



# Benthic meiofaunal diversity and distribution in Nagapattinam coastal waters, India

A Tracy Austin Kumar, R Punniyamoorthy, S Mariyappan, Sasmita Swain, P Murugesan

Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, 608502, Tamil Nadu, India

Corresponding Author: [moorthykas24@gmail.com](mailto:moorthykas24@gmail.com)

## To Cite this Article

A Tracy Austin Kumar, R Punniyamoorthy, S Mariyappan, Sasmita Swain and P Murugesan. Benthic meiofaunal diversity and distribution in Nagapattinam coastal waters, India. *International Journal for Modern Trends in Science and Technology* 2022, 8 pp. 9-18. <https://doi.org/10.46501/IJMTST0801002>

## Article Info

Received: 15 November 2021; Accepted: 12 December 2021; Published: 29 December 2021

## ABSTRACT

In the present study, benthic meiofaunal diversity and distribution in Nagapattinam coastal waters was studied. A total of 40 meiobenthic species belonging to four meio-faunal taxa foraminiferans, nematodes, ostracods and harpacticoids were recorded with maximum density of meiofauna (428Nos/10cm<sup>2</sup>) in offshore station and minimum in estuarine station. Among the four meio-faunal taxa, foraminiferans topped the list with 24 species followed by nematodes (7 species), ostracods (6 species) and harpacticoids (3 species). Seasonally, the maximum number of meiofaunal species (31 species) was recorded at offshore stations during postmonsoon and minimum (19 species) was recorded at inshore stations during monsoon. CCA and BIO-ENV (Biota-Environmental matching) analysis showed that the environmental parameters such as DO, W, pH, salinity, sand, clay and TOC manifested as best match ( $q\omega = 0.948$ ) in determining meiofaunal distribution in the surveyed stations. The maximum species diversity (3.447) and evenness (0.995) was recorded at offshore station and similarly the maximum species richness (7.362) was recorded at inshore station. The results of present study helps to develop an understanding on the meiofaunal distribution based on physico-chemical parameters, which will form a reliable tool in bio-monitoring studies.

**KEYWORDS:** Meiofauna, density, diversity, Nagapattinam coast, India

## 1. INTRODUCTION

The ocean covers 71% of the Planet Earth and holds 97% of the Earth's water. It is a key ecosystem that encompasses most of the living space on Earth and plays several crucial roles that support the health of the planet and the livelihood of humans [1]. The environmental parameters such as temperature, salinity, dissolved oxygen and nutrients are of profound biological significance and are used as population indicators [2]. Benthic system regulates energy flow in aquatic ecosystems and therefore studies have been made in order to better understand the mechanisms of

the benthic ecosystem. Benthic faunal groups plays important role in benthic community processes such as bioturbation (organic decomposition, nutrient cycling, redistribution of organic material, oxygenation of the sediment) and also form an effective link in food web [3]. However, their large abundance attracts a large number of fin-fishes and shell fishes who visit the coastal belts at regular intervals in order to gain energy from the benthic habitats, mostly in the intertidal and sub tidal zones.

Meiofauna are generally, the interstitial benthic invertebrates are distinguished from macro benthos by

their smaller sizes and shares tremendous amount of total benthic biomass in marine habitats [4]. Meiofauna include both small metazoans (e.g., nematodes, ostracods, and harpacticoids) and ecologically relevant protists (e.g., foraminifera and ciliates) that inhabit all sediment types in all climatic zones [5, 6]. Physical factors such as tidal elevation and amplitude regulate various abiotic factors, such as temperature, salinity, dissolved oxygen, hydrodynamics, and sedimentary processes, which, in turn influence the diversity and distributions of meiofauna [7, 8]. Meiofauna are very important in marine ecosystems, since they facilitate bio-mineralization, support various higher trophic levels and show a high sensitivity to anthropogenic pressures, making them excellent group for pollution bio-monitoring studies [9].

In this backdrop, taking cognizance of the facts elaborated above, the present study has been made to investigate the spatial distribution of benthic meiofauna with special emphasis on the seasonal changes in environmental entities in Nagapattinam coastal waters, Southeast coast of India.

## 2. MATERIALS AND METHODS

### Study area

In the present study, the seasonal sampling was carried out in Nagapattinam coastal waters (10°45'16.43"N and 79°52'27.86"E) for a period of one year from April 2017 (Summer) to March 2018 (Post monsoon). Six sampling sites were selected based on the depth (Table 1, Fig. 1). The monthly data were amalgamated to seasons and the results are presented seasonally. The details of sampling stations are given below:

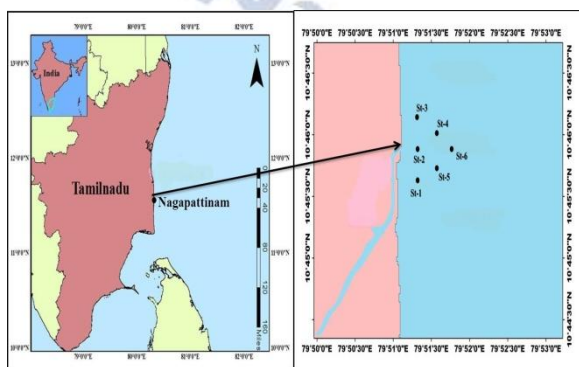


Fig. 1. Map showing the sampling stations in Nagapattinam coast water

Table 1. Geographical locations of sampling stations in Nagapattinam coast waters

Sl. No	Stations Code	Latitude	Longitude
1.	St-1	10°45'16.43"N	79°51'32.26"E
2.	St-2	10°45'49.55"N	79°51'32.84"E
3.	St-3	10°46'24.45"N	79°51'32.61"E
4.	St-4	10°46'14.45"N	79°52'30.53"E
5.	St-5	10°45'30.30"N	79°52'50.70"E
6.	St-6	10°45'57.05"N	79°52'27.86"E

### Water and sediment analysis

Measurements of temperature (hand-held mercury thermometer), salinity (Refractometer, ATAGO, Japan) and pH (pH pen, model LI-120, Eutech Instrument, Singapore) were recorded during each sampling event. Bottom water dissolved oxygen (DO) was estimated by using Winkler's method [10]. Undisturbed surface-sediment subsamples were shade dried for estimation of Petroleum Hydrocarbon (PHC), Total Organic Carbon (TOC) and sediment texture. The sediment grain-size analysis (i.e., sediment texture) was done by following pipette method of [11]. TOC estimation was done by following [12] and the level of heavy metals was detected by using Inductively Coupled Plasma Mass Spectrophotometer (AGILENT -7700x ICP-MS). Total petroleum hydrocarbon analysis in sediment sample was done by using the methods suggested by Laboratory Analytical Work Instruction, 2011.

### Benthic meiofauna analyses

For faunal analysis, a total of six surface three replicate sediment samples were collected using a Van Veen grab with a sampling area of 0.1m<sup>2</sup> in a depth ranging between 8.0 and 12.0 m (Fig. 1 & Table 1). Sub-sampling the top layer of each grab (~1 cm thick) taken and samples were then stored in cold box in sealed plastic bags. Sediment sub-samples (~100 g) for meiofauna analysis were placed in labeled plastic bags, immediately fixed in 4% buffered formalin in distilled water, and brought to the laboratory. The sediments were washed with tap water through a set of 0.5 mm and 0.063 mm sieves. The sediment retained on the 0.063 mm sieve was decanted to extract meiofauna following the methodology of [13]. Sorting of metazoan

meiofauna (foraminiferans, nematode, harpacticoids, and ostracods) from sediment was done by flotation and decantation using a sieve with 0.040 mm mesh size as the efficiency of this technique has been reported as 95% by various researchers [14, 15, 16]. The organisms retained on the sieve were placed into Petri dishes for sorting and preserved in 70% ethyl alcohol with 5% glycerol [17]. A few drops of Rose Bengal (1 g/l) were also added to this solution to facilitate the counting process. Subsequently, the sorted meiobenthic organisms were counted and identified to species level under a stereomicroscope (EISCO Stereo Binocular Microscope) by consulting the standard works of [18, 19, 20, 21, 22, 23, 24, 25] for foraminifera; [26, 27, 28, 29, 30, 31] for nematodes; [32, 33, 34] for ostracods; and [35, 36, 37] for harpacticoids. The numerical abundance of the meiofauna was expressed in individuals per 10 cm<sup>2</sup> [38].

### Statistical analysis

Environmental and meiofauna data were statistically treated using univariate, graphical/distributional and multivariate methods available in the statistical software PRIMER (Ver. 7.0) [39]. The diversity index (H') [40], richness index (d) [41], evenness (J') [42], and dominance (D) [43] were calculated using benthic meifaunal species abundance. To determine the correlation between the biological variables and environment, BIO-ENV matching ( $\rho_w$ ) was used [44]. The statistical package 'R' (v. 3.4.4; [45]) was used for Principal component analysis (PCA) to visualize correlation between the physico-chemical parameters and sampling stations and similarly, Canonical Correspondence Analysis (CCA) was also done to relate the abundance of meiofaunal taxa with linear representations of environmental variables.

## 3.RESULTS

### Physico-chemical characteristics of water and sediment

The values of physico-chemical parameters of water and sediment are summarized. Temperature ranged from 10.0 to 36.5°C and the minimum was recorded at St-3 during monsoon and maximum was at St-5 during summer. Salinity fluctuated between 15 and 35.5 ppt, with the minimum was recorded at St-2 during

monsoon and maximum was at St-6 during summer. Water pH varied from 8.35 at St-6 during summer and 8.13 at St-2 during premonsoon. Dissolved Oxygen (DO) ranged from 3.42 mg/l at St-5 during summer to 5.39 mg/l at St-2 during monsoon. In the sediments, the PHC ranged from 0.57 µg/g at St-1 during monsoon to 2.51 µg/g at St-2 during post-monsoon. TOC content ranged from 2.41 to 8.26 mgC/g with maximum was recorded at St-2 during monsoon and minimum was at St-6 during summer. Sand content ranged between 7.35 and 88.10%, with maximum value was recorded at St-2 during summer and minimum was at St-2 during monsoon; silt content varied from 6.40 to 31.15% with maximum was at St-4 during monsoon and minimum at St-3 in summer and the clay content in the sediment fluctuated between 6.40 and 74.45% with maximum (St-2) was in postmonsoon and minimum (St-6) in summer.

Lead content varied from 0.94 to 3.26 mg/kg with the maximum (St-2) in summer and minimum (St-6) in premonsoon. Copper values ranged between 1.14 and 5.18 mg/kg with the maximum was recorded during summer (St-2) and minimum during pre-monsoon (St-6). Cadmium varied from 2.09 to 4.27 mg/kg with the maximum level was recorded at St-3 during monsoon and minimum at St-5 during pre-monsoon. Chromium level varied from 0.65 ± 0.18 to 3.05 mg/kg and the maximum (St-2) was recorded during monsoon and minimum (St-6) during summer.

### Benthic Meiofauna

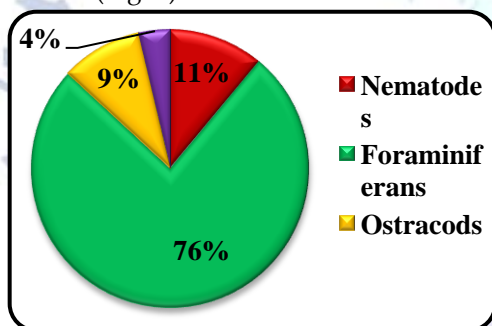
In the present study, as many as 41 species belonging to four groups of benthic meiofauna namely Foraminiferans, Nematodes, Ostracods and Harpacticoida were recorded in various stations in Nagapattinam coastal waters (Table 2). Among them, foraminiferans topped the list with 24 species; nematodes were found to be the next dominant group with 7 species; ostracods came next with 7 species and Harpacticoida came last with 3 species only.

Among the foraminiferans, *Ammonia beccarii*, *A. tepida*, *Bolivina limbata*, *Elphidium texanum*, *Rosalina globularis* and *Trochammina adaperata* were found commonly in various stations. With respect to nematodes, *Desmodora cambelli*, *Halalaimus filum* and *Astomonema jenneri* were found to be the common species in the surveyed stations. The ostracods species such as *Basslerites liebauti*, *Bairdoppilata scaura*, *Keijella*

*reticulate* and Harpacticoids, *Laophonte thoracica*, *Paramesochra dubia* and *Macrosetella gracilis* were found to be common in the surveyed stations. The maximum abundance was recorded at station St-6 with 428 ind./10 cm<sup>2</sup> during postmonsoon and the minimum was at St-2 with 117 ind/10 cm<sup>2</sup> during monsoon. Seasonally, the maximum number of meiofaunal species (31 species) was recorded at offshore station during post-monsoon and minimum (19 species) was recorded at inshore stations during monsoon.

#### Percentage contribution

The results of percentage composition of meiofauna revealed that foraminiferans constituted the maximum with 76% of the total meiobenthic organisms. Nematodes, ostracods and harpacticoids contributed with 11%, 9% and 4% respectively to the total meiobenthic samples collected from Nagapattinam coastal waters (Fig. 2).



**Fig. 2. Percentage contribution of meiofaunal groups recorded in various sampling stations of Nagapattinam coastal waters**

#### Diversity Indices

Shannon diversity ( $H'$ ) index showed minimum (2.815) at St-2 during monsoon and maximum (3.447) was at St-6 during postmonsoon. Margalef species richness ( $d$ ) showed lowest value (4.726) at St-4 during monsoon and highest (7.362) at St-2 during postmonsoon. Pielou's species evenness ( $J'$ ) varied between 0.528 and 0.874 with the minimum value in St-2 during monsoon and the maximum in St-6 during summer. Simpson dominance index varied from 0.586 to 0.841 with lowest in St-5 during monsoon and the highest in St-2 during postmonsoon (Table 3).

#### Statistical analyses

The principal component analysis was performed using physico-chemical parameters to set a well-defined distinction between the stations. The PCA plot revealed that St-4, St-5 and St-6 showed high correlation with

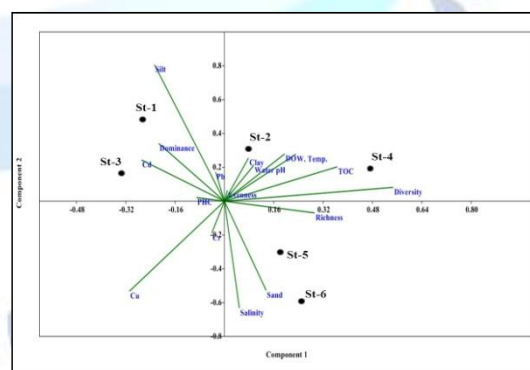
parameters such as DO, salinity, water pH, sand, evenness ( $J$ ) and diversity ( $H'$ ); while St-1, St-2 and St-3 negatively correlated with other parameters such as water silt, PHC and heavy metals (Fig. 3).

**Table 3. Diversity indices Shannon diversity ( $H'$ ); Margalef richness ( $d$ ), Pielou's evenness ( $J'$ ) and Simpson dominance ( $D$ ) calculated for Meiobenthos in Nagapattinam coastal waters**

Station	Shannon diversity ( $H'$ )	Margalef richness ( $d$ )	Pielou's evenness ( $J'$ )	Simpson dominance ( $D$ )
St-1	3.021	6.839	0.607	0.784
St-2	2.815	7.362	0.528	0.841
St-3	3.050	6.317	0.747	0.769
St-4	3.302	4.726	0.851	0.653
St-5	3.213	5.249	0.836	0.586
St-6	3.447	5.635	0.874	0.596

#### Statistical analyses

The principal component analysis was performed using physico-chemical parameters to set a well-defined distinction between the stations. The PCA plot revealed that St-4, St-5 and St-6 showed high correlation with parameters such as DO, salinity, water pH, sand, evenness ( $J$ ) and diversity ( $H'$ ); while St-1, St-2 and St-3 negatively correlated with other parameters such as water silt, PHC and heavy metals (Fig. 3).



**Fig. 3. Principal Component Analysis plot drawn for environmental parameters and meiofaunal diversity in Nagapattinam coastal waters**

**Table 2. Occurrence of meiofaunal species in various stations of Nagapattinam coastal waters**

Name of the species	S. Code	St-1	St-2	St-3	St-4	St-5	St-6
<b>Nematodes</b>							
<i>Daptonema conicum</i>	Dco	+	+	-	+	+	+
<i>Metadasynemallea</i> sp.	Msp	+	+	+	+	+	-
<i>Halalaimus filum</i>	Hfi	+	-	-	+	+	-
<i>Oxystomina clavicauda</i>	Ocl	+	-	+	+	+	+
<i>Enoplolaimus abnormis</i>	Eab	+	+	+	+	+	+
<i>Astomonema jenneri</i>	Aje	-	+	-	+	-	+
<i>Neocamacolaimus parasiticus</i>	Npa	-	+	+	+	+	+
<b>Foraminiferans</b>							
<i>Ammodiscus exsertus</i>	Aex	+	+	-	-	+	+
<i>Ammonia beccarii</i>	Abe	+	+	+	+	+	+
<i>A. tepida</i>	Ate	+	+	+	+	+	+
<i>Bolivina punctuate</i>	Bva	+	+	+	+	+	+
<i>B. vadeszens</i>	Bau	+	-	+	+	+	+
<i>Cancris auricula</i>	Cau	+	+	+	-	+	+
<i>Discorbinella bertheloti</i>	Dbe	+	+	-	+	+	+
<i>Edentostomina cultrata</i>	Ecu	-	+	+	-	+	-
<i>Elphidium advenum</i>	Ead	-	+	+	-	+	+
<i>Fissurina marginata</i>	Fma	+	+	+	+	-	-
<i>Globigerina globularis</i>	Ggl	+	+	-	+	+	-
<i>Globorotalia menardii</i>	Gme	+	+	+	-	+	+
<i>Lagena hispida</i>	Lhi	-	+	+	-	-	+
<i>Miliolinella semicostata</i>	Mse	-	+	+	-	+	+
<i>Quinqueloculina debenayi</i>	Qde	+	+	-	-	-	+
<i>Q. seminula</i>	Qse	-	+	+	+	+	-
<i>Q. zhengi</i>	Qzh	+	+	+	+	-	-
<i>Recurvoides trochamminiformis</i>	Rtr	+	+	+	-	-	-
<i>Rosalina globularis</i>	Rgl	+	+	-	+	-	-
<i>Spirillina limbata</i>	Sli	-	-	-	+	-	+
<i>S. tuberculata</i>	Stu	+	+	+	+	+	-
<i>Spiroloculina bradyi</i>	Sbr	+	+	-	+	+	+
<i>S. depressa</i>	Sde	+	+	+	+	+	+
<i>Trichohyalus aguayoi</i>	Tag	+	+	+	+	-	-
<b>Ostracods</b>							

<i>Basslerites liebauti</i>	Bli	-	+	-	-	+	-
<i>Paracytheroma sudaustralis</i>	Psu	+	+	+	-	+	-
<i>Keijella reticulata</i>	Kre	+	+	+	+	+	-
<i>Paracytherideis</i> sp.	Psp	+	+	+	-	-	+
<i>Stenocypris major</i>	Sma	+	+	-	+	+	-
<i>Microcytherura nigrescens</i>	Mni	-	-	+	-	+	-
<i>Tanella gracilis</i>	Tgr	+	-	+	-	-	+
<b>Harpacticoida</b>							
<i>Paramesochra dubia</i>	Pdu	-	+	-	+	+	+
<i>Macrosetella gracilis</i>	Mgr	+	+	+	+	-	+
<i>Tisbe furcata</i>	Tfu	+	-	+	-	+	-

**+: Present; -: Absent;**

The CCA analysis, which was done to find out the correlation among environmental parameters and species abundance, revealed that the vectors for most environmental parameters were relatively short, indicating their relatively limited variability and individual influence on the assemblages of benthic meiofauna. The total variance of the species-environment relationships and eigenvalues for axes 1 and 2 are 0.397, 0.318, 0.265, and 0.171 respectively. From the CCA plot, it was again evident that species such as *Ammonia beccarii*, *A. tepida*, *Bolivina limbata*, *Elphidium texanum*, *Quinqueloculina granulocostata*, *Rosalina globularis*, *Spirillina lateseptata*, *Spiroloculina excavate*, *Desmodora cambelli*, *Halalaimus filum*, *Astomonema jenneri*, *Basslerites liebauti*, *Neocytherideis senescens*, *Keijella reticulata*, *Paijenborchella cymbula*, *Macrosetella gracilis* got positively correlated with temperature, W. pH, salinity, dissolved oxygen, sand, clay, and total organic carbon at St-4, St-5 and St-6. It was also evident that species such as *Globorotalia hirsute*, *Lagena lacunata*, *Neowigerina hispida*, *Nonion grateloupi*, *Orbulina universa*, *Pararotalia ozawai*, *Sorites marginalis*, *Triloculina tricarinata*, *Trochammina adaperta*, *Oxystomina clavicauda*, *Enoplolaimus abnormis*, *Oxystomina clavicauda*, *Enoplolaimus abnormis*, *Bairdoppilata scaura*, *Stenocypris major*, *Laophonte thoracica*, *Paramesochra dubia* were negatively correlated to the silt, petroleum hydrocarbon and heavy metals at St-1, St-2 and St-3 (Fig. 4).



offshore stations (St-4, St-5 and St-6). The higher concentration of metals in nearshore stations could be attributed to the heavy rainfall and subsequent river runoff, bringing much industrial and land derived materials along with domestic, municipal, and agricultural wastes, which include residue of heavy metal containing pesticides. [54, 55, 56] also reported similar range of heavy metal distribution in Ennore estuary and [57] in Karaikal coastal waters. The values recorded in the present study are comparable to the reports made by [58, 59, 60] from Uppanar estuary, India.

With respect to faunal entities, a total of 41 meiofaunal species belonging to four groups of meiobenthos organisms namely Foraminiferans, Nematodes, Ostracods and Harpacticoids were recorded. Among them, Foraminiferans topped the list with 24 species. Nematodes were found to be the next dominant group in the order of abundance with 7 species. Ostracods and Harpacticoids came next with 6 and 3 species respectively. Among the foraminiferans, *Ammonia beccarii*, *A. tepida*, *Bolivina limbata*, *Spiroloculina excavate*, *Rosalina orbicularis* and *Spirillina lateseptata* were found commonly in various stations. With respect to nematodes, *Astomonema jenneri* and *Halalaimus filum* were found to be the common species in the samples collected in various stations. The ostracods species such as, *Basslerites liebau* and *Bairdoppilata scaura* harpacticoids, *Harpacticus chelifer* and *Laophonte thoracica* were found to be common species in the surveyed stations. The lower diversity and density of meiofauna was recorded in nearshore stations, which might be due to the freshwater influx and shallow depth, leading to unfavorable environment for meiofaunal population. Similar range of meio-faunal density was also reported earlier by [61] in East coast of the Yucatan peninsula (Mexico); [62] in Red Sea coast, Sudan.

Species diversity can be an expression of the environmental stress on benthic meiofaunal assemblages, with higher diversity in more stable environments. Species diversity and evenness value was found minimum in nearshore stations during monsoon and maximum in offshore stations during summer season, which might be due to the influence of freshwater influx, temperature and low salinity as reported earlier by [63]. Similar range of meiofaunal diversity values were also reported by [64] from Conero

coast, Adriatic. Species richness and dominance showed minimum value at offshore stations during pre-monsoon and higher value in nearshore stations in summer. Similar trend was also observed by [65] from Dongsha Lagoon, China. BIO-ENV and CCA results displayed a good ordination pattern with a combination of temperature, dissolved oxygen, salinity and pH in the distribution and composition of meiofaunal species in the surveyed stations. Similar trend was also observed by [66] from the Moorea, French Polynesia and [67] from Cuddalore coast, India.

## 5. CONCLUSION

The present study provided base line information about the diversity and distribution of meiofauna along the Nagapattinam coastal waters and further the present findings also contribute additional knowledge on the influence of seasonal variation on the meiofaunal assemblage, since only a minimum studies are available on this aspects in Indian coastal waters. Analysis of data undertaken with conventional tools like univariate and multivariate methods clearly revealed the healthy nature of the coasts and species estimation showed that the sample size of present study is quite adequate for the efforts taken to document all the meiofaunal species occurring in the surveyed coast. Moreover, this study also emphasized that temperature, DO, salinity and pH are the most important factors determining the distribution of meiofauna in Nagapattinam coastal waters.

## Acknowledgements

Authors are grateful to the Director & Dean, CAS in Marine Biology & authorities of Annamalai University for providing necessary facilities.

## Conflict of interest statement

Authors declare that they do not have any conflict of interest.

## REFERENCES

- [1] World Health Organization (WHO). World Health Statistics 2012. Geneva: WHO. Available from: [http://www.who.int/gho/publications/world\\_health\\_statistics/EN\\_WHS2012\\_Full.pdf](http://www.who.int/gho/publications/world_health_statistics/EN_WHS2012_Full.pdf)
- [2] Head, J.D. and Zerner, M.C., 1985. A Broyden—Fletcher—Goldfarb—Shanno optimization procedure for molecular geometries. *Chemical physics letters*, 122(3); 264-270.
- [3] Tenore, K.R., 1977. Utilization of aged detritus derived from different sources by the polychaete *Capitella capitata*. *Marine Biology*, 44(1), pp.51-55.

- [4] Zeppilli, D., Sarrazin, J., Leduc, D., Arbizu, P.M., Fontaneto, D., Fontanier, C., Gooday, A.J., Kristensen, R.M., Ivanenko, V.N., Sørensen, M.V. and Vanreusel, A., 2015. Is the meiofauna a good indicator for climate change and anthropogenic impacts?. *Marine Biodiversity*, 45(3), pp.505-535.
- [5] Urban-Malinga, B., Drgas, A., Gromisz, S. and Barnes, N., 2014. Species-specific effect of macrobenthic assemblages on meiobenthos and nematode community structure in shallow sandy sediments. *Marine biology*, 161(1), pp.195-212.
- [6] Sergeeva, N. G., Ürkmez, D., Dovgal, I. V., and Sezgin, M., 2017. Protists (Ciliophora, Gromiida, Foraminifera) in the Black Sea meiobenthic communities: *Journal of the Black Sea/Mediterranean Environment*, v. 23, p. 121–155.
- [7] Górska, B., Grzelak, K., Kotwicki, L., Hasemann, C., Schewe, I., Soltwedel, T., and Włodarska-Kowalczyk, M., 2014. Bathymetric variations in vertical distribution patterns of meiofauna in the surface sediments of the deep Arctic Ocean (HAUSGARTEN, Fram strait): Deep Sea Research, Part I: Oceanographic Research Papers, v. 91, p. 36–49.
- [8] Majdi, N., Threis, I., and Traunspurger, W., 2017. It's the little things that count: Meiofaunal density and production in the sediment of two headwater streams: *Limnology and Oceanography*, v. 62, p. 151–163.
- [9] Bakshi, A. and Panigrahi, A.K., 2018. A comprehensive review on chromium induced alterations in fresh water fishes. *Toxicology reports*, 5, pp.440-447.
- [10] Strickland, J.D.H., Parsons, T.R., 1972. A Practical Handbook of Seawater Analysis. 2nd edn. Fisheries Research Board of Canada Bull. 167 Alger Press, 310 pp.
- [11] Krumbein, W. C., and Pettijohn, F. J., 1938. Manual of Sedimentary Petrology: Appleton-Century-Crofts, Inc., New York, 549 p.
- [12] Topping, G., 1972. Heavy metals in shellfish from Scottish waters. *Aquaculture*. 1, 379–384.
- [13] Higgins, R. P., and Thiel, H., 1988. Introduction to the Study of Meiofauna: Smithsonian Institution Press, Washington, D.C., 488 p.
- [14] Somerfield, P. J., and Warwick, R. M., 1996. Meiofauna in marine pollution monitoring programmes. A laboratory manual: Directorate of Fisheries Research (MAFF), Lowestoft, UK, 71 p.
- [15] Danovaro, R., Gambi, C., Luna, G. M., and Mirto, S., 2004. Sustainable impact of mussel farming in the Adriatic Sea (Mediterranean Sea): Evidence from biochemical, microbial and meiofaunal indicators: *Marine Pollution Bulletin*, v. 49, p. 325–333.
- [16] Giere, O., 2009. Meiobenthology: The Microscopic Motile Fauna of Aquatic Sediments. 2: Springer-Verlag, Berlin, p. 373–415.
- [17] Tolhurst, T. J., Defew, E. C., and Dye, A., 2010. Lack of correlation between surface macrofauna, meiofauna, erosion threshold and biogeochemical properties of sediments within an intertidal mudflat and mangrove forest: *Hydrobiologia*, v. 652, p. 1–13.
- [18] Loeblich Jr, A.R., and H. Tappan, 1994. Foraminifera of the Sahul Shelf and Timor Sea. *Cushman Found. Foram. Res., Spec. Pub.*, 31pp.
- [19] Coccioni, R., Frontalini, F., Marsili, A. and Mana, D., 2009. Benthic foraminifera and trace element distribution: a case-study from the heavily polluted lagoon of Venice (Italy). *Marine Pollution Bulletin*, 59(8-12), pp.257-267.
- [20] Frontalini, F., Coccioni, R. and Bucci, C., 2010. Benthic foraminiferal assemblages and trace element contents from the lagoons of Orbetello and Lesina. *Environmental monitoring and assessment*, 170(1), pp.245-260.
- [21] Mohan, P. M., Dhivya, P., and Narayanamurthy, K., 2013. Distribution of live planktonic and benthic foraminifera in the shelf off Port Blair and Hut Bay, Andaman group of islands, India, in *Ecology and Conservation of Tropical Marine Faunal Communities*: Springer, Berlin, p. 19–42.
- [22] Loeblich, A. R., Jr., and Tappan, H., 2015. Foraminiferal Genera and Their Classification: Van Nostrand Reinhold, New York, 970 p.
- [23] Brunović, D., Miko, S., Ilijanić, N., Peh, Z., Hasan, O., Kolar, T., Šparica Miko, M. and Razum, I., 2019. Holocene foraminiferal and geochemical records in the coastal karst dolines of Cres Island, Croatia. *Geologia Croatica*, 72(1), pp.19-42.
- [24] Ballesteros-Prada, A., 2019. Modern Benthic Foraminifera “Phylum Foraminifera (D’Orbigny 1826)” of the Panama Bight: A Census Report Based on Thanatocoenoses from the Continental Slope. In *Advances in South American Micropaleontology* (pp. 175-213). Springer, Cham.
- [25] Hayward, B.W., Coze, F.L., Vandepitte, L. and Vanhorne, B., 2020. Foraminifera in the World Register of Marine Species (Worms) taxonomic database. *Journal of Foraminiferal Research*, 50(3), pp.291-300.
- [26] Chitwood, M. B., 1958. A redescription of *Anatrichosoma cynamolgi* Smith and Chitwood, 1954, in *Proceedings of the Helminthological Society of Washington*, v. 25, p. 112–117.
- [27] Lamshead, P. J. D., 2004. Marine nematode biodiversity, in Chen, Z. X., Chen, S. Y., and Dickson, D. W. (eds.), *Nematology, Advances and Perspectives*: ACSE-TUP Book Series, p. 436–467.
- [28] De Ley, P., De Ley, I. T., Morris, K., Abebe, E., Mundo-Ocampo, M., Yoder, M., Heras, J., Waumann, D., Rocha-Olivares, A., Jay Burr, A. H., and Baldwin, J. G., 2005. An integrated approach to fast and informative morphological vouchering of nematodes for applications in molecular barcoding: *Philosophical Transactions of the Royal Society B: Biological Sciences*, v. 360, p. 1945–1958.
- [29] Poinar, G., 2008. Global diversity of hairworms (Nematomorpha: Gordiacea) in freshwater: *Hydrobiologia*, v. 595, p. 79–83.
- [30] Vovlas, N., Troccoli, A., Palomares-Rius, J. E., De Luca, F., Liébanas, G., Landa, B. B., Subbotin, S. A., and Castillo, P., 2011. *Ditylenchus gigas* n. sp. parasitizing broad bean: A new stem nematode singled out from the *Ditylenchus dipsaci* species complex using a polyphasic approach with molecular phylogeny: *Plant Pathology*, v. 60, p. 762–775.
- [31] Ahmed, M., Sapp, M., Prior, T., Karssen, G., and Back, M., 2015. Nematode taxonomy: From morphology to metabarcoding: *Soil Discussions*, v. 2, p. 1175–1220.
- [32] Brouwers, E. M., Cronin, T. M., Horne, D. J., and Lord, A. R., 2000. Recent shallow marine ostracods from high latitudes: Implications for late Pliocene and Quaternary palaeoclimatology: *Boreas*, v. 29, p. 127–142.
- [33] Tanaka, G., 2008. Recent benthonic ostracod assemblages as indicators of the Tsushima Warm Current in the southwestern Sea of Japan: *Hydrobiologia*, v. 598, p. 271–284.
- [34] Yasuhara, M., Stepanova, A., Okahashi, H., Cronin, T. M., and Brouwers, E. M., 2014. Taxonomic revision of deep-sea Ostracoda from the Arctic Ocean: *Micropaleontology*, v. 60, p. 399–444.

- [35] Huys, R., and Boxshall, G. A., 1991. Copepod Evolution. London (United Kingdom): Ray Society, London, 159 p.
- [36] Wells, J. B. J., 2007. An annotated checklist and keys to the species of Copepoda Harpacticoida (Crustacea): Zootaxa, v. 1568, p. 1–872.
- [37] Yeom, J., and Lee, W., 2020. A new species of the genus *Sarsamphiascus* Huys, 2009 (Copepoda: Harpacticoida: Miraciidae) from a sublittoral zone of Hawaii: PeerJ, v. 8, p. 8506.
- [38] Fernando, S. A., Khan, S. A., and Kasinathan, R., 1983. Observations on the distribution of benthic fauna in Vellar estuary, Porto Novo: Mahasagar, Bulletin of National Institute of Oceanography, v. 16, p. 341–348.
- [39] Clarke, K. R., Somerfield, P. J., and Gorley, R. N., 2016. Clustering in non-parametric multivariate analyses: Journal of Experimental Marine Biology and Ecology, v. 483, p. 147–155.
- [40] Shannon, C. E., and Weaver, W., 1949. The Mathematical Theory of Communication: University of Illinois Press, Urbana, 117 p.
- [41] Margalef, R., 1958, Information Theory in Biology, General Systems Yearbook, v. 3, p. 36–71.
- [42] Pielou, E. C., 1966, The measurement of diversity in different types of biological collections: Journal of Theoretical Biology, v. 13, p. 131–144.
- [43] Simpson, E. H., 1949, Measurement of diversity: Nature, v. 163, p. 688.
- [44] Clarke, K. R., and Ainsworth, M., 1993. A method of linking multivariate community structure to environmental variables: Marine Ecology-Progress Series, v. 92, p. 205–219.
- [45] Oksanen, J., Guillaume Blanchet, F., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P., Stevens M. H. H., Szoecs, E., and Wagner, H., 2017. Vegan: Community Ecology Package: R package version 2.4–3.
- [46] Ellis, T.D. and Cushman, J.H., 2018. Indirect effects of a large mammalian herbivore on small mammal populations: Context-dependent variation across habitat types, mammal species, and seasons. *Ecology and evolution*, 8(23), pp.12115-12125.
- [47] Al-Dubai, T.A., Antoni, S., Al-Zubieri, A.G. and Majeed, J., 2017. Composition and Characteristic of the Surficial Sediments In The Southern Corniche Of Jeddah, Red Sea Coast. *Journal of Geoscience, Engineering, Environment, and Technology*, 2(1), pp.39-45.
- [48] Kucharska, B. and Olejnik, E., 2019. The Temperature Stability of Nanometric Multilayers of Copper and Chromium–Nickel Steel (Cu/310S). *International Journal of Thermophysics*, 40(4), pp.1-20.
- [49] Amao, A.O., Kaminski, M.A., Rostami, M.A., Gharaie, M.H.M., Lak, R. and Frontalini, F., 2019. Distribution of benthic foraminifera along the Iranian coast. *Marine Biodiversity*, 49(2), pp.933-946.
- [50] Nagendra, R. and Reddy, A.N., 2019. Benthic foraminiferal response to ecosystem pollution in the Uppanar Estuary, Tamil Nadu Coast, India. *Journal of the Geological Society of India*, 93(5), pp.555-566.
- [51] Rombouts, I., Beaugrand, G., Artigas, L. F., Dauvin, J.-C., Gevaert, F., Goberville, E., et al. (2013). Evaluating marine ecosystem health: case studies of indicators using direct observations and modelling methods. *Ecol. Indic.* 24, 353–365.
- [52] Martins, M.D.O., Almeida, T.C.M.D. and Domenico, M.D., 2015. Vertical distribution of meiofauna on reflective sandy beaches. *Brazilian Journal of Oceanography*, 63, pp.469-480.
- [53] Frontalini, F., Semprucci, F., du Châtelet, E.A., Francescangeli, F., Margaritelli, G., Rettori, R., Spagnoli, F., Balsamo, M. and Coccioni, R., 2014. Biodiversity trends of the meiofaunal and foraminiferal assemblages of Lake Varano (southern Italy). *Proceedings of the Biological Society of Washington*, 127(1), pp.7-22.
- [54] Ananthan, G., Sampathkumar, P., Palpandi, C. and Kannan, L., 2006. Distribution of heavy metals in Vellar estuary, Southeast coast of India. *Journal of Ecotoxicology & Environmental Monitoring*, 16(2), pp.185-191.
- [55] Karthikeyan, R., Vijayalakshmi, S. and Balasubramanian, T., 2007. Monthly variations of heavy metals and metal resistant bacteria from the Uppanar estuary (Southeast coast of India). *Res J Microbiol*, 2(1), pp.50-57.
- [56] Chitrarasu, P., Ali, A.J., Babuthangadurai, T. and Manickam, N., 2013. Studies on the heavy metal analysis of sediment at Ennore Estuary in Southeast coast of India. *Current Biotica*, 7(1/2), pp.1-7.
- [57] Jeshma, P., M. S. Gandhi and N. R. Rao. 2016. Benthic foraminifera and geochemical assessment of Puravadaiyanar and Vettar estuaries, Karaikal, southeast coast of India-Implication for pollution monitoring studies. *Reg. Stud. Mar. Sci.*, 9: 76-88
- [58] Kesavan, K. and V. Ravi, 2013. Heavy metal accumulation in molluscs and sediment from Uppanar Estuary, southeast coast of India. *Thalassas*, 29 (2): 15–22.
- [59] Gandhi, M. S. and A. S. Nathan. 2014. Benthic foraminifera and geochemical studies with influence on pollution studies along the coast of Cuddalore, Tamil Nadu-ITS, India. *Arab. J. Geosci.*, 7 (3): 917-925.
- [60] Nagendra, R. and Reddy, A.N., 2019. Benthic foraminiferal response to ecosystem pollution in the Uppanar Estuary, Tamil Nadu Coast, India. *Journal of the Geological Society of India*, 93(5): 555-566.
- [61] Pusceddu, A., Gambi, C., Corinaldesi, C., Scopa, M., and Danovaro, R., 2014. Relationships between meiofaunal biodiversity and prokaryotic heterotrophic production in different tropical habitats and oceanic regions: PLoS One, 9, p. 91056.
- [62] Khalil, A. S., 2019. Meiofauna of the Red Sea mangroves with emphasis on their response to habitat degradation: Sudan's mangroves as a case study, in *Oceanographic and Biological Aspects of the Red Sea*: Springer, Cham, p. 419–435.
- [63] Xuan Quang, N.G.O., Smol, N. and Vanreusel, A., 2013. The meiofauna distribution in correlation with environmental characteristics in 5 Mekong estuaries, Vietnam. *Cah. Biol. Mar.*, 54, pp.71-83.
- [64] Frontalini, F., Semprucci, F., Di Bella, L., Caruso, A., Cosentino, C., Maccotta, A., Scopelliti, G., Sbrocca, C., Bucci, C., Balsamo, M. and Martins, M.V., 2018. The response of cultured meiofaunal and benthic foraminiferal communities to lead exposure: Results from mesocosm experiments. *Environmental toxicology and chemistry*, 37(9), pp.2439-2447.
- [65] Chen, C. and Lin, H.L., 2017. Applying benthic foraminiferal assemblage to evaluate the coral reef condition in Dongsha Atoll lagoon. *Zoological studies*, 56.
- [66] Fajemila, O.T., Langer, M.R. and Lipps, J.H., 2015. Spatial patterns in the distribution, diversity and abundance of benthic

foraminifera around Moorea (Society Archipelago, French Polynesia). *PloS one*, 10(12), p.e0145752.

[67] Sigamani, S., Samikannu, M. and Alagiri, T.G., 2019. Assessment of Effluent Stressed Ecosystem of Cuddalore Coastal Waters—a Bio-Indicator Approach. *Thalassas: An International Journal of Marine Sciences*, 35(2), pp.437-449.

