2.17	60.3	26.2	9.35
12	UMB UIT		8.63	68.1	19.7	3.46
13	MSD MIT			1.6	38.2	60.19
14	MSD UIT			1.2	39.3	59.53
15	WAK1 MIT			7.0	43.5	49.55
16	WAK1 UIT			5.3	51.0	43.72
17	WAK2 MIT		2.14	37.1	37.9	22.86
18	WAK2 UIT		9.21	48.8	22.1	19.87
19	ZUB MIT		0.16	28.7	47.4	23.7
20	ZUB UIT			31.5	48.3	20.27

Table 3 Granulometry Measurements of Sediments Collected from 10 Stations in the Intertidal Areas of Qatar

No.	Location	Mean Φ	Type	Sorting σ	index
1	AKR MIT	2.48	fine sand	1.7	poorly sorted
2	AKR UIT	1.5	medium sand	1.83	poorly sorted
3	DUK MIT	0.33	coarse sand	0.71	moderately sorted
4	DUK UIT	0.2	coarse sand	0.61	moderately well sorted
5	FWR MIT	1.51	medium sand	0.63	moderately well sorted
6	FWR UIT	1.37	medium sand	0.84	moderately sorted
7	RWS MIT	1.19	medium sand	0.9	moderately sorted
8	RWS UIT	1.34	medium sand	0.87	moderately sorted
9	SIM MIT	2.28	fine sand	1.58	poorly sorted
10	SIM UIT	2.63	fine sand	1.37	poorly sorted
11	UMB MIT	1.53	medium sand	0.92	moderately sorted
12	UMB UIT	1.95	medium sand	1	moderately sorted
13	MSD MIT	0.3	coarse sand	0.64	moderately well sorted
14	MSD UIT	0.31	coarse sand	0.63	moderately well sorted
15	WAK1 MIT	0.44	coarse sand	0.73	moderately sorted
16	WAK1 UIT	0.5	coarse sand	0.66	moderately well sorted
17	WAK2 MIT	1.14	medium sand	1.03	poorly sorted
18	WAK2 UIT	1.63	medium sand	1.39	poorly sorted
19	ZUB MIT	0.96	coarse sand	0.86	moderately sorted
20	ZUB UIT	1.05	medium sand	0.83	moderately sorted

Table 4. Total Organic Matter (%) and Carbonate Composition (%) of Sediments Collected from the 10 Stations in the Intertidal Areas of Qatar

No.	Location	% TOM	% carbonate
1	AKR MIT	1.30	79.2
2	AKR UIT	0	85.3
3	DUK MIT	1.94	39.6
4	DUK UIT	0.72	41.0
5	FWR MIT	0	97.2
6	FWR UIT	0	96.8
7	RWS MIT	6.54	95.9
8	RWS UIT	3.64	95.7
9	SIM MIT	0.70	96.2
10	SIM UIT	2.45	96.1
11	UMB MIT	2.18	68.5
12	UMB UIT	1.24	74.2
13	MSD MIT	0	15.3
14	MSD UIT	0	17.2
15	WAK1 MIT	0	92.2
16	WAK1 UIT	2.71	92.0
17	WAK2 MIT	0	81.8
18	WAK2 UIT	0.31	82.3
19	ZUB MIT	0.81	84.3
20	ZUB UIT	0.88	83.5

Table 5. Measurements of Various Nitrogen Forms and Phosphates of Sediments Collected from the 10 Stations in the Intertidal Areas of Qatar

No.	Location	NO_2 (mg/kg sediment)	NO_3 (mg/kg sediment)	NH_4 (mg/kg sediment)	PO_4 (mg/kg sediment)
1	AKR MIT	3.95	28.8	161.67	0.05
2	AKR UIT	3.72	44.05	174.71	2.99
3	DUK MIT	0.92	24.16	1.45	0.05
4	DUK UIT	0.95	19.61	2.2	0
5	FWR MIT	4.4	27.58	48.06	12.19
6	FWR UIT	3.38	28.19	44.84	5.41
7	RWS MIT	0.9	22.5	3.12	4.81
8	RWS UIT	1.18	25.97	11.71	3.07
9	SIM MIT	0.91	22.15	4.4	4.07
10	SIM UIT	0.97	24.81	1.18	4.29
11	UMB MIT	0.93	26.95	3.24	3.52
12	UMB UIT	1.04	25.27	5.77	1.27
13	MSD MIT	3.51	36.45	108.81	0.05
14	MSD UIT	5.09	27.16	47.16	0.04
15	WAK1 MIT	0.87	18.09	3.13	7.49
16	WAK1 UIT	0.97	18.29	2	6.1
17	WAK2 MIT	1.1	21.75	4.97	8.02
18	WAK2 UIT	0.82	21.2	6.11	6.91
19	ZUB MIT	3.65	28.55	97.18	6.79
20	ZUB UIT	4.52	33.47	72.38	2.26

4.4 Taxonomic Composition

A total of 74 taxonomic groups of meiofauna belonging to 14 phyla was recorded during this study with a total mean density of 120.9 ind/10cm^2. Elopsidae A, an order of Nematoda, is the most abundant group of with a mean density of 52.4 ind/10cm^2 and comprises 43.4% of the entire meiofauna population. The other two types of Elopsids are likewise included in the top ten most abundant groups, making the Elopsids the most abundant taxon comprising 77.1% of the entire recorded individuals.

Other groups showing high densities include Tanaidae (9.1%), Harpacticoides (4.3%), *Cypridopus vidua* (3.1%), Hesionidae (3.0%), Bivalves (3.0%), Rotifers (2.1%), *Leptastacus sp.* (2.0%), *Euterpina sp.* (2.0%) and harpacticoid nauplii (2.0%) (Table 7).

Nematode is the most abundant phylum comprising 51.0% of the overall meiofaunal assemblages with a mean density of 61.78 ind/10cm^2 (Fig. 2). Only one order of nematode, the order Enoplidae was observed. This was further grouped into three types based on the general shape of the body. Enoplidae A, the most abundant type comprising 84.9% of nematodes and is described as moderately long with moderately sized body diameter relative to the other types. Enoplidae B type has very long and slim body, while Enoplidae C has moderate length but with wider body diameter. These last two types of Enoplidae equally comprised 7.0% of the nematodes in the sample (Fig. 3). Figures 4 show the typical representative for each type of Enoplidae.

Phylum Arthropoda comprised 31.6% of all meiofaunal samples with a mean density of 38.33 ind/10cm^2. All groups recorded are crustaceans except for the rarely occurring marine species of Acarid of the Class Arachnida. A total of 38 crustacean taxa was recorded in this study. The most abundant group is the Harpacticoides with a mean density of 14.42 ind/10cm^2, which comprised 37.7% of all crustaceans (Fig. 3). Tanaidae and Ostracod also exhibited high abundances comprising 28.9% (mean density of 11.01 ind/10cm^2) and 15.4% (mean density of 5.91 ind/10cm^2), respectively. Other prominent crustacean groups include Cephalocarida (4.6%), Syncarida (2.7%), and nauplius and copepodite stages of copepods (3.7%).

Table 6. Mean Density (individuals/10cm^2) of Meiobenthic Assemblages per Station and Zone

Station	Middle intertidal	Upper intertidal
Umm Bab	0.830	5.899
Dukhan	3.535	2.604
Al Zubara	6.849	11.239
Al Ruwais	5.145	7.893
Fuwairit	3.553	1.101
Al Khor	16.730	1.730
Simaisma	9.679	9.987
Al Wakra1	8.258	11.912
Al Wakra2	5.604	4.597
Mesaieed	3.327	0.421
	total mean	120.89
	sd	4.29
	median	5.37
	min	0.42
	max	16.73

Table 7. Twenty Most Abundant Taxa of Meiofauna Collected from the Intertidal Areas of Qatar

Taxon	Phylum	Mean density (ind/10cm^2)	Relative density (%)
Elopsidae A	Nematoda	52.440	43.4
Tanaidae	Arthropoda	11.013	9.1
Harpacticoides	Arthropoda	5.252	4.3
Elopsidae B	Nematoda	4.321	3.6
Elopsidae C	Nematoda	4.296	3.6
Cypridopus vidua	Arthropoda	3.730	3.1
Hesionidae	Annelida	3.610	3.0
Bivalve	Mollusca	3.591	3.0
Rotifer	Rotifera	2.497	2.1
Leptastacus sp.	Arthropoda	2.453	2.0
Euterpina sp.	Arthropoda	2.409	2.0
harpacticoid nauplii	Arthropoda	2.358	2.0
Turbellarian	Platyhelminthis	2.019	1.7
Cephalocarida	Arthropoda	1.748	1.4
Polychaete juvenile	Annelida	1.679	1.4
Clytemnestra sp.	Arthropoda	1.660	1.4
Gastropod Prosobranch	Mollusca	1.465	1.2
copepod nauplius	Arthropoda	1.346	1.1
Spionidae	Annelida	1.245	1.0
Loricifera	Loricifera	1.063	0.9

The Phylum Annelida, with a mean density of 7.87 ind/10cm^2, comprising 6.1% of the meiofaunal samples, is totally made up of taxa belonging to Class Polychaeta. The most abundant group is the Family Hesionidae occurring at a mean density of 3.61 ind/10cm^2. Juvenile stages of unidentified polychaetes and individuals belonging to Family Spionidae also occurred in relatively high abundance with mean densities of 1.70 ind/10cm^2 and 1.24 ind/10cm^2, respectively. Phylum Mollusca comprised 4.5% of all meiofaunal samples with a mean density of 5.41 ind/10cm^2. Juvenile stages of various species of bivalves dominated the group with a mean density of 3.59 ind/10m^2 and gastropod mean density of 1.74 ind/10cm^2 only. A comprehensive list of all recorded taxa is found in Appendices B to E.

4.5 Distribution of Meiofaunal Assemblages

Overall mean density was highest in Al Wakra 1 at 20.17 ind/10cm^2. Higher densities in the same order of magnitude were recorded in Simaisma ($\bar{x}$ density = 19.67 ind/10cm^2), Al Khor ($\bar{x}$ density = 18.46 ind/10cm^2) and Al Zubara ($\bar{x}$ density = 18.09 ind/10cm^2). Lowest mean densities were recorded in Fuwairit ($\bar{x}$ density = 4.65 ind/10cm^2) and Mesaieed ($\bar{x}$ density = 3.75 ind/10cm^2). Overall, mean densities in the middle intertidal zones were slightly higher than their corresponding upper intertidal zones. However, the range of differences between the two zones depends on the location. The middle and upper intertidal zones in Al Khor exhibited the highest difference in mean densities at 16.73 ind/10cm^2 for the former and 1.73 ind/10cm^2 for the latter. Densities in Fuwairit and Mesaieed also revealed much higher values in the middle intertidal than the upper intertidal zones. In contrast, Umm Bab, Al Zubara and Al Wakra 1 exhibited higher densities in their upper intertidal samples that the corresponding middle intertidal zones (Table 6).

4.6 Ecological Indices

Regardless of location, the middle intertidal zones exhibited higher species richness than their corresponding upper intertidal zones. Al Zubara revealed the highest richness in both zones with 38 taxa in the middle intertidal and 34 taxa in the upper intertidal zone. Moderate species richness was also recorded in Al Ruwais, Simaisma, Al Khor, and the Al Wakra stations. The lowest species richness was found in Mesaieed in both zones and in the upper intertidal zone of Fuwairit (Fig. 5B).

Similarly, the middle intertidal zones revealed a higher index of diversity than their corresponding upper intertidal zones except for Mesaieed where the upper intertidal had a slightly higher diversity index than the middle intertidal zone. The highest diversity was recorded in Al Zubara in both of its middle and upper intertidal zones. High diversity indices were also recorded in Dukhan, Umm Bab, and Simaisma (Fig. 5C). The high diversity in Al Zubara is supported by the high expH' values in the area, i.e., 13 equally important taxa in the middle intertidal and 9 taxa in the upper intertidal zone. Generally, the middle intertidal zones showed a higher number of important taxa than the upper intertidal zones, except for Al Khor and Mesaieed where the upper intertidal have a slightly higher number of important taxa than the middle intertidal zones.

A high number of important taxa were also found in the middle intertidal zones of Dukhan, Umm Bab, Simaisma, Al Ruwais, and Fuwairit (Fig 6A). The upper intertidal zones of Dukhan and Umm Bab, likewise exhibited a high number of equally important taxa. Only three taxa were considered equally important in the middle intertidal zone of Al Khor and upper intertidal zones of Fuwairit and Simaisma.

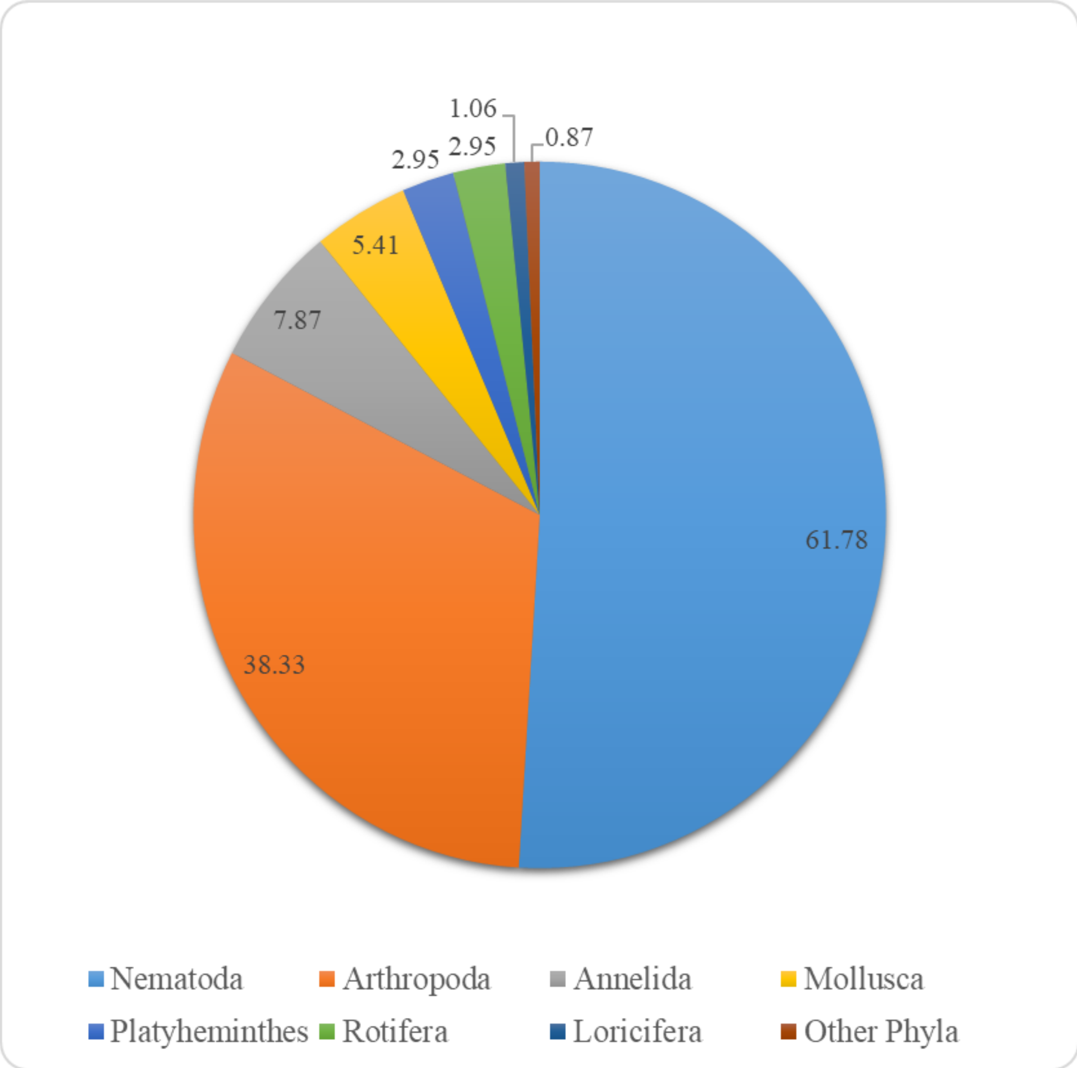

Figure 2. Mean density (individuals /10cm ^{2}) by phylum of meiofauna collected in the intertidal areas around Qatar.

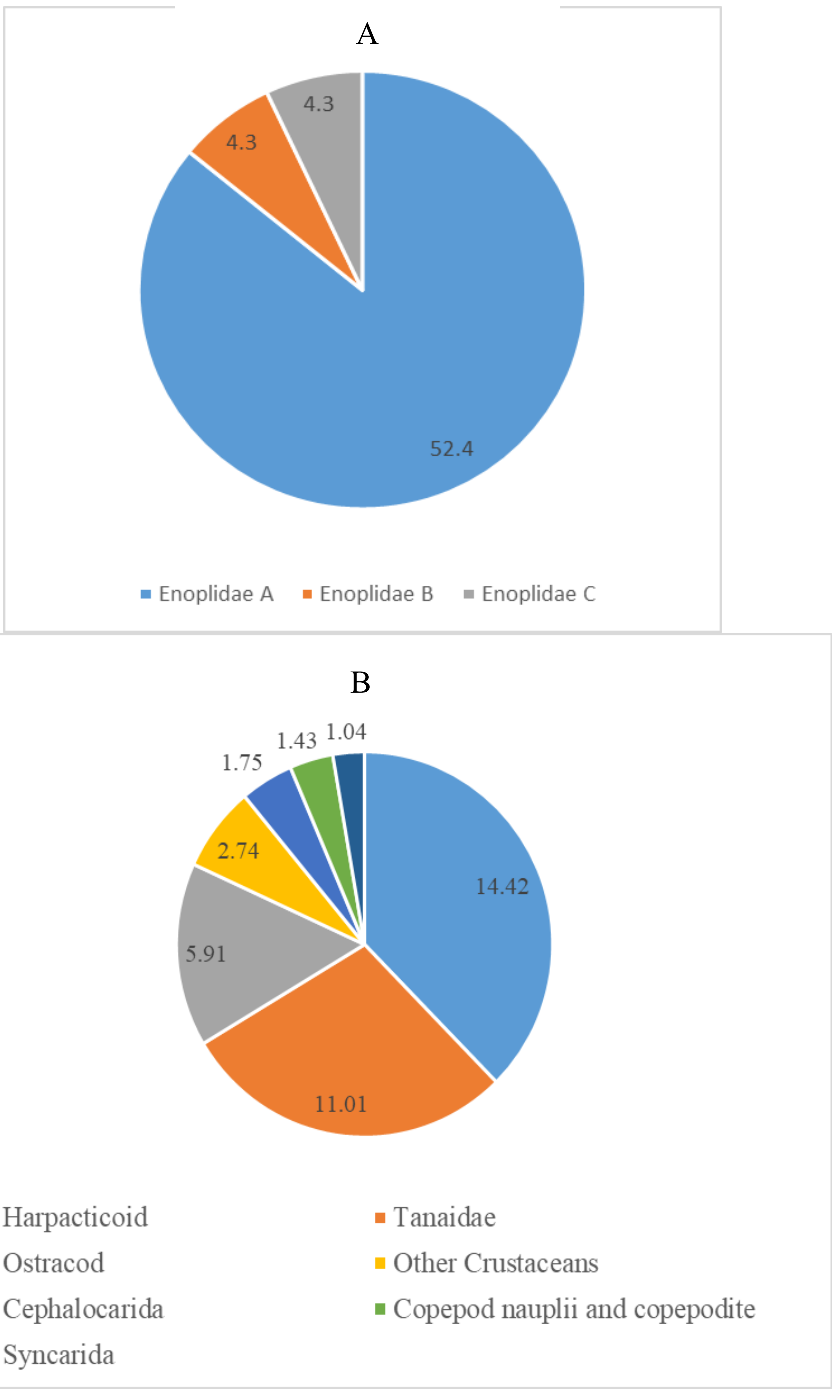

Figure 3. Mean density (individuals /10cm ^{2}) of meiofauna collected in the intertidal areas around Qatar. A: three types of nematodes; B: different groups under Subphylum Crustacea.

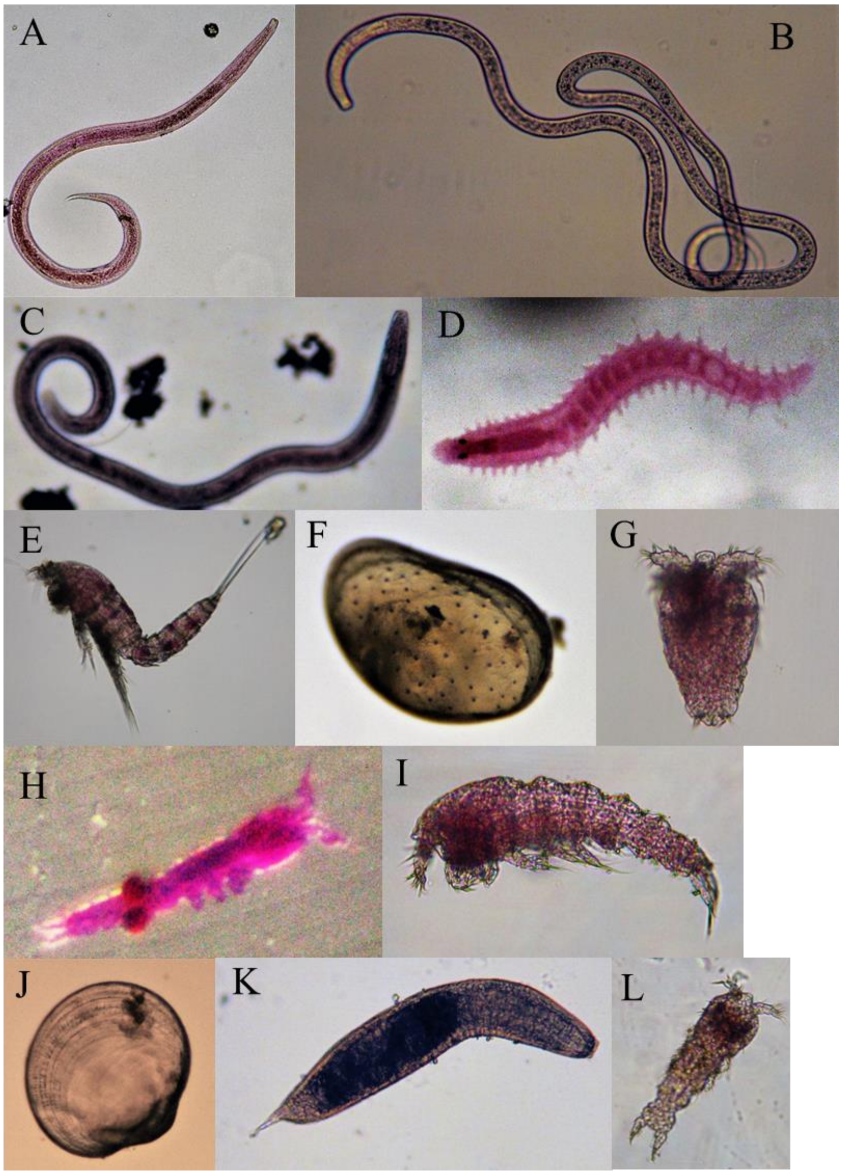

Figure 4. Specimens of the meiofauna collected from the intertidal area of Qatar. (A). Nematode Enoplidae A; (B). Nematode Enoplidae B; (C). Nematode Enoplidae C; (D). Polychaete Hesionidae; (E). Harpacticoides; (F). Ostracod *Cypridopus vidua*; (G). Rotifers; (H). Tanaidae; (I). *Leptastacus sp*.; (J). Bivalve; (K). Turbellarian; (L). *Clytemnestra sp*.

Pielous’ Index showed generally higher evenness in the middle intertidal than the corresponding upper intertidal zones except for Al Khor and Al Wakra 1 where the upper intertidal have slightly more evenness than the middle intertidal zones. This result is consistent with the revealed expH’ values. For middle intertidal zones, highest evenness values were found in Al Zubara and Dukhan, with moderate evenness in Umm Bab and Fuwairit. For upper intertidal zones, the highest evenness values were recorded in Mesaieed, with moderate values in Dukhan, Umm Bab, and Al Zubara (Fig. 6B). The middle intertidal zone of Al Khor and upper intertidal zone of Simaisma recorded the lowest evenness indices.

4.7 Nematode/Copepod Ration (N/C Ratio)

The N/C Ratio for all sampling locations are shown in Figure 6C. Higher population of nematodes relative to copepods were recorded, generally in the middle intertidal zones, with few exceptions. Nematodes were more dominant in the upper intertidal zones of Al Wakra 2, Umm Bab and Simaisma and the middle intertidal zones of Mesaieed and Fuwairit. Interestingly, no copepods were recorded in the upper intertidal zone of Fuwairit. On the other hand, copepods were more abundant than nematodes in the middle intertidal zones of Dukhan and Al Zubara.

4.8 Cluster Analysis

Cluster analysis of meiofaunal densities revealed two major distinct clusters. Cluster 1 formed with similarity level of 49.3% and is comprised mostly of stations on the eastern coast of Qatar. This cluster further formed into two subclusters: Cluster 1A which is exclusively comprised of west coast locations. i.e., both zones of Dukhan, the upper intertidal zone of Umm Bab and the middle intertidal zone of Al Zubara. The middle intertidal zones of Simaisma, and Umm Bab, however, comprised Cluster 1B with a similarity level of 73.4%.

The rest of the stations formed a Cluster 2 within a similarity level of 56.3%. Further clustering revealed that at 85.9% similarity level, a subcluster was formed by both zones of Al Khor, Al Ruwais, Al Wakra 2, and the upper intertidal zones of Simaisma and Al Zubara. (Fig. 7).

4.9 Principal Component Analysis

The resulting Eigenanalysis of the correlation matrix of the principal component analysis are shown in Table 8. Out of 22 variables included in the analysis, only six principal components showed a significant relationship on the data (Eigenvlaue > 1.0). These six components explain 82.0% of the variation in the data.

The first component (PC1) has a high association with sediment characteristics, i.e., positively associated with silt and clay composition and sorting index, and negatively associated with sand composition, temperature and salinity. Nematodes and rotifers are positively associated with this interaction. The second component (PC2) is positively associated with NO_2, NO_3, and NH_4 and negatively associated with carbonate and temperature. The overall density of meiofauna and that of crustaceans are highly associated with this component. These abovementioned first two components explain only 47.5% of the variation in the data. Evidently, this variation is a result of not only from these components but also due to some other complex interactions.

Nematodes and rotifers are positively correlated with silt and clay composition and sorting index and negatively correlated with sand composition, interstitial waters' temperature, and salinity. Crustacean showed positive correlation with carbonate, TOM, all N-forms, and sorting index. Copepods, specifically, showed positive correlation with NO_2 and salinity and negative correlation with PO_4, carbonate, and sorting index. Ostracod also showed a negative correlation with PO_4 and CO_3, and additionally with TOM. Molluscs showed a negative correlation with PO_4, carbonate, TOM, and pH. Flatworms, on the other hand, showed a positive correlation with TOM and negative correlation with PO_4 and carbonate.

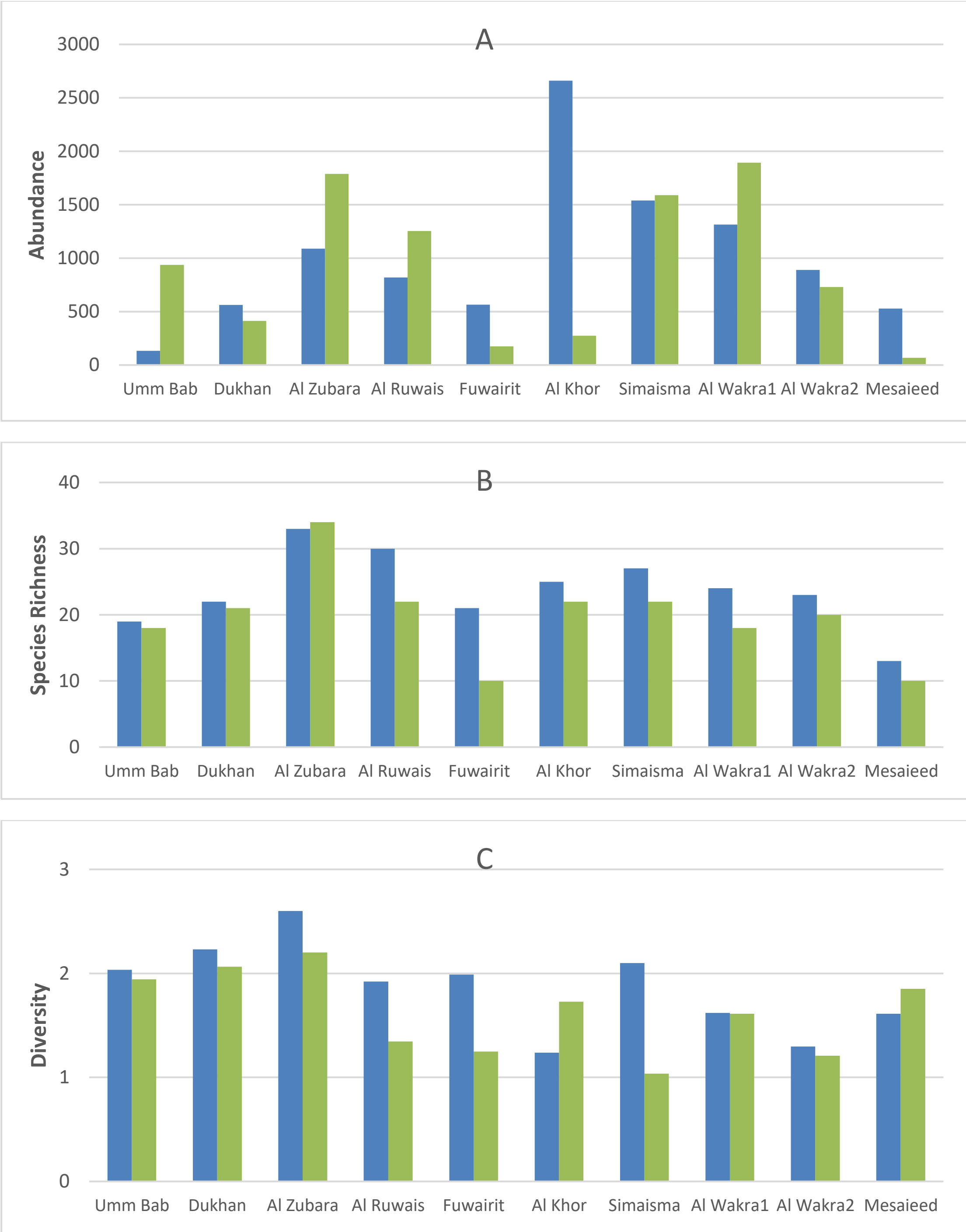

Figure 5. (A) Species abundance, (B) richness, and (C) Shannon's Index of Diversity of meiofauna, collected in the intertidal areas around Qatar; blue: middle intertidal; green= upper intertidal.

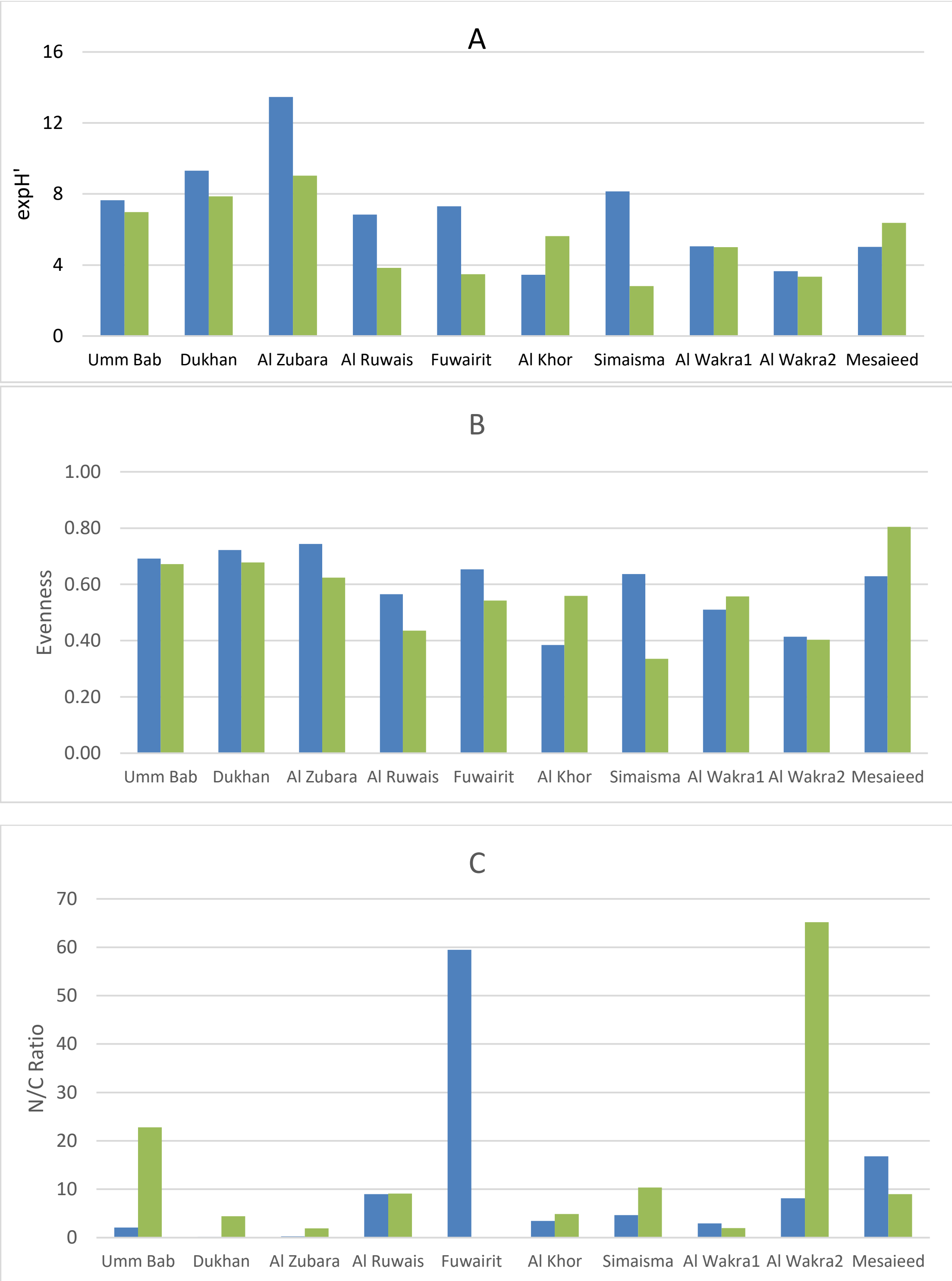

Figure 6. (A) Statistical H', (B) evenness index, and (C) nematode/copepod ratio of meiofaunal assemblage collected in the intertidal areas around Qatar; blue: middle intertidal; green: upper intertidal.

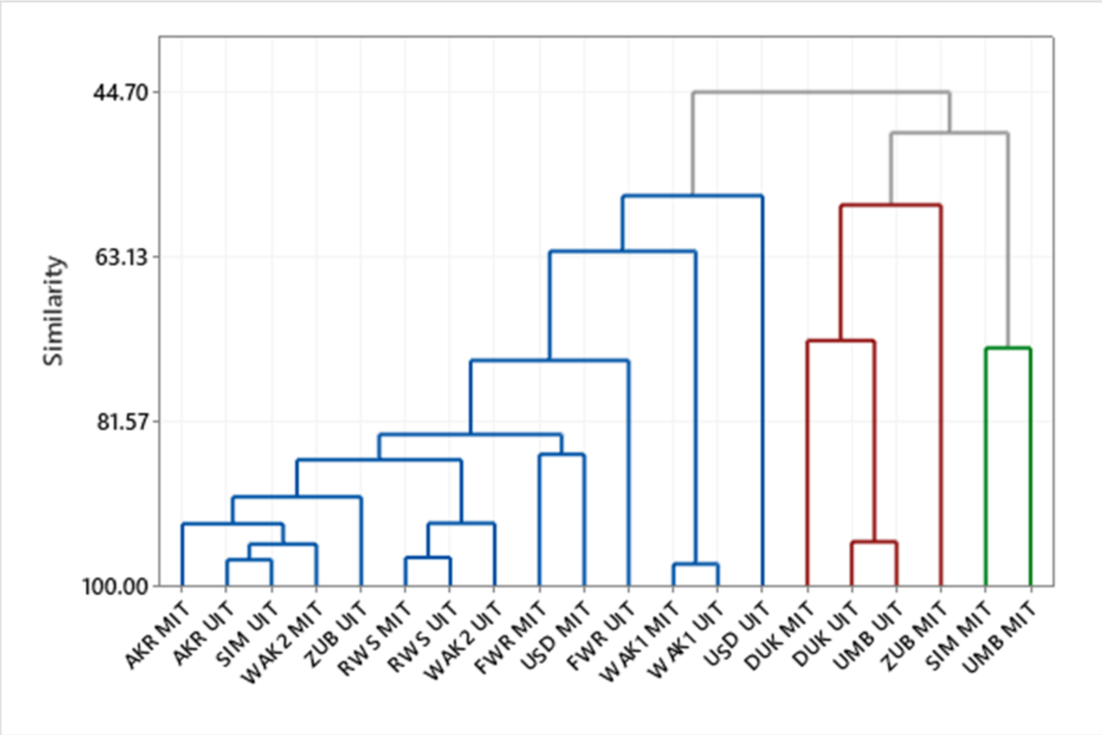

Figure 7. Cluster analysis showing the similarity of meiofaunal assemblage between all sampling stations.

Table 8 The Eigenanalysis of Correlation Matrix from Principal Component Analysis of various Physico-Chemical and Biological Variables

Variable	PC1	PC2	PC3	PC4	PC5	PC6
Temp	-0.26	0.28	0.03	-0.14	-0.18	0.15
Sal	-0.24	0.02	0.05	0.32	0.12	0.12
pH	-0.18	-0.18	-0.13	0.16	0.03	0.33
%TOM	-0.01	0.26	0.05	0.06	0.40	-0.38
NO2	0.10	-0.37	-0.33	-0.07	0.01	-0.06
NO3	0.15	-0.39	-0.09	-0.02	0.07	-0.28
NH4	0.23	-0.33	-0.23	0.06	-0.06	-0.16
PO4	-0.06	0.20	-0.15	-0.44	-0.33	-0.15
CO3	0.13	0.32	-0.10	-0.26	-0.21	-0.30
% clay	0.35	0.07	0.15	0.01	-0.02	0.08
% silt	0.35	0.07	0.20	0.06	-0.08	0.09
sand	-0.35	-0.05	-0.20	-0.04	0.10	-0.07
Sorting σ	0.32	0.02	0.20	0.02	-0.11	-0.07
density	0.22	0.30	-0.26	0.21	0.05	0.16
polychaete	-0.08	0.16	-0.50	-0.08	0.10	-0.06
crust	0.01	0.24	-0.36	0.25	-0.15	0.17
mollusc	-0.10	0.05	0.01	0.40	-0.26	-0.55
nemat	0.30	0.23	-0.03	0.09	0.13	0.19
flatworm	0.09	0.14	0.03	-0.07	0.58	-0.16
rotif	0.25	-0.12	-0.19	-0.09	-0.20	0.15
ostrac	-0.11	0.04	0.19	0.42	-0.33	-0.12
copepod	0.18	0.11	-0.34	0.33	0.03	-0.09
Eigenvalue	6.65	3.79	2.75	2.28	1.39	1.18
Proportion	0.30	0.17	0.13	0.10	0.06	0.05
Cumulative	0.30	0.48	0.60	0.70	0.77	0.82

CHAPTER 5: DISCUSSION

The coastal ecosystem of Qatar is characterized as highly dynamic as an effect of complex interactions between different types of habitats, which are influenced by extreme natural factors with high impact from anthropogenic activities.

Physical parameters recorded in this study are in the range of what was previously reported in the area (Al Maslamani, *et al.*, 2015; Quigg, *et al.*, 2013; Al Khayat, 2005). Albeit, there are no available studies on the physical parameters of interstitial waters in Qatar's intertidal zones, the abovementioned studies somehow revealed the range of values for different parameters in the area. The temperature of interstitial waters is lower than those recorded in the deep water column or coastal waters. Temperature variation is a function of season, and to some extent at the time of the day the field sampling was conducted. Consequently, temperature readings in this study are lowest in the winter months (December – January) and higher in early and late summer (April and November). Salinity readings, on the other hand, revealed spatial variability. Stations along the western coast of Qatar showed higher salinity readings compared with the rest of the area. This is consistent with what was reported by Al-Maslamani, *et al.*, (2015) in Umm Bab, and Beltagy (1983) in various western coastal stations. This high salinity is due to the enclosed characteristic of the western coast which minimizes the flushing rate in the area. The pH readings in all stations in this study are all alkaline, which was reported to be typical in the Qatar waters (Al-Khayat and Al-Ansi, 2008). This alkalinity is attributed to high calcium carbonate in sediments of most coastal areas of the country. Lowest pH, apparently, was recorded in areas adjacent to mangrove habitats, i.e., Al Khor, Al Wakra 2, and Simaisma, and those with expansive intertidal area, i.e., Al Ruwais and Al Wakra 1. Sediments along the coastal areas of Qatar are general sandy with high carbonate composition. Poorly sorted sediment containing a relatively high proportion of silt and clay are present in locations adjacent to mangroves areas. Mangrove forests act as a barrier against high energy current and waves, thus promoting retention of finer sediments.

The density of meiofauna recorded in this study is slightly lower compared to what has been reported in several adjacent areas of the Arabian Gulf (in the Arabian Sea: Sajan, *et al.*, 2016; Sommer and Pfannkuche, 2000; in the Red Sea: Hedfi, *et al.*, 2018; Al-Sofyani and El-Sherbiny, 2018). The abovementioned studies also reported the dominance of nematodes in their samples because this group can adapt to different conditions in any habitat. According to Sahraean, *et al.* (2017), nematodes and harpacticoids are the two most abundant meiofaunal components in the northern part of the Arabian Gulf, which is consistent with this study except for the high occurrence of Tanaids in few stations. Densities of meiofauna have been reported to vary based on habitat type and the associated abiotic and biological factors present in the area (Gheskiere, *et al.*, 2005; Gallucci, *et al.*, 2005).

The factor that influences the pattern of distribution of meiofaunal densities in this study cannot be determined by a single variable alone. The observed high levels of N-forms in Al Khor might be the result of the presence of high meiofaunal population in the area. It has been reported that high abundance and diversity of meiofauna in soft-sediments ecosystem promote high denitrification by the process of microturbation, which in turn stimulates both nitrifying and denitrifying bacteria (Bonaglia, *et al.*, 2014). The organic matter content of the area is relatively low which may be due to the same fact that meiofauna population stimulates sediment bacterial community resulting to enhanced mineralization of organic matter (Nascimento, *et al*., 2012).

In contrast, Al Ruwais has the highest organic matter content but with very low N-form levels. High meiofaunal density in this area can therefore be attributed to a high availability of food. High densities in the upper intertidal zones of Simaisma and Al Wakra 1 can also be explained by high food availability as both have high organic matter content in their sediments, as well. In fact, based on principal component analysis, the densities of meiofauna are positively associated with organic matter content and inversely with all N-forms.

Sediment characteristic, however, is shown to be the major determinant of meiofaunal density, especially for nematodes which comprise the bulk of meiofaunal composition. Despite being sandy, some areas in this study contain a considerable amount of silt and clay composition. This proportion of clay-silt-sand composition must be ideal for the meiofaunal population, as in the case of Al Khor, Al Zubara, Al Ruwais, and Simaisma. No sampled stations contain silt and clay greater than 50%. Silty or clayey areas produce very tight interstitial spaces resulting in an anoxic environment which is detrimental to most organisms. Very coarse sand, on the other hand, is characteristic of high energy coastlines (*e.g.*, Mesaieed), with recurrent variations in temperature and salinity and a high turnover rate of interstitial waters, which impedes bacterial growth. It has been shown that sediment heterogeneity affects the distribution of meiofauna (Decho, *et al.*, 1985).

The low meiofaunal density, however, is usually compensated with high diversity (Griere, 2009), which is also revealed in this study. Areas with low densities, *i.e.*, Umm Bab, Dukhan, and Mesaieed, have high diversity with statistical H' of more than 10 taxonomic groups. The lack of a dominant group promotes co-habitation with other taxa, especially the rare ones, because of reduced competition with resources, *e.g.*, food and space. Moreover, high diversity can also indicate the absence of ideal conditions necessary for the high population growth rate of certain dominant groups, which in turn, promotes the presence of other taxonomic groups.

Meiofaunal studies are oftentimes used to determine ecosystem health. Morad, *et al*. (2017) studied meiobenthic distribution in relation to pollution gradient and revealed that the density of nematodes increases with the level of pollution in the studied area. Alnashiri, *et al.,* (2018) compared species richness and diversity of the meiofaunal community between two areas in the Red Sea and found out that variation in density of meiofauna is due to high anthropogenic pollution in the area. In this study, relatively low species richness and diversity in stations along the eastern coast might be indicative of poor water quality. Pollution studies in relation to meiofauna are a little bit complex; the definition of pollutants should be clearly defined because organic and toxic pollution have different effects on benthic organisms. The latter increases food supply resulting in a high abundance of organisms (Vincx and Help, 1991). Moreover, seasonal changes in temperature and salinity, which also affect meiofaunal assemblage, should also be considered.

One important parameter of meiofaunal assemblage that being used in pollution studies is the nematode/copepod ration (N/C ratio). According to Warwick (1981) high N/C ratio is indicative of pollution. Being the two most abundant groups, the nematode-copepod relationship is oftentimes used to determine ecosystem health, as the latter is more sensitive to stress than the former. In this study, the N/C ratio is very high in Fuwairit (the upper intertidal zone even has zero records of copepod) and the upper intertidal zone of Al Wakra 2. Sediments in these two areas contain none to very low organic matter. Fuwairit has moderate to below moderate levels of N-forms, while Al

Wakra 2 is in the low spectrum in terms of N-form levels. Phosphate levels, on the other hand, are very high in Fuwairit and above moderate levels in Al Wakra 2. Therefore, phosphates can be considered as pollutants, in this case. Moderately higher N/C ratios were also observed in Umm Bab, which have exclusively high organic matter content, and Mesaieed, which have high ammonia levels. The N/C ratio, however, is also affected by sediment characteristics and seasonal changes. Thus, further studies should be conducted to determine the effect of pollution on meiofauna composition.

5.1 Future Research and Recommendations

Further research on the meiobenthos of Qatar should gear towards determining the relationship between meiofaunal assemblage and water quality. Qatar is at the peak of industrialization resulting in intensive coastal modifications and increasing waste inputs from municipal wastes and several industries to the coastal marine ecosystem. This present study, somehow, provides baseline information on density, composition, and distribution of meiofauna in the country's coastline. Determining meiofaunal composition in Qatari waters, in particular, and the Arabian Gulf, in general, is important because these species are highly adaptive to extreme temperature and salinity in the Gulf. Therefore, they are essential in addressing climate change concerns in the future.

Higher-resolution investigations of specific coastal areas should be done. Ecologically important areas should be studied intensively and monitored regularly to determine the seasonal and inter-annual variations in the meiofaunal community and to relate this variation in the likewise varying physico chemical parameters and pollutants.

Taxonomic identification of the organisms should be further enhanced, at least for the most dominant groups. Effect of different environmental conditions is oftentimes species-specific. Each species of nematode, for example, has different modes of feeding and food preference. Knowledge of this characteristic will give deeper insights on complex trophic dynamics in the meiofaunal community, especially on the energy partitioning between nematodes and copepods.

REFERENCES

Al-Ansi, M.A. and J.A. Al-Khayat. (1999). Preliminary study on coral reef and its associated biota in Qatari waters, Arabian Gulf. Qatar Univ. Sci J. 19:294-311.

Al-Khayat, J.A. (2005). Some macrobenthic invertebrates in the Qatari waters, Arabian Gulf. Qat. Univ. Sci. Bull., 25: 126-136.

Al-Khayat, Jassim & M.A, Al-Ansi. (2008). Ecological Features of Oyster Beds Distribution in Qatari Waters, Arabian Gulf. Asian Journal of Scientific Research. 1(6).

Al-Khayat, J.A. and F. Al-Khayat. (2000). Study of macrobenthic invertebrates in the Qatari waters, Arabian Gulf. Bull. Nat. Inst. Oceanog and Fish. 26:125-148.

Al-Maslamani, I., Al-Masdi, A., Smyth, D., Chatting, M., Obbard, J. and B. Giraldes (2015). Baseline monitoring gastropods in the intertidal zone of Qatar - target species and bioindicators for hyper-thermic and hyper-saline conditions. International Journal of Research Studies in Biosciences, 3 (12): 62-72.

Alnashiri, H.B.M.H., AbdAllah, A.T, Maqbool T. K., and A.M. Alhababy. (2018). A comparative study of biodiversity of meiobenthos as bioindicator for water quality from the Red Sea coasts of Jazan and Farasan Island, Saudi Arabia. Life Science Journal, 15(8).

Al-Sofyani, A., and M. El-Sherbiny. (2018). Meiobenthic assemblage of the grey mangrove (*Avicennia marina*) along the Saudi Arabian coast of the Red Sea with emphasis on free-living nematodes. Oceanological and Hydrobiological Studies, 47 (4).

Beltagy, A.I. (1983). Some oceanographic measurements in the Gulf waters around Qatar peninsula. Qatar Univ. Sci. Bull., 3: 329-341.

Bonaglia, S., Nascimento, F.J.A., Bartoli, M., Klawonn, I., and V. Brüchert. (2014). Meiofauna increases bacterial denitrification in marine sediments. Nature Communications, 5:5133.

Brook, M.C., Al Shoukri, S., Amer, K.M., Boer, B. and Krupp, F. (2006). Physical and Environmental Setting of the Arabian Peninsula and Surrounding Seas in *Policy Perspectives for Ecosystem and Water Management in the Arabian Peninsula*. Eds. Amer, K.M. Boer, B., Brook, M.C., Adeel, Z., Clusener-Godt, M., and Saleh, W.

Coull, B.C. and G.T. Chandler. (1992). Pollution and meiofauna: field, laboratory and mesocosmstudies. Oceanography and Marine Biology: An Annual Review 30, 191–271.

Decho, A.W., Hummon, W.D., and J.W. Fleeger. (1985). Meiofauna-sediment interactions around subtropical seagrass sediments using factor analysis. Journal of Marine Research, 43, 237-255.

Dezfouli, T.T., Nabavi, S.M.B., Ghatromi, E.R. and N. Sajjadi. (2016). Study on the meiofauna community structure in Sajafi Shores as the bio-indicator of environmental pollution. Open J. of Ecol., 6, 632-644.

Ferrero, T.J. Barnes, N, and R. Huys. (2010) in Hendrick, G., Berrera, T.N., Cnudde, C., Deprez, T., Derycke, S., De Troch, M., Ingels, J., Merckx, B., Moens, T., Pape, E., Vanaverbeke, J., Vaneusel, A., and M. Vincx (Eds). 14th International Meiofauna Conference, Aula Academica, Ghent, 11-16 July 2010. Book of Abstracts, VLIZ Special Publication, 44, xxii+237p.

Fonseca, G, and T.N. Bezerra. (2014). Order Monhysterida Filipjev, 1929. In Schmidt-Rhaesa, A (ed) *Handbook of Zoology* 1st edition. De Gruyter. pp.435-465.

Gallucci, F., Steyaert, M., and T. Moens. (2005). Can field distributions of marine predacious nematodes be explained by sediment constraints on their foraging success? Mar Ecol Prog Ser, 304:167-178.

Gheskiere, T., Vincx M., Urban-Malinga, B., Rossano, C., Scapini, F., and S. Degraer. (2005). Nematodes from wave-dominated sandy beaches: diversity, zonation patterns and testing of the isocommunities concept. Estuarine, Coastal and Shelf Science, 62(1):365-375.

Giere, O. (2009*). Meiobenthology: The Microscopic Motile Fauna of Aquatic Sediments*. 2nd ed. Springer-Verlag, Berlin, Germany.

Hedfi, A., Ali, M.B., NourEl-Deen, A.H., Albogami, B, Hassan, M.M.S., Saif, T., and B. Fehmi. (2018). Distribution and abundance of benthic meiofauna in the eastern Red Sea coasts (Jeddah, Saudi Arabia). Annual Research & Review in Biology, 26 (2).

Higgins, P.R. and H. Thiel, H. (1988). Introduction to the Study of Meiofauna. Smithsonian Institution Press, Washington DC.

Holme, N.A. and A.D. McIntyre. (1984). Methods for the Study of Marine Benthos. Blackwell Sceintific Publications. Great Yarmouth, Norfolk.

Hulings, N.C., and J.S. Gray. (1971). A Manual for the Study of Meiofauna. Smithsonian Institution Press. Washington DC, USA.

Identification Course on Aquatic Nematodes (ICAN). (2018). Faculty of Science, Ghent University. Ghent, Belgium.

Kennedy, A.D. and C.A. Jacoby. (1999). Biological indicators of marine environmental health: meiofauna—a neglected benthic component? Environmental Monitoring and Assessment 54, 47–68.

Mare, M.F. (1942). A study of a marine benthic community with special reference to the micro-organisms. J. of the Mar. Bio. Ass. of the U.K. 25, 517–554.

Morad, T.Y., Dubinsky, Z., and D. Iluz. (2017). Meiobenthos sssemblages as bioindicators for coastal pollution assessment. Open Journal of Marine Science, 7, 409-423. https://doi.org/10.4236/ojms.2017.73028.

Moreno, M., Semprucci, F., Balsamo, M., Fabiano, M., and G. Albertelli. (2011). The use of nematodes in assessing ecological quality status in the Mediterranean coastal ecosystems. Ecol. Ind. 11, 328–336.

Nascimento, F.J.A., Naslund, J., and R. Elmgren. 2012. Meiofauna enhamnces organic matter mineralization in soft-sediment ecosystem. Limnol. Oceanogr. 57(1), 238 – 346.

Parsons, T.R., Maita, Y., and C.M. Lalli. 1984. A manual of chemical and biological methods for seawater analysis. 1st edition. Pergamon Press, New York.

Platt, H.M. and R.M. Warwick. (1988). Free Living Marine Nematodes. Cambridge University

Quigg, A., Al-Ansi, M., Al Din, N.N., Wei, C-L., Nunnally, C.C., Al-Ansari, I.S., Rowe, G.T., Soliman, Y., Al-Maslamani, I., Mahmoud, I., Youssef, N., and M.A. Abdel-Moati (2013). Phytoplankton along the coastal shelf of an oligotrophic hypersaline environment in a semi-enclosed marginal sea: Qatar (Arabian Gulf). Continental Shelf Research. 60: 1-16.

Regional Organization for the Protection of Marine Environment (ROPME). (1999). Manual of Oceanographic Observations and Pollutant Analyses Methods. 3rd ed. Kuwait.

Sahraean, N., Bezerra, T.C., Khanaghan, K.E., Mosallanejad, H., Van Ranst, E., and T. Moens. (2017). Effects of pollution on nematode assemblage structure and diversity on beaches of northern Persian Gulf. Hydrobiologia 799(1): p. 349-369.

Sajan, S., Joydas, T.V., and R. Damodaran (2016). Meiofauna of the western continental shelf of India, Arabian Sea. Estuarine, Coastal and Shelf Science, 86: 665–674.

Schratzberger, M. (2012). On the relevance of meiobenthic research for policy-makers. Mar. Poll. Bull. 64, 2639–2644.

Schratzberger, M., Gee, J.M., Rees, H.L., Boyd, S.E., and C.M. Wall. (2000). The structure and taxonomic composition of sublittoral meiofauna assemblages as an indicator of the status of the marine environment. J. of the Mar. Bio. Ass. of the U.K. 80, 969–980.

Sommer, S. and O. Pfannkuche. (2000). Metazoan meiofauna of the deep Arabian Sea: standing stocks, size spectra and regional variability in relation to monsoon induced enhanced sedimentation regimes of particulate organic matter. Deep-Sea Research II,47: 2957-2977.

Urban-Malinga, B. (2013). Meiobenthos in marine coastal sediments. In: Martini, I.P., Wanless, H.R., (Eds.), *Sedimentary Coastal Zones from High to Low Latitudes: Similarities and Differences*. Geological Society, London, Special Publications.

Vincx, M. and C. Help (1991). The use of meiobenthos in pollution monitoring studies: a review in *Benthic Communities: Use in Monitoring point-Source Discharges.* Techniques in marine Environmental Sciences, 16: 50-67.

Warwick, R.M. (1981). The nematode/copepod ration and its use in pollution ecology. Mar. Poll. Bull., 12 (10): 329-333.

APPENDIX

Appendix A.. Details of Sampling Conducted on 10 Stations in the Intertidal Waters of Qatar

No.	Location	Coordinates		Date	Sampling time
		N	E		
1	Al Khor MIT	25.6897	51.5050	1/26/2020	1100
2	Al Khor UIT	25.6897	51.5050	1/27/2020	1020
3	Dukhan MIT	25.4203	50.7531	3/3/2019	1326
4	Dukhan UIT	25.4203	50.7531	3/3/2019	1346
5	Fuwairit MIT	26.0389	51.3678	11/26/2019	1019
6	Fuwairit UIT	26.0389	51.3678	11/26/2019	1019
7	Al Ruwais MIT	26.1272	51.1783	3/19/2019	1030
8	Al Ruwais UIT	26.1272	51.1783	3/19/2019	1050
9	Simaisma MIT	25.5776	51.4893	3/6/2019	1130
10	Simaisma UIT	25.5774	51.4893	3/6/2019	1050
11	Umm Bab MIT	25.2097	50.7677	2/8/2019	1730
12	Umm Bab UIT	25.2097	50.7677	2/8/2019	1730
13	Mesaieed MIT	24.8450	51.5078	1/31/2020	1500
14	Mesaieed UIT	24.8450	51.5078	1/31/2020	1320
15	Al Wakra1 MIT	25.1833	51.6150	4/27/2019	1155
16	Al Wakra1 UIT	25.1833	51.6150	4/27/2019	1215
17	Al Wakra2 MIT	25.1797	51.6172	4/27/2019	1300
18	Al Wakra2 UIT	25.1797	51.6172	4/27/2019	1320
19	Al Zubara MIT	26.0069	51.0344	12/9/2019	1100
20	Al Zubara UIT	26.0069	51.0358	12/10/2019	1031

Appendix B. Checklist of all Taxonomic Groups Recorded from the Meiofaunal Samples Collected in the Intertidal Waters around Qatar, Stations 1-5 (Station Numbers Correspond to Locations as Indicated in Table 1)

Classification	**Taxon**	**1**	**2**	**3**	**4**	**5**
Phylum Rotifera						
Class Eurotatoria						
Subclass Bdelloidea						
Family Philodinidae	*Philodina sp.*	+	+		+	+
Phylum Loricifera	Loricifera	+			+	+
Phylum Ciliata	Ciliates	+	+		+	
Phylum Gnathostomulidae	Gnathostomulidae					+
Phylum Nematoda						
Class Enoplea						
Order Enoplida	Enoplid A	+	+	+	+	+
	Enoplid C	+	+	+	+	+
	Enoplid B			+	+	
Phylum Annelida						
Class Polychaeta						
Subclass Errantia						
Order Phyllodocida						
Family Hesionidae	Hesionidae					+
Subclass Sedentaria						
Order Terebellidae						
Family Ampharetidae	Ampharetidae			+		
Family Opheliidae	*Armandia sp.*	+	+			+
Polychaete juvenile	Polychaete juvenile	+		+		+
Other Annelida (*incertae sedis*)	Aeolosomatidae		+		+	
Phylum Platyheminthes						
Subphylum Rhabditophora						
Order Macrostomida	Macrostomid		+			
Order Rhabdocoela						
Family Polycystidae	*Gyratrix sp.*		+			
Class Turbellaria	Turbellarian	+			+	+
Phylum Mollusca						
Class Bivalvia	Bivalve juvenile	+	+	+	+	+
Subclass Caenogastropoda						
Order Littorinimorpha	Juvenile	+	+	+	+	
Subclass Prosobranchia	Prosobranch	+	+	+	+	+
Subclass Heterobranchia						

Order Pteropoda						
Family Creseidae	*Creseis sp.*			+		
Phylum Arthropoda						
Subphylum Chelicerata						
Class Arachnida						
Subclass Acari	Acari			+		
Subphylum Crustacea						
Class Branchiopoda						
Subclass Phyllopoda						
Order Diplostraca						
Family Chydoridae	Aloninae				+	
Class Hexanauplia						
Subclass Copepoda						
Order Calanoida						
Other Calanoid	Calanoid	+				
Order Canuelloida						
Family Longipediidae	*Longipedia sp.*	+	+			
Order Cyclopoida						
Family Oithonidae	*Oithona sp.*			+		
Family Sapphrinidae	*Sapphrina sp.*				+	
Other Cyclopoida	Cyclopoid	+				
Order Harpacticoida						
Family Leptastacidae	*Leptastacus sp.*	+		+		
Family Peltidiidae	*Clytemnestra sp.*	+	+	+	+	
Family Tachidiidae	*Euterpina sp.*	+	+			+
Family Thalestridae	*Parathalestis sp.*			+		
Other Harpacticoida	Harpacticoids	+	+	+	+	+
Harpacticoida larvae	nauplius	+	+			
Copepoda larvae	copepod nauplius	+	+	+		
Subclass Thecostraca	cirripedia nauplius			+	+	
Class Malacostraca						
Subclass Eumalacostraca						
Order Amphipoda	Gammarids					+
Order Cumacea	Cumacean					+
Order Syncarida	Syncarida	+	+		+	+
Order Tanaidacea	Tanaidae		+			+
Class Oligostraca						
Subclass Mystacocarida						
Order Mystacocaridida						
Family Derocheilocarididae	*Derocheilocaris sp.*		+			+
Class Ostracoda						
Subclass Myodocopa						

Order Halocyprida						
Family Polycopidae	*Polycope sp.*			+		+
Subclass Podocopa						
Order Podocopida						
Family Cyprididae	*Cypridopus vidua* (O.F. Müller, 1776)	+	+	+	+	+
Family Cytherideidae	*Cytherura sella* Sars, 1866	+		+	+	
Family Cytheruridae	cypris larvae	+	+	+	+	
Other Ostracod				+	+	+
Phylum Chordata						
Subphylum Tunicata						
Class Appendicularia						
Order Copelata						
Family Fritillaridae	*Appendicularia sp.*	+				

Appendix C. Checklist of all Taxonomic Groups Recorded from the Meiofaunal Samples Collected in the Intertidal Waters around Qatar, Stations 6-10 (Station Numbers Correspond to Locations as Indicated in Table 1)

Classification	**Taxon**	**6**	**7**	**8**	**9**	**10**
Phylum Rotifera						
Class Eurotatoria						
Subclass Bdelloidea						
Family Philodinidae	*Philodina sp.*	+				+
Subclass Monogononta						
Order Ploima						
Family Trichocercidae	*Trichocerca sp.*			+	+	
Family Notommatidae	*Enteroplea sp.*				+	
Phylum Loricifera	Loricifera					+
Phylum Ciliata	Ciliates			+		
Phylum Gastrotricha						
Order Macrodasyida						
Family Thaumastodermatidae	*Thaumastoderma sp.*				+	
Phylum Gnathostomulidae	Gnathostomulidae		+	+	+	+
Phylum Brachiopoda						
Class Lingulata						
Order Lingula						
Family Lingulidae	Lingula larvae				+	
Phylum Nematoda						
Class Enoplea						
Order Enoplida	Enoplid A	+	+	+	+	+
	Enoplid C		+	+	+	+
	Enoplid B		+	+	+	+
Phylum Annelida						
Class Polychaeta						
Subclass Errantia						
Order Phyllodocida						
Family Hesionidae	Hesionidae		+	+		
Subclass Sedentaria						
Order Terebellidae						
Family Opheliidae	*Armandia sp.*	+	+			
Trocophore larvae	Trocophore		+			
Other Annelida (*incertae sedis*)	Aeolosomatidae		+	+		
Phylum Nemertea	**Nemertina**		+			

Phylum Platyheminthes						
Subphylum Rhabditophora						
Order Rhabdocoela						
Infraorder Eukalyptorhynchia	Eukalyptorhynchia				+	
Family Polycystidae	*Gyratrix sp.*	+			+	+
Class Turbellaria	Turbellarian	+	+	+		+
Phylum Mollusca						
Class Bivalvia	Bivalve juvenile	+	+	+	+	
Subclass Caenogastropoda						
Order Littorinimorpha	Juvenile				+	+
Subclass Prosobranchia	Prosobranch	+	+	+	+	+
Subclass Heterobranchia						
Order Pteropoda						
Family Creseidae	*Creseis sp.*		+			
Phylum Tardigrada	Tardigrada					+
Phylum Arthropoda						
Subphylum Chelicerata						
Class Arachnida						
Subclass Acari	Acari	+	+			
Subphylum Crustacea						
Class Branchiopoda						
Subclass Phyllopoda						
Order Diplostraca						
Family Chydoridae	Aloninae			+	+	+
	Chydorus sp.		+		+	
Class Hexanauplia						
Subclass Copepoda						
Order Calanoida						
Family Paracalanidae	*Paracalanus sp.*				+	
Family Pseudodiaptomidae	*Pseudodiaptomus sp.*		+			
Order Cyclopoida						
Family Corycaeidae	*Corycaeus sp.*				+	
Family Oithonidae	*Oithona sp.*				+	
Family Oncaeidae	*Oncaea sp.*		+			
Family Sapphrinidae	*Sapphrina sp.*		+	+		+
Order Harpacticoida						
Family Ectinosomatidae	*Arenosetella sp.*					+
Family Leptastacidae	*Leptastacus sp.*		+			+
Family Peltidiidae	*Clytemnestra sp.*		+	+	+	+
Family Tachidiidae	*Euterpina sp.*		+	+		
Family Thalestridae	*Parathalestis sp.*				+	
Family Tisbidae	*Tisbe sp.*				+	

Other Harpacticoida	Harpacticoids		+	+	+	+
Harpacticoida larvae	nauplius					+
Copepoda larvae	copepod nauplius		+		+	
Copepoda juvenile	copepodite				+	
Subclass Thecostraca	cirripedia nauplius		+			
Class Malacostraca						
Subclass Eumalacostraca						
Order Syncarida	Syncarida	+	+	+		+
Order Tanaidacea	Tanaidae		+			
Class Oligostraca						
Subclass Mystacocarida						
Order Mystacocaridida						
Family Derocheilocarididae	*Derocheilocaris sp.*		+	+		+
Class Ostracoda						
Subclass Podocopa						
Order Podocopida						
Family Cyprididae	*Cypridopus vidua* (O.F. Müller, 1776)		+	+	+	+
Family Cytherideidae	*Cytherura sella* Sars, 1866			+		
Family Cytheruridae	cypris larvae	+	+	+	+	+
Other Ostracod			+	+		
Ostracod larvae					+	
Phylum Chordata						
Subphylum Tunicata						
Class Appendicularia						
Order Copelata						
Family Fritillaridae	*Appendicularia sp.*					

Appendix D. Checklist of all Taxonomic Groups Recorded from the Meiofaunal Samples Collected in the Intertidal Waters around Qatar, Stations 11 – 15 (Station Numbers correspond to locations as indicated in Table 1)

Classification	**Taxon**	**11**	**12**	**13**	**14**	**15**
Phylum Rotifera						
Class Eurotatoria						
Subclass Bdelloidea						
Family Philodinidae	*Philodina sp.*			+	+	+
Phylum Loricifera	Loricifera			+	+	
Phylum Ciliata	Ciliates					+
Phylum Gnathostomulidae	Gnathostomulidae			+		
Phylum Cnidaria						
Class Hydrozoa						
Subclass Hydroidolina	Hydroids				+	
Phylum Nematoda						
Class Enoplea						
Order Enoplida	Enoplid A		+	+	+	+
	Enoplid B	+	+			
Phylum Annelida						
Class Polychaeta						
Subclass Errantia						
Order Phyllodocida						
Family Hesionidae	Hesionidae			+	+	+
Subclass Sedentaria						
Order Terebellidae						
Family Opheliidae	*Armandia sp.*		+			+
Family Spionidae	Spionidae					+
Other Polychaete	Polychaete			+		
Other Annelida (incertae sedis)	Aeolosomatidae					+
Phylum Nemertea	Nemertina	+				
Phylum Platyheminthes						
Subphylum Rhabditophora						
Order Rhabdocoela						
Family Polycystidae	*Gyratrix sp.*				+	
Class Turbellaria	Turbellarian	+		+	+	+
Phylum Mollusca						
Class Bivalvia	Bivalve juvenile	+	+			+
Subclass Caenogastropoda						
Order Littorinimorpha	Juvenile	+	+			
Subclass Prosobranchia	Prosobranch	+	+		+	+

Subclass Heterobranchia						
Family Rhodopidae	*Rhodope sp.*	+				
Order Pteropoda						
Family Creseidae	*Creseis sp.*	+				
Phylum Tardigrada	Tardigrada			+		+
Phylum Arthropoda						
Subphylum Crustacea						
Class Branchiopoda						
Subclass Phyllopoda						
Order Diplostraca						
Family Chydoridae	Aloninae		+			+
Class Cephalocarida	Cephalocarida			+		
Class Hexanauplia						
Subclass Copepoda						
Order Calanoida						
Family Paracalanidae	*Paracalanus sp.*	+				
Family Pontellidae	*Calanopia sp.*		+			
Family Pseudodiaptomidae	*Pseudodiaptomus sp.*		+			
Family Tortanidae	*Tortanus sp.*	+				
Other Calanoid	Arcocalanus	+				
Other Calanoid	Calanoid	+	+			
Order Cyclopoida						
Family Oithonidae	*Oithona sp.*		+			
Family Oncaeidae	*Oncaea sp.*	+				+
Order Harpacticoida						
Family Leptastacidae	*Leptastacus sp.*					+
Family Peltidiidae	*Clytemnestra sp.*	+				+
Family Tachidiidae	*Euterpina sp.*		+	+		+
Family Thalestridae	*Parathalestis sp.*		+			
Other Harpacticoida	Harpacticoids	+		+		+
Harpacticoida larvae	nauplius			+		+
Copepoda larvae	copepod nauplius	+	+		+	+
Class Malacostraca						
Subclass Eumalacostraca						
Order Syncarida	Syncarida				+	
Order Tanaidacea	Tanaidae			+		+
Class Oligostraca						
Subclass Mystacocarida						
Order Mystacocaridida						
Family Derocheilocarididae	*Derocheilocaris sp.*					+
Class Ostracoda						
Subclass Podocopa						

Order Podocopida						
Family Cyprididae	*Cypridopus vidua* (O.F. Müller, 1776)	+	+			+
Family Cytherideidae	*Cytherura sella* Sars, 1866	+	+			
Family Cytheruridae	cypris larvae		+			+
Other Ostracod		+	+			+

Appendix E. Checklist of all Taxonomic Groups Recorded from the Meiofaunal Samples Collected in the Intertidal Waters around Qatar, Stations 16 – 20 (Station Numbers correspond to locations as indicated in Table 1)

Classification	**Taxon**	**16**	**17**	**18**	**19**	**20**
Phylum Rotifera						
Class Eurotatoria						
Subclass Bdelloidea						
Family Philodinidae	*Philodina sp.*	+	+		+	+
Phylum Loricifera	Loricifera		+	+		+
Phylum Ciliata	Ciliates					+
Phylum Gnathostomulidae	Gnathostomulidae			+		
Phylum Cnidaria						
Class Hydrozoa						
Subclass Hydroidolina	Hydroids					+
Phylum Nematoda						
Class Enoplea						
Order Enoplida	Enoplid A	+	+	+	+	+
	Enoplid C		+	+	+	+
	Enoplid B			+		
Phylum Annelida						
Class Polychaeta						
Subclass Errantia						
Order Eunicidae						
Family Lumbrineridae	Lumbrinereid					+
Order Phyllodocida						
Family Hesionidae	Hesionidae	+	+	+	+	+
Family Nereididae	Nereidae				+	
Family Syllidae	Syllidae					+
Subclass Sedentaria						
Order Terebellidae						
Family Opheliidae	*Armandia sp.*				+	+
Family Spionidae	Spionidae	+			+	+
Polychaete juvenile	Polychaete juvenile				+	+
Other Polychaete	Polychaete				+	
Trocophore larvae	Trocophore				+	
Other Annelida (incertae sedis)	Aeolosomatidae	+			+	+
Phylum Platyheminthes						
Subphylum Rhabditophora						
Order Macrostomida	Macrostomid					+

Order Rhabdocoela						
Family Polycystidae	*Gyratrix sp.*					+
Class Turbellaria	Turbellarian	+	+	+	+	+
Phylum Mollusca						
Class Bivalvia	Bivalve juvenile	+	+	+	+	
Subclass Caenogastropoda						
Order Littorinimorpha	Juvenile		+	+		+
Subclass Prosobranchia	Prosobranch			+	+	+
Order Pteropoda						
Family Creseidae	*Creseis sp.*				+	
Phylum Tardigrada	Tardigrada	+	+			
Phylum Arthropoda						
Subphylum Chelicerata						
Class Arachnida						
Subclass Acari	Acari		+			
Subphylum Crustacea						
Class Branchiopoda						
Subclass Phyllopoda						
Order Diplostraca						
Family Chydoridae	Aloninae	+				+
	Chydorus sp.			+		
Family Podonidae	*Evadne sp.*				+	
Class Hexanauplia						
Subclass Copepoda						
Order Calanoida						
Family Pseudodiaptomidae	*Pseudodiaptomus sp.*				+	
Other Calanoid	Calanoid				+	
Order Canuelloida						
Family Longipediidae	*Longipedia sp.*					+
Order Cyclopoida						
Family Corycaeidae	*Corycaeus sp.*			+	+	
Family Oithonidae	*Oithona sp.*				+	
Family Oncaeidae	*Oncaea sp.*		+			
Family Sapphrinidae	*Sapphrina sp.*		+	+	+	+
Other Cyclopoida	Cyclopoid				+	
Order Harpacticoida						
Family Leptastacidae	*Leptastacus sp.*	+	+			+
Family Peltidiidae	*Clytemnestra sp.*		+		+	+
Family Tachidiidae	*Euterpina sp.*	+	+	+	+	+
Other Harpacticoida	Harpacticoids	+	+		+	+
Harpacticoida larvae	nauplius	+	+		+	+
Copepoda larvae	copepod nauplius	+	+	+	+	+

Copepoda juvenile	copepodite				+	
Subclass Thecostraca	cirripedia nauplius	+	+		+	
Class Malacostraca						
Subclass Eumalacostraca						
Order Cumacea	Cumacean				+	
Order Syncarida	Syncarida			+		+
Order Tanaidacea	Tanaidae	+	+		+	+
Class Oligostraca						
Subclass Mystacocarida						
Order Mystacocaridida						
Family Derocheilocarididae	*Derocheilocaris sp.*		+			+
Class Ostracoda						
Subclass Podocopa						
Order Podocopida						
Family Cyprididae	*Cypridopus vidua* (O.F. Müller, 1776)	+	+	+	+	+
Family Cytherideidae	*Cytherura sella* Sars, 1866			+		+
	Ostracod					
Family Cytheruridae	cypris larvae			+	+	+
Other Ostracod		+	+	+		
Phylum Chordata						
Subphylum Tunicata						
Class Appendicularia						
Order Copelata						
Family Fritillaridae	*Appendicularia sp.*					+