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Diversity of meiobenthic polychaetes along the Tamil Nadu coast, India

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Original Article

Abstract

This study investigates the spatial and temporal variations of meiobenthic polychaete assemblages along the Tamil Nadu coast from April 2021 to November 2024. Benthic sampling at eight transects, each with near-shore and offshore stations with two replicate samples, revealed that Spionidae, especially *Prionospio polybranchiata*, dominated the community. Nearshore sites exhibited significantly higher diversity compared to offshore locations, correlating with environmental factors such as total organic carbon (TOC), sediment silt content, and dissolved oxygen. Of the total transects, Mahabalipuram stations displayed a unique community composition, characterised by the absence of Spionidae and presence of Syllidae and Sigalionidae, reflecting localised habitat heterogeneity linked to sediment characteristics and low TOC. Overall, the findings highlight the critical role of organic matter and sediment texture in shaping meiobenthic polychaete distribution and thereby emphasise the ecological significance of these taxa in coastal ecosystems. The study underscores the importance of integrated long-term monitoring to distinguish and also to ascertain the inter-annual variability from anthropogenic impacts along this dynamic coastline.

Keywords: *Meiobenthic polychaetes, Spionidae, Prionospio polybranchiata, spatial variation, temporal variation, total organic carbon*

Introduction

The study of marine meiobenthos began in the mid-1960s in the northwestern Black Sea (Vorobyova *et al*., 2008). Meiobenthos are microscopic, bottom-dwelling invertebrates, typically ranging in size from 20 to 100 µm (Majdi *et al*., 2020; 2022). They play a vital role in stimulating microbial organic matter mineralisation and nutrient cycling in sediments, which enhances nitrogen cycling and supports primary production (Aller, 1982; Ólafsson and Moore, 1990; Coull, 1999; Danovaro *et al*., 2007). Meiobenthic organisms also serve as a food source for higher trophic levels, with up to 75% of their production transferred to these levels in soft-bottom ecosystems (Brodnicke *et al.,* 2022). The meiobenthic community includes diverse taxa such as polychaetes, nematodes, copepods, and foraminiferans. Polychaetes, although traditionally considered macrobenthic, can occur in the meiobenthic fraction, especially as juvenile forms or small-bodied interstitial species (McIntyre, 1969; Kryvokhyzhyna *et al*., 2022). These organisms serve as an important transitional group between meiofaunal and macrofaunal communities, with ecological significance that warrants clarification of their size-based distinction.

Polychaetes are abundant and diverse in benthic ecosystems, with studies on meiobenthic polychaetes being limited (Shah and Mohan, 2021). These species, inhabiting interstitial spaces in sediment, are highly adaptable and possess specialised morphological features for their lifestyle (Giere, 2009). Early studies on meiobenthic polychaetes were conducted by Rao (1972) and Westheide (1977), with later studies expanding on distribution and diversity patterns (Rao and Misra, 1983; Westheide, 1991; Villora-Moreno, 1997). Research from the Chennai coast (Kesavaraj *et al*., 2024) and the Aamayizhanchan Canal (Sumesh and Abraham, 2024) highlights the role of polychaetes in ecosystem functioning and their potential as bioindicators. Similarly, studies around the Andaman–Nicobar archipelago (Gopal *et al*., 2020) emphasise their contribution to ecosystem dynamics across various habitats. Despite these findings, significant knowledge gaps remain regarding the diversity of meiobenthic polychaetes along the Tamil Nadu coast. The present study aims to explore the diversity and inter-annual variations of these polychaetes to better understand their distribution and environmental relationships.

Material and methods

Study area

The present study was conducted along the Tamil Nadu coastline. A total of eight transects perpendicular to the shoreline were fixed in the following coastal belt: Ennore, Adyar, Mahabalipuram, Puducherry, Cuddalore, Parangipettai, Karaikal, and Thoothukudi. Each transect comprised two sampling sites representing distinct hydrographic regimes: a nearshore (NS) site, located within 0.5–2 km from the coastline, and an offshore (OS) site, situated in deeper waters 3–10 km from the shoreline. Sixteen sampling stations were fixed. This sampling design was made in such a way as to consider horizontal environmental gradients, from areas strongly influenced by anthropogenic activities to relatively pristine open coastal waters (Fig. 1).

Sample collection

Sampling was conducted annually from April 2021 to December 2024 to ascertain both spatial and temporal variations in meiobenthic polychaete communities along the Tamil Nadu coast. At each site, sediment samples were collected using a Van Veen grab sampler covering an area of 0.4 m^2, then meiobenthic samples were collected with a corer covering an area of 12.5 cm^2. From each station, two replicate sediment samples were collected and stored in a zip-lock cover and brought to the shore. Sediments were sieved through a two-stage sieving system: collected sediment samples initially sieved with a 1mm mesh sieve for collecting the macrobenthos, if any, and later with a 63 µm mesh, following the standard meiobenthic extraction protocols (Holme and Macintyre, 1972). The sieve remains were preserved in 70% ethanol along with a few drops of Rose Bengal stain to facilitate easy spotting of specimens during sorting and identification. In the laboratory, sediment samples were processed carefully to maintain structural integrity and minimise sample loss. Accordingly, benthic specimens were meticulously sorted using fine tungsten needles and a brush, then assessed for morphological characters critical for taxonomic identification. The meiobenthic polychaetes obtained from sediment samples were carefully examined under a Leica DM 2500 LED compound microscope. Meiobenthic polychaetes were identified to the lowest possible taxonomic level using authoritative references and standard taxonomic keys, including Southern (1921), Fauvel (1953) and Day (1967).

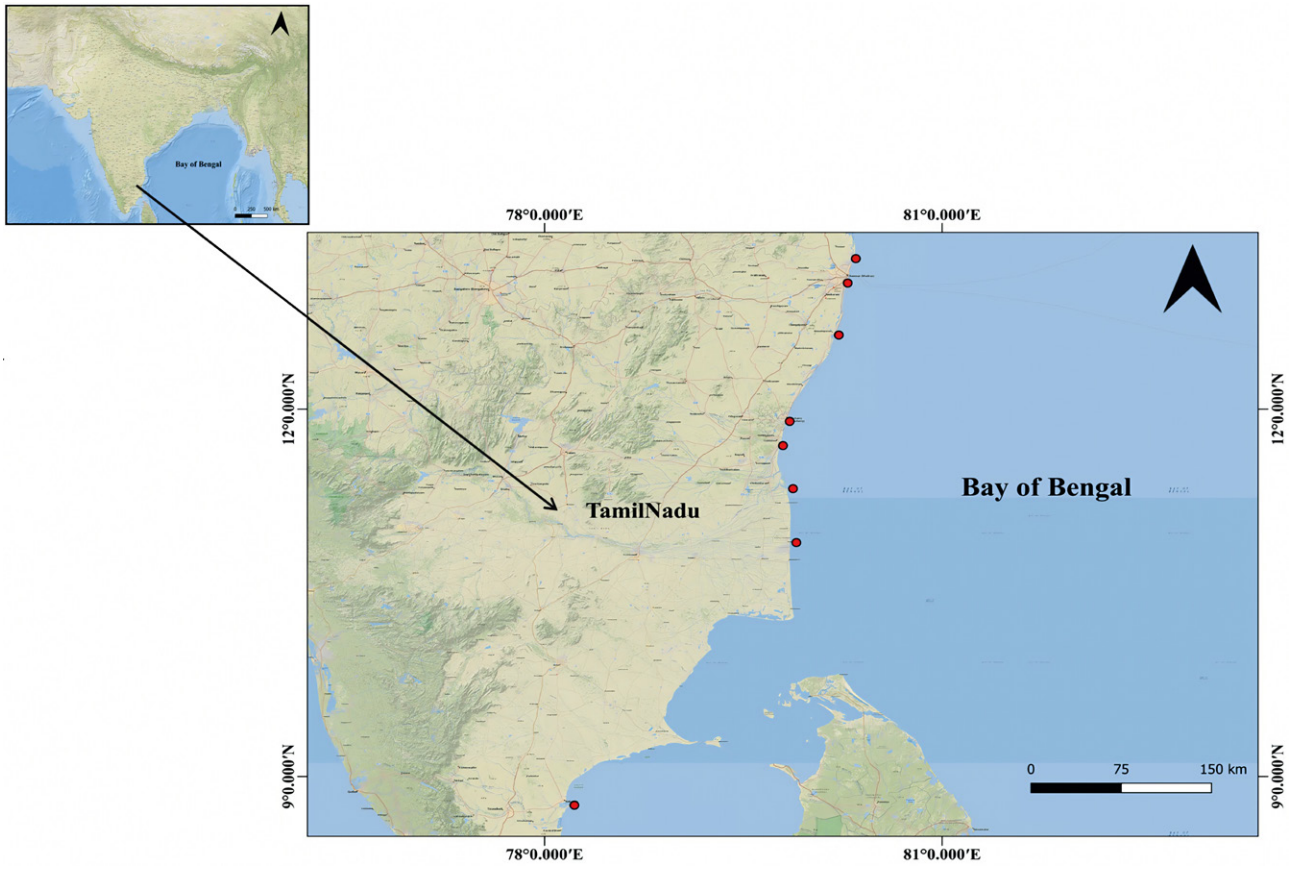

Fig. 1. Map showing sampling sites at Tamil Nadu Coastal waters

The abundance of meiobenthic polychaetes was recorded as the number of individuals per core and standardised to individuals per 1 m^2 of sediment.

Analysis of environmental parameters

In parallel, the water samples were taken from the respective stations to measure salinity (ppt), temperature (°C), pH, dissolved oxygen (DO, mg L^{-1}), sediment texture and Total Organic Carbon (TOC) analyses to characterise sediment composition and organic matter, respectively, using the Walkley–Black method (Gaudette *et al.*, 1974).

Data analysis

Quantitative analyses of meiofauna included species diversity and dominance indices. Multivariate community analyses were also performed using PRIMER v7 software. Cluster analyses and ordination techniques, including non-metric multidimensional scaling (MDS), were employed to visualise relationships spatially and temporally. SIMPER test was also computed to find out the similarity/dissimilarity in meiobenthic community composition among stations. Correlations between environmental variables and polychaete community patterns were assessed using the BIO-ENV routine, providing insight into environmental drivers of spatial and temporal variability.

Results

Environmental characteristics

Physico-chemical parameters measured in water and sediment samples across 16 stations along the Tamil Nadu coast over three years (I: 2021–2022, II: 2022–2023, III: 2023–2024) (NS: Nearshore, OS: Offshore) showed clear spatial and temporal variability. Salinity varied from 31.74 ppt at I-Thoothukudi-NS to a maximum of 34.49 ppt at I-Mahabalipuram-OS and II-Mahabalipuram-NS. Water temperature ranged between 27.07 °C at I-Ennore-NS and 30.04 °C at I- and III-Puducherry-NS. pH values remained relatively stable across all stations, ranging from 7.90 to 8.01. Dissolved oxygen (DO) exhibited a pronounced spatial gradient, with the lowest value recorded at I-Mahabalipuram-NS (2.71 mg/l) and the highest at II-Parangipettai-NS and III-Parangipettai-OS (6.53 mg/l). Sediments were predominantly sandy, with sand fractions generally exceeding 85–95%, particularly at nearshore stations such as Mahabalipuram and Puducherry, ranging from 99.42% at I-Puducherry-NS to 2.37% at III-Parangipettai-OS. Silt content showed wide variation, from 0.28% at I-Puducherry-NS to 89.81% at III-Parangipettai-OS, while clay fractions remained consistently low (0.30–7.72%). Total organic carbon (TOC) concentrations ranged from 2.22 mgC/g at I-Puducherry-OS to a maximum of 18.41 mgC/g at II–III-Parangipettai-NS during the study period.

Community structure

A total of 19 species of meio-benthic polychaete species were recorded throughout the study period (2021–2024) from the selected stations along the Tamil Nadu coast. Among the species collected, members of Spionidae were found to be dominant with 6 species, followed by Sigalionidae with 5 species, Syllidae and Cossuridae came next in the order with 2 species each and lastly Cirratulidae, Capitellidae, Melinnidae and Phyllodocidae with 1 species each. Among the stations, the maximum species (6) was found in Adyar and Parangipettai (Near shore station) in 2022-23, Karaikal (Near shore) in 2023-24, and the minimum (2) was at mostly offshore stations. Looking at the species composition, *Prinospio polybranchiata, Paraprionospio lamellibranchia* (juvenile) were the dominant species found in almost all the stations except Mahabalipuram. Overall, the density varied from

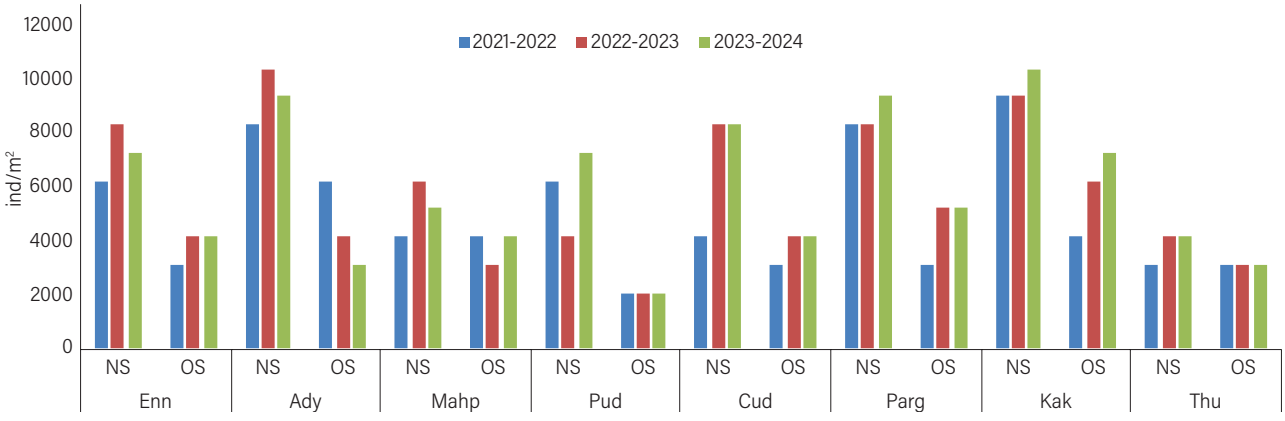

Fig. 2. Density of meiobenthic polychaetes recorded at different sampling stations during the study period. Sampling stations categorised as nearshore (NS) and offshore (OS), including Ennore (Enn), Adyar (Ady), Mahabalipuram (Mahp), Puducherry (Pud), Cuddalore (Cud), Parangipettai (Parg), Karaikal (Kak), and Thoothukudi (Thu)

2083 ind/m^2 at Puducherry (Offshore) for all three years to 10,417 ind/m^2 during 2022-23 (Adyar- Near shore), and 2023-24 (Karaikal- Near shore).

Over the years, the density varied from 79,167 ind/m^2 in 2021-22 to 94,793 ind/m^2 in 2023-24. Spatially, in near-shore stations, the minimum density (3125 ind/m^2) was recorded in Thuthukudi during 2021-22 and the maximum (10,417 ind/m^2) in Adyar during 2022-23 and in Karaikal during 2023-24. Similarly, when the values were looked at offshore stations, a minimum density of 2083 ind/m^2 was recorded in Puducherry during 2021-24, and a maximum of 7291 ind/m^2 was in Karaikal during 2023-24 (Fig. 2).

Diversity indices (Table 1) revealed a clear spatial and temporal variation. The Shannon- diversity index varied from 0.56 to 1.7 with minimum was in Ennore (off shore) and Cuddalore (off shore) during 2022-23 and maximum was in Parangipettai (Nearshore) during 2022-23 was in Parangipettai (Nearshore) during 2022-23; Margalef's species richness ranged from a minimum of 0.12, recorded in offshore samples from Mahabalipuram and Karaikal during 2021–22, Ennore and Cuddalore offshore during 2022–23, and Ennore offshore during 2023–24, to a maximum of 0.55 at the Parangipettai nearshore station during 2022–23; Pielou's evenness ranged from 0.81 to 1 with minimum at Off shore regions in Ennore and Cuddalore during 2022-23 and in Ennore during 2023-24; Simpson dominance index was found to vary from 0.37 to 0.81 with minimum in the samples collected Off shore regions of Ennore and Cuddalore in 2022-23 and in Ennore during 2023-24 and maximum at Paranipettai (Nearshore) during 2022-23 (Table 1).

The SIMPER analysis revealed that average within-group similarity was 29.33%, 34.81%, 33.42% for I, II and III

Table 1. Diversity indices of meiobenthic polychaetes recorded from coastal waters of Tamil Nadu during 2021–2024, including total number of species, total number of individuals, Shannon–Wiener diversity (H'), Margalef species richness (d), Pielou's evenness (J'), and Simpson's dominance (D). Sampling stations categorised as nearshore (NS) and offshore (OS), including Ennore (Enn), Adyar (Ady), Mahabalipuram (Mahp), Puducherry (Pud), Cuddalore (Cud), Parangipettai (Parg), Karaikal (Kak), and Thoothukudi (Thu)

Period	Sample	Total Species	Total Individuals	Margalef richness (d)	Pielou's evenness (J')	Shannon Diversity H'(log2)	Simpson Dominance (D)
2021-2022	Enn-NS	3	6250	0.23	0.92	1.01	0.61
	Enn-OS	3	3125	0.25	1	1.09	0.67
	Ady-NS	4	8333	0.33	0.87	1.21	0.66
	Ady-OS	3	6250	0.23	0.92	1.01	0.61
	Mahp-NS	3	4167	0.24	0.95	1.04	0.62
	Mahp-OS	2	4167	0.12	1	0.69	0.51
	Pud-NS	3	6250	0.23	0.92	1.01	0.61
	Pud-OS	2	2083	0.13	1	0.69	0.52
	Cud-NS	3	4167	0.24	0.95	1.04	0.62
	Cud-OS	3	3125	0.25	1	1.09	0.67
	Parg-NS	4	8333	0.33	0.95	1.32	0.72
	Parg-OS	2	3125	0.13	0.92	0.64	0.44
	Kak-NS	4	9375	0.33	0.88	1.21	0.67
	Kak-OS	2	4167	0.12	1	0.69	0.51
	Thu-NS	3	6250	0.23	0.92	1.01	0.61
	Thu-OS	3	3125	0.25	1	1.09	0.67
2022-2023	Enn-NS	5	8333	0.44	0.93	1.49	0.75
	Enn-OS	2	4167	0.12	0.81	0.56	0.37
	Ady-NS	6	10417	0.54	0.95	1.69	0.81
	Ady-OS	3	4167	0.24	0.95	1.04	0.62
	Mahp-NS	4	6250	0.34	0.96	1.33	0.72
	Mahp-OS	2	3125	0.13	0.91	0.64	0.44
	Pud-NS	3	4167	0.24	0.95	1.04	0.62
	Pud-OS	2	2083	0.13	1	0.69	0.52
	Cud-NS	4	8333	0.33	0.95	1.32	0.72
	Cud-OS	2	4167	0.12	0.81	0.56	0.37
	Parg-NS	6	8333	0.55	0.97	1.73	0.81
	Parg-OS	4	5208	0.35	0.96	1.33	0.72
	Kak-NS	4	9375	0.33	0.88	1.21	0.67
	Kak-OS	4	6250	0.34	0.96	1.33	0.72
	Thu-NS	3	4167	0.24	0.95	1.04	0.62
	Thu-OS	2	3125	0.13	0.92	0.64	0.44

Period	Sample	Total Species	Total Individuals	Margalef richness (d)	Pielou's evenness (J')	Shannon Diversity H'(log2)	Simpson Dominance (D)
2023-2024	Enn-NS	5	7292	0.45	0.96	1.55	0.77
	Enn-OS	2	4167	0.12	0.81	0.56	0.37
	Ady-NS	4	9375	0.33	0.94	1.31	0.71
	Ady-OS	2	3125	0.13	0.92	0.64	0.44
	Mahp-NS	3	5208	0.23	0.86	0.95	0.56
	Mahp-OS	3	4167	0.24	0.95	1.04	0.62
	Pud-NS	4	7292	0.34	0.92	1.28	0.69
	Pud-OS	2	2083	0.13	1	0.69	0.52
	Cud-NS	5	8333	0.44	0.93	1.49	0.75
	Cud-OS	3	4167	0.24	0.95	1.04	0.62
	Parg-NS	5	9375	0.44	0.95	1.52	0.76
	Parg-OS	3	5208	0.23	0.86	0.95	0.56
	Kak-NS	6	10417	0.54	0.95	1.70	0.8
	Kak-OS	5	7292	0.45	0.92	1.47	0.73
	Thu-NS	3	4167	0.24	0.95	1.04	0.62
	Thu-OS	2	3125	0.13	0.92	0.64	0.44

years, respectively. Across the years, the assemblage was overwhelmingly formed by a single dominant species, *Prinospio polybranchiata*, which contributed the largest proportion of within-group similarity as 66.98%, 72.24% and 72.90% respectively in I, II & III years. Two other species *Paraprionospio lamellibranchi* (juvenile) and *Capitella singularis* (juvenile), were the next most important contributors, typically > 85% similarity during the study period. In 1st Year (2021–2022), the average similarity was 29.33% with contributors *P. polybranchiata* with 66.98%, *P. lamellibranchia* (juvenile) with 18.34% and *C. singularis* (juveniles) with 10.33%. During II Year (2022–2023), average similarity was 34.81%; *P. polybranchiata* remained dominant by contributing 72.24%, and with moderate contributions from *P. lamellibranchia* (juvenile) (8.12%), *C. singularis* juveniles (4.37%) and *Parapionosyllis subterranea* (4.25%). During the 3rd year (2023–2024), the average similarity was 33.42%; *P. polybranchiata* continued to contribute more with 72.90%, followed by *P. lamellibranchia* (juvenile) with 8.13% and *Polydora hornelli* with 4.17%, as these were the principal similarity drivers; *Sphaerosyllis minima* also contributed within the top five taxa (cumulative ~90.9%).

The average dissimilarity during I and II; I and III, and II and III years was 67.20%, 65.56% and 64.50%, respectively. The taxa most responsible for inter-year dissimilarity were consistently *P. lamellibranchia* (juvenile), *Prinospio polybranchiata* and *C. singularis* juveniles, supplemented by species such as *P. subterranea*, *Cossura* spp., *Ctenodrilus serratus*, *Polydora hornelli* and *Sphaerosyllis minima* depending on the pairwise comparison.

Average within-group similarity for nearshore (NS) and offshore (OS) samples was 33.45% and 31.59%, respectively. Nearshore samples showed greater taxonomic heterogeneity than offshore samples. NS assemblages were dominated by *P. polybranchiata* (Average. Similarity- 19.21), contributing 57.43%, followed by *P. lamellibranchia* (juvenile) with 15.86% and *Capitella singularis* juveniles with 8.68%. Several secondary taxa, namely *Parapionosyllis subterranea*, *Prionospio krusadensis*, *Pseudopolydora kempi*, also contributed cumulatively to nearshore similarity, reflecting higher diversity. With regard to OS, faunal assemblages were highly dominated by *Prinospio polybranchiata*, which alone accounted for 85.13% of within-group similarity, and a few other taxa contributed meaningfully. The average dissimilarity between NS and OS groups was 67.34%, with top contributors between these two being *P. lamellibranchia* (12.64%), *Capitella singularis* juveniles (9.95%) and *P. polybranchiata* (9.86%) followed by *Parapionosyllis subterranea*, *Cossura* spp., and *Sphaerosyllis minima* with a meagre.

The Bray–Curtis similarity (fourth-root transformed) clustering (Fig. 3) and corresponding non-metric multidimensional scaling (nMDS) (Fig. 4) jointly depicted a coherent pattern of moderate overlapping of years and shore types. Most of the NS and OS stations got clustered together from all three years, demonstrating overall structural stability in community composition. Interestingly, both nearshore and offshore stations of Mahabalipuram during all three years and that of Karaikal and Thoothukudi only in I year were found apart from the main clustering pattern, which might be due to the absence of spionidae.

The BIOENV (BEST) analysis was performed to identify the combination of environmental variables that best explains the variation observed in the biotic similarity matrix using Spearman's rank correlation. The environmental dataset

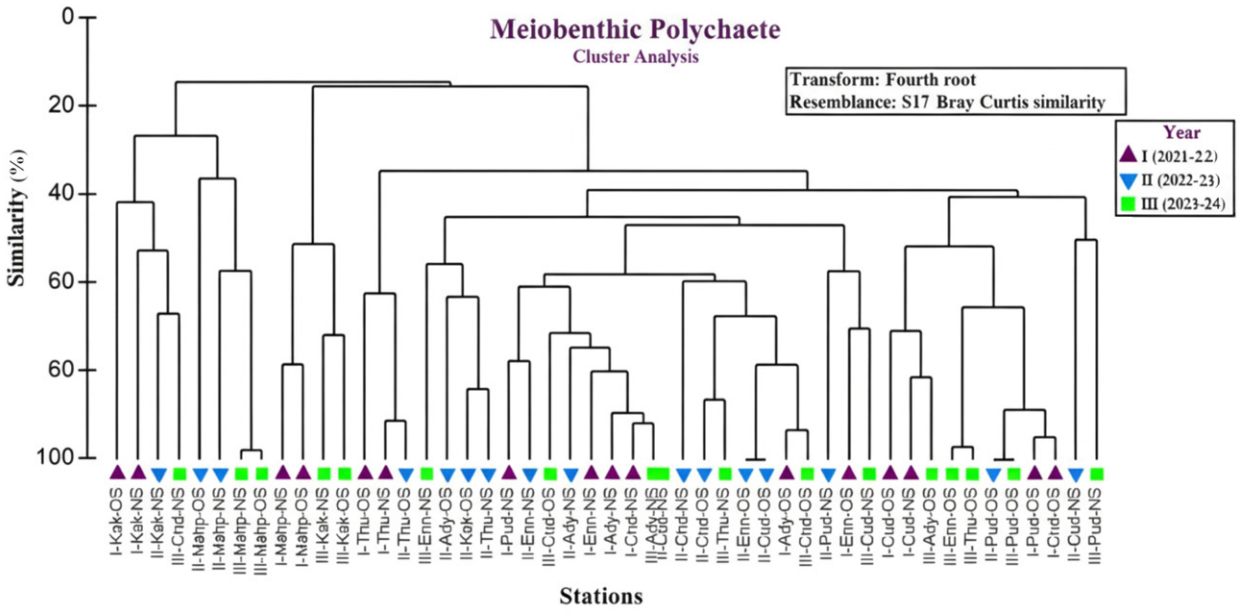

Fig. 3. Cluster analysis of meiobenthic polychaete abundance data collected over three years (2021–2024) from the coastal waters of Tamil Nadu. Sampling stations were categorised as nearshore (NS) and offshore (OS), including Ennore (Enn), Adyar (Ady), Mahabalipuram (Mahp), Puducherry (Pud), Cuddalore (Cud), Parangipettai (Parg), Karaikal (Kak), and Thoothukudi (Thu)

included nine variables: total organic carbon (TOC), total organic matter (TOM), sand, silt, clay, dissolved oxygen (DO), temperature, salinity, and pH. The resemblance among environmental samples was based on Euclidean distance. The BIOENV results revealed that, among the variables, TOC alone emerged as a single parameter showing the highest correlation ($\rho = 0.731$) with the biotic pattern. When combined variables were tested, Silt and TOC emerged as the best two-variable match with a correlation of $\rho = 0.652$. The top three-variable combination (TOC, silt, and DO) produced a correlation of $\rho = 0.649$. Further combinations of more than three variables did not significantly improve the correlation, indicating that TOC, either alone or in association with silt and DO, was the most influential environmental factor structuring the distribution of meiobenthic organisms biota (Table 2).

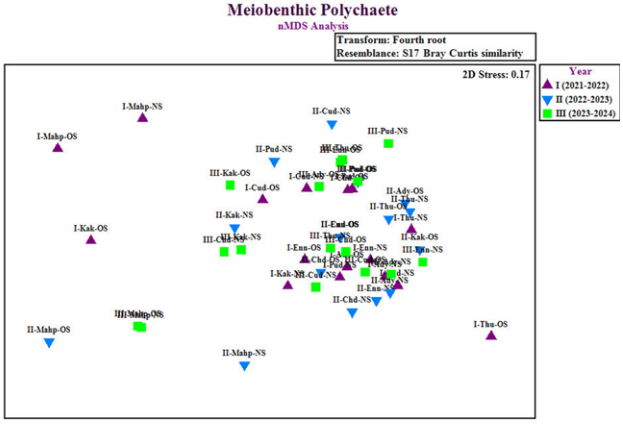

Fig. 4. Non-metric multidimensional scaling (nMDS) ordination of meiobenthic polychaete abundance data collected over three years (2021–2024) from coastal waters of Tamil Nadu. Sampling stations were categorised as nearshore (NS) and offshore (OS), including Ennore (Enn), Adyar (Ady), Mahabalipuram (Mahp), Puducherry (Pud), Cuddalore (Cud), Parangipettai (Parg), Karaikal (Kak), and Thoothukudi (Thu)

Table 2. Spearman rank correlation (pω) between meiobenthic polychaete abundance and environmental similarity matrices in various stations of Tamil Nadu coastal waters during 2021-2024. Environmental variables categorized as Total organic carbon (TOC*), Dissolve Oxygen (DO*), Temperature (Temp.*)

Variables	Correlati (pω)
TOC	0.731
Silt, TOC	0.652
TOC, Silt, DO	0.649
TOC, DO	0.633
Silt, TOC, Temp.	0.629
TOC, Silt, DO, Temp.	0.628

Discussion

The present study reveals clear spatial and temporal variation in meiobenthic polychaete assemblages along the Tamil Nadu coast, with distinct dominance patterns and environmental structuring across stations and years. Among the polychaete families recorded, Spionidae emerged as the most speciose and abundant group, consistent with their known adaptability to a wide range of sedimentary and organic conditions as stated by Blake (1996) and Taghon *et al.* (1980). Their dominance, particularly of *P. polybranchiata*, across all the years and stations underscores the opportunistic and

eurytopic nature of this taxon in organically enriched and fine-grained sediments. In their study, Vorobyova *et al.* (2008), on meiobenthic polychaetes in the northwestern Black Sea, reported similar dominance of spionids in shallow coastal environments, suggesting this family's prevalence in meiofaunal size classes may be a widespread phenomenon in productive coastal ecosystems globally. Notably, macrobenthic studies done during yesteryears from the Tamil Nadu coast have also documented overwhelming spionid dominance in adult polychaete assemblages (Joydas and Damodaran, 2009; Murugesan *et al*., 2018; Sivadas and Carvalho, 2020), with species such as *Prionospio* spp., *Polydora* spp., and *Paraprionospio* spp. consistently ranking among the most abundant taxa in shallow coastal sediments. The congruence between our meiofaunal findings and these macrobenthic patterns strongly suggests that the juvenile spionids documented in our study represent recruitment stages of the dominant macrofaunal populations, creating a vertically integrated community structure where spionids dominate across both size classes. This ontogenetic continuity with juveniles in the meiofaunal fraction transitioning to adults in the macrofaunal assemblage underscores the ecological and numerical importance of Spionidae throughout their life cycle in Bay of Bengal coastal ecosystems.

A total of 19 meiobenthic polychaete species recorded in the present study is comparable to the findings of Vorobyova *et al.* (2008), who reported 20 species in a similar kind of investigation in Black Sea. This similarity may be attributed to the fact that polychaetes constitute a relatively small component of the meiobenthic community compared to other meiofaunal groups. In the Indian context, across estuaries, canals, and nearshore shelf, meiobenthic polychaetes are reported to form ~3–11% of individuals, most often at the lower end (2–7%), with foraminifera or nematodes strongly dominating the taxa (Sumesh and Abraham, 2024). These observations collectively suggest that relatively low species richness of meiobenthic polychaetes is a common pattern one can see across different coastal systems, reflecting their subordinate contribution to overall meiobenthic diversity.

Univariate diversity indices indicated generally low to moderate species richness and diversity (Table 1), reflecting the smaller group of polychaete in the meiobenthic group, as polychaetes are mainly temporary meiobenthos (Ansari *et al*., 2012). The higher species diversity and richness at nearshore sites, particularly Parangipettai Nearshore suggests according to this study, this particulatr stations' habitats have offered favourable conditions, such as enhanced organic availability and sediment stability. Along the Aamayizhanchan Canal of Thiruvananthapuram City, Kerala, Sumesh and Abraham (2024) demonstrated similar dominance of meiobenthic polychaetes where organic matter and finer sediments were prevalent, with distributions strongly responding to organic carbon (C org), total organic matter (TOM), and carbohydrate content. Similarly, maximum evenness recorded at several offshore stations indicates relatively balanced species abundances where multiple taxa co-occurred, while low values at nearshore reflecting strong dominance (Table 1).

The density pattern further supports these observations, with nearshore stations exhibiting higher polychaete densities compared to offshore stations. The elevated densities recorded in nearshore habitats are plausibly associated with higher organic matter deposition and the prevalence of finer sediments, which providing conducive environment for detritivorous and tubicolous polychaete taxa such as *Prionospio* and *Paraprionospio* spp. The strong temporal stability in assemblage composition, as shown by similar within-year similarities (~30–35%) and repeated dominance by the same few species, suggests resilience of these opportunistic taxa under fluctuating coastal conditions. However, the observed interannual dissimilarities (64–67%) indicate subtle shifts in community composition, likely driven by episodic changes in sediment texture and organic matter input associated with monsoonal cycles, as well as localised anthropogenic disturbances such as sewage and industrial discharges and increased boating activity.

Spatially, nearshore (NS) assemblages exhibited greater taxonomic heterogeneity than offshore (OS), despite both being dominated by *Prionospio polybranchiata*. The contribution of secondary taxa such as *Paraprionospio lamellibranchia, Capitella singularis*, *Parapionosyllis subterranea*, and *Pseudopolydora kempi* at NS sites reflects microhabitat diversity and varying organic enrichment levels. The clustering (Fig. 3) and nMDS (Fig. 4) ordination revealed an overall structural stability in community composition, but the consistent outlier pattern of Mahabalipuram samples might be due to the replacement of Spionid polychaetes with Syllidae and Sigalionidae, indicating localised habitat heterogeneity.

The BIOENV analysis identified total organic carbon (TOC) as the single most influential environmental variable shaping meiobenthic polychaete assemblages, with the best correlations achieved when TOC was combined with silt and dissolved oxygen (Table 2). This finding corroborates the earlier studies emphasising the role of organic enrichment in structuring small-sized benthic fauna (Coull, 1999; Giere, 2009). The positive association between TOC and polychaete abundance indicates that moderate enrichment enhances food availability for deposit feeders.

The consistent absence of Spionidae at both nearshore and offshore stations of Mahabalipuram across all three years

represents a marked deviation from the general assemblage structure along the Tamil Nadu coast. Spionid polychaetes, particularly *Prionospio* and *Paraprionospio,* are typically associated with fine-grained, organically enriched sediments that favour tube-building and deposit-feeding strategies (To-Orn *et al*., 2015; Johnson *et al*., 2025). Their absence at Mahabalipuram suggests locally unsuitable sedimentary conditions, such as coarser substrates, lower organic matter availability, or increased sediment mobility, which may limit tube stability and feeding efficiency. In contrast, the dominance of Syllidae and Sigalionidae indicates a shift toward more mobile or predatory taxa adapted to heterogeneous or physically disturbed habitats. Similar taxonomic replacements under low organic enrichment or altered sediment conditions have been reported elsewhere, underscoring the role of fine-scale habitat heterogeneity in structuring meiobenthic polychaete assemblages. Targeted, site-specific studies are required to elucidate the precise environmental drivers underlying the distinctive meiobenthic assemblage structure observed at Mahabalipuram.

Added to this, Spionid polychaetes are widely recognised as effective bioindicators of organic enrichment, eutrophication, and certain forms of pollution in soft-sediment environments, particularly when assessed at the community level rather than through total abundance alone. Reviews of Latin American and Caribbean studies identify Spionidae as a key indicator family, with genera such as *Scolelepis*, *Spiophanes*, *Streblospio*, *Polydora*, and *Prionospio* frequently used in assessments of sediment disturbance and organic loading (Elías *et al*., 2020). However, species-specific responses within the family are well documented, with some spionids exhibiting high tolerance to organically enriched or reducing sediments, while others are more sensitive to environmental stressors (Agustina *et al*., 2018). Consequently, recent studies emphasise the use of spionids within multimetric or trait-based frameworks rather than as binary indicators of disturbance (Elías *et al*., 2020; Maximov and Berezina, 2023). In the present study, the dominance of spionid taxa across most stations, coupled with clear spatial differentiation in community composition revealed by nMDS, supports the interpretation that organic matter availability and sediment characteristics jointly structure meiobenthic assemblages, rather than spionid presence alone serving as a simple indicator of disturbance.

The observed spatial variability in meiobenthic polychaete assemblages highlights the sensitivity of these organisms to subtle changes in sedimentary and organic matter conditions. Many juvenile polychaetes pass through a short-lived meiobenthic phase that is closely linked to reproductive timing and bottom-water temperature, resulting in rapid shifts in local α-diversity under changing environmental conditions in black sea (Bondarenko and Vorobyova, 2023). Similarly, in the Matla River of Sundarbans estuary, meiobenthic communities are characterised by small body size, high abundance, short generation times, and limited mobility, making them particularly responsive to fine-scale variations in sediment characteristics and organic matter availability (Ghosh and Mandal, 2021). Earlier studies indicate that small, worm-shaped or actively swimming meiobenthic taxa respond rapidly to changes in substrate stability and organic enrichment, with community structure shifting under altered sediment and food conditions (Kryvokhyzhyna *et al*., 2022). Polychaetes are, therefore, widely recognized as effective bioindicators of environmental quality and anthropogenic disturbance across diverse marine regions (Elías *et al*., 2020), and functional trait-based approaches demonstrate that traits such as body size, mobility, and feeding mode reliably reflect gradients in organic matter, sediment composition, and habitat complexity (Charrier *et al*., 2022; Miri *et al*., 2023).

Overall, the present study highlights that meiobenthic polychaete assemblages along the Tamil Nadu coast are strongly influenced by organic enrichment and sediment characteristics. The recurrent dominance of Spionid polychaetes, particularly *Prionospio polybranchiata*, coupled with maximum diversity at nearshore stations, reflects a community typical of organically influenced coastal systems. However, continued monitoring, integrating environmental and biological indicators, is essential to assess long-term ecological changes and also to distinguish natural variability from anthropogenic impacts along this dynamic coastline.

Conclusion

The study concludes that meiobenthic polychaete assemblages along the Tamil Nadu coast exhibit clear spatial and temporal variations, with Spionidae, particularly *Prionospio polybranchiata*, dominating the community. Nearshore stations harboured significantly higher density and diversity compared to offshore sites, reflecting more favourable environmental conditions such as organic enrichment and sediment stability for the recoupment of meiobenthic polychaetes. The assemblage structure shows resilience over time but also subtle inter-annual shifts likely influenced by environmental fluctuations. Total organic carbon (TOC), along with silt and dissolved oxygen, emerged as the key environmental factors shaping these meiobenthic polychaetes. The absence of Spionidae and the appearance of other families like Syllidae and Sigalionidae at Mahabalipuram highlight localised habitat heterogeneity driven by sediment characteristics. The findings underscore the strong influence of organic matter and sediment texture on meiobenthic polychaete distribution, emphasising the ecological importance of these taxa in coastal

ecosystems and the need for integrated long-term monitoring to discern natural variability from anthropogenic impacts.

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Author contributions

Conceptualisation: SS, PM; Methodology: SS, RR, PM; Data Collection: SS; Data Analysis: SS, RR; Writing Original Draft: SS, RR; Writing Review and Editing: PM; Supervision: PM

Data availability

The data are available and can be requested from the corresponding author.

Conflicts of interest

The authors declare that they have no conflict of financial or non-financial interests that could have influenced the outcome or interpretation of the results.

Ethical statement

No ethical approval is required, as the study does not involve activities that necessitate ethical approval or involve protected organisms/human subjects, or the collection of samples from protected environments.

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