



## A STUDY ON MEIOFAUNAL ASSEMBLAGE IN RELATION TO ENVIRONMENTAL DEGRADATION ALONG THOOTHUKUDI COAST, TAMILNADU, INDIA

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### ABSTRACT

Significantly, this study examined the abundance and diversity of meiofauna in relation to environmental parameters across four selected stations along the Thoothukudi coast from October 2023 to March 2024. These stations were selected based on pollution gradients, with Station 1 serving as a reference site and Stations 2–4 being influenced by anthropogenic activities. The analysis focused on meiofaunal groups, including nematodes, copepods, polychaetes and foraminifera, alongside environmental variables; such as temperature, salinity, pH, dissolved oxygen and sediment organic carbon. The results revealed significant spatial and temporal variations, with nematodes dominating all stations (70–260 individuals per sample) but showing reduced abundance in the polluted Station 2 (25–130 individuals per sample), likely due to elevated temperatures (29–32°C) from thermal effluent discharge. Copepods exhibited a marked decline, underscoring their sensitivity to pollution. Key environmental stress markers included lower pH levels (7.6–8.5), indicating progressive acidification, while dissolved oxygen (3.4–4.5 ml/l) and organic carbon content (0.138–0.911 mgC/g) correlated strongly with shifts in meiofaunal assemblages. The findings highlight severe meiofaunal stress near sewage outfalls, particularly in Punnakayal, emphasizing the urgent need for long-term monitoring and targeted mitigation strategies to address coastal degradation in the region.

**Keywords:** Meiofauna, Thoothukudi coast, Environmental stress, Nematodes, Coastal pollution

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## 1. INTRODUCTION

Coastal ecosystems represent some of the most productive and ecologically significant environments on Earth, supporting high biodiversity while providing critical ecosystem services (Barbier *et al.*, 2011). Among the myriad organisms inhabiting these zones, meiofauna—microscopic benthic invertebrates ranging from 38 to 500  $\mu\text{m}$  in size—play a disproportionately important role in sediment biogeochemistry and nutrient cycling (Giere, 2009; Zeppilli *et al.*, 2015). These organisms, including nematodes, copepods, polychaetes and foraminifera, serve as vital links in benthic food webs while contributing significantly to organic matter decomposition (Coull, 1999; Schratzberger & Ingels, 2018). Their small size, rapid generation times and sensitivity to environmental changes make them particularly valuable as bioindicators of ecosystem health (Balsamo *et al.*, 2012; Moreno *et al.*, 2011).

The Gulf of Mannar region along India's southeast coast, where Thoothukudi is situated, represents a unique marine ecosystem recognized for its biodiversity (Kumaraguru *et al.*, 2005). This region supports extensive coral reefs, seagrass beds and mangrove forests that provide critical habitats for numerous marine species (Kannan *et al.*, 2023). The Thoothukudi coast, in particular, has experienced substantial ecological changes due to its status as a major industrial and port hub (Manokaran *et al.*, 2015).

Typically, the anthropogenic impacts on coastal ecosystems manifest through multiple stressors, including chemical pollution, organic enrichment, habitat modification and climate change effects (Halpern *et al.*, 2008). Along the Thoothukudi coast, major pollution sources include thermal power plant discharges (contributing to thermal pollution), industrial effluents containing heavy metals and other contaminants, domestic sewage inputs and port-related activities such as dredging and ballast water discharge (Joydas *et al.*, 2017; Ramesh *et al.*, 2019). These stressors can significantly alter sediment characteristics and water quality parameters that are critical for meiofaunal survival and distribution (Pusceddu *et al.*, 2007; Semprucci *et al.*, 2015).

Critically, temperature is an environmental parameter for meiofauna, as it directly influences its metabolic rates and life history strategies (Giere, 2009). The release of cooling waters from thermal power plants along the Thoothukudi coast has been documented to increase local seawater temperatures by 3-5°C above ambient levels (Suresh *et al.*, 2021). Such thermal modifications can result in substantial alterations in meiofaunal community structure, typically favoring thermotolerant species such as certain nematodes, while disadvantaging more sensitive groups like copepods (Austen *et al.*, 2009; Danovaro *et al.*, 2004).

Ocean acidification, driven by rising atmospheric CO<sub>2</sub> levels and localized pollution inputs, poses another escalating threat to coastal ecosystems (Doney *et al.*, 2009). The pH levels in Tuticorin's coastal waters have exhibited a declining trend over the past two decades, with current measurements ranging from 7.6 to 8.5, compared to historical values of 8.0-8.4 (Kalaiselvi *et al.*, 2022). This acidification can impact meiofauna both directly through physiological stress and indirectly by altering sediment chemistry and microbial communities that constitute the base of benthic food webs (Widdicombe & Spicer, 2008). Significantly, the organic enrichment from sewage and industrial discharges represents another stressor for Tuticorin's coastal ecosystems (Kalaiselvi *et al.*, 2022). While moderate organic inputs can enhance meiofaunal abundance by providing additional food resources, excessive enrichment often leads to hypoxic conditions that favor only the most tolerant species (Diaz & Rosenberg,



2008). Previous studies in similar environments have documented a shift from diverse meiofaunal communities to nematode-dominated assemblages under conditions of severe organic pollution (Schratzberger & Warwick, 1999; Moreno *et al.*, 2011).

Despite the ecological significance of meiofauna and the increasing environmental pressures on the Thoothukudi coast, comprehensive studies focusing on meiofaunal communities in this region remain limited (Joydas *et al.*, 2017). Most prior research has either concentrated on macrobenthic organisms or examined pollution impacts through chemical analyses without considering biological responses (Manokaran *et al.*, 2015; Ramesh *et al.*, 2019). This represents a significant knowledge gap given the demonstrated value of meiofauna as early warning indicators of ecosystem stress (Balsamo *et al.*, 2012; Schratzberger & Ingels, 2018). This study aims to address this gap by investigating meiofaunal assemblage structure in relation to key environmental parameters along the Thoothukudicoast. Specifically, this study delves with:

- (1) Spatial and temporal patterns in meiofaunal abundance and diversity across sites with varying pollution levels;
- (2) Relationships between meiofaunal community structure and environmental variables including temperature, salinity, pH, dissolved oxygen and organic carbon content; and
- (3) The potential of meiofaunal indices to serve as bioindicators of coastal degradation.

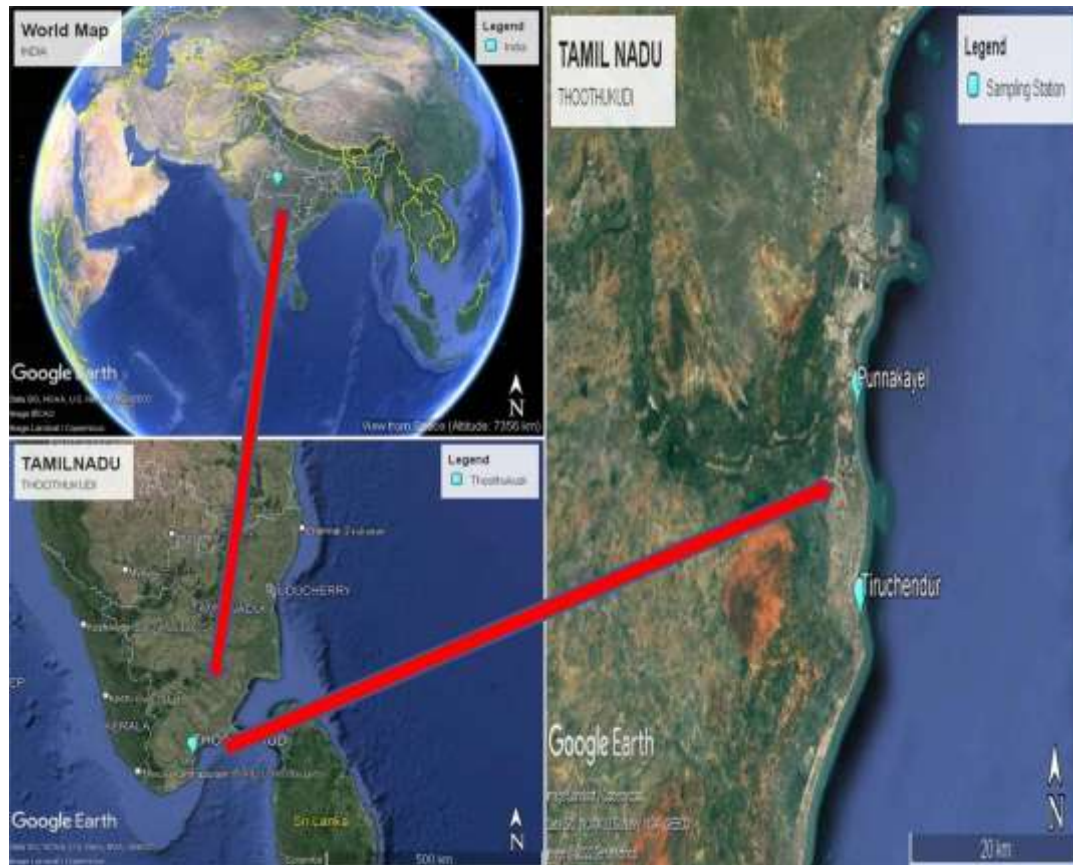
Surely, the findings will contribute to a better understanding of benthic ecosystem health in this anthropogenically impacted region while providing valuable baseline data for future monitoring efforts. From an applied perspective, results may inform coastal management strategies aimed at mitigating pollution impacts and preserving biodiversity in the Gulf of Mannar region.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The present study was conducted in the coastal region of Thoothukudidistrict (also known as Thoothukudi), located between latitudes 8°30' and 8°50'N and longitudes 78°5' and 78°20'E. This region is notable for being a major salt-producing area in India, contributing approximately 30% of the nation's total salt output. Covering an area of 4,621 km<sup>2</sup>, the district lies along the biologically diverse Gulf of Mannar. The 163.5 km stretch of coastline in Thoothukudisupports 21 fishing villages and hosts several industrial installations, including thermal power plants, a heavy water production facility and the state's second-largest seaport. Four sampling stations were strategically selected along a gradient of pollution to assess environmental and biological variations. Station 1 at Punnakayal (8°38'18.50"N; 78°07'41.69"E) served as the reference site, representing relatively pristine conditions. Station 2 at Tiruchendur (8°30'31.74"N; 78°07'31.36"E) was identified as being impacted by sewage discharge and was selected to represent anthropogenically influenced conditions. Figure 1 illustrates the geographical positioning of the sampling sites.





**Fig.1 Map showing study area**

## 2.2 Environmental Parameter Analysis

Environmental variables were assessed through monthly collections of interstitial water and sediment samples from October 2023 to March 2024, coinciding with the post-monsoon and pre-summer periods. All sampling was performed during low tide to ensure consistency in environmental conditions. Temperature was recorded using a mercury thermometer with a precision of  $\pm 0.1^{\circ}\text{C}$ . Salinity was determined using an ERMA hand refractometer. The pH levels of the sediment and overlying water were measured separately using a Takemura soil tester and standard pH paper strips, respectively. Dissolved oxygen (DO) concentrations were estimated following Winkler's titrimetric method as standardized by Strickland and Parsons (1972). Organic carbon content in the sediment was analyzed using the wet oxidation method described by Elwakeel and Riley (1957), which involves the chemical digestion of organic material to quantify its carbon content.

## 2.3 Meiofauna Sampling Protocol

To investigate meiofaunal communities, a standardized sampling design was adopted. At each station, three replicate samples were collected using a stainless-steel corer with a surface area of  $10\text{ cm}^2$  and a penetration depth of 10 cm. The core samples were carefully sectioned into two vertical layers (0–5 cm and 5–10 cm) to capture depth-wise distribution of meiofauna. Collected samples were preserved in the field using 4% buffered formalin stained with 0.1% Rose Bengal dye to aid in the visual identification of organisms under a microscope, as per the protocol established by Pfannkuche and Thiel (1988).



The meiofaunal organisms were extracted from sediment samples using the suspension-decantation method (Wieser, 1960), a technique that allows for the separation of fauna from sediment particles using repeated washing and sieving through a 62- $\mu\text{m}$  mesh. To facilitate the relaxation of the organisms and enhance recovery, sediment samples were pre-treated with a 7% magnesium chloride ( $\text{MgCl}_2$ ) solution, a method recommended by Neira and Rackemann (1996). This step helps in immobilizing the organisms without causing damage.

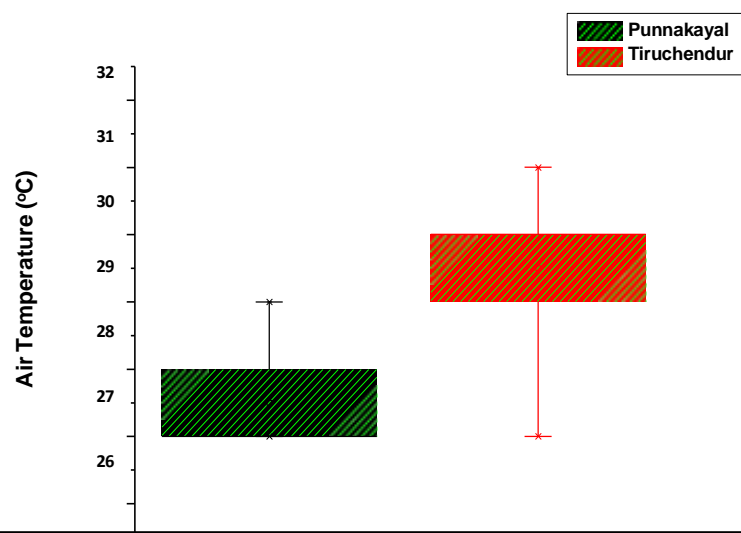
**Enumeration of meiofauna** was performed under a stereomicroscope following the guidelines of Altaff *et al.*, (2005). The major meiofaunal taxa—namely nematodes, copepods and polychaetes—were identified and counted, although species-level classification was not undertaken in this study. The data thus generated provided insights into the abundance and distribution patterns of dominant meiofaunal groups across different pollution gradients in the study area.

### 3. RESULTS AND DISCUSSION

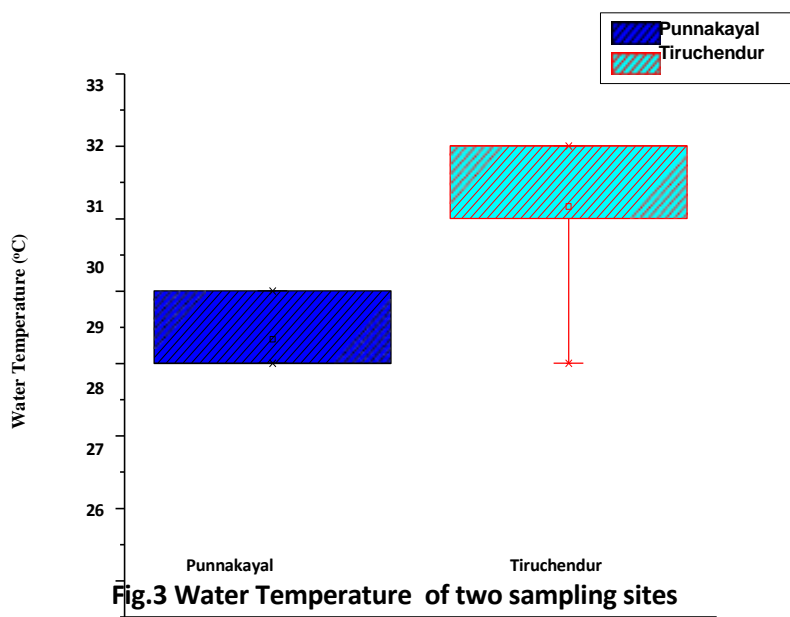
#### 3.1 Environmental Parameters and Anthropogenic Impacts

In this study, certain environmental parameters of interstitial water of the study locality; including temperature, salinity, pH, dissolved oxygen and organic carbon, were assessed during meiofauna collection. Anthropogenic activities such as industrial development, agriculture, mining, dredging and dumping introduce substantial pollutants into marine environments, creating significant ecological impacts (Balsamo *et al.*, 2012). These pollutants, whether from point or non-point sources can profoundly affect benthic organisms living within and at the sediment interface of the study areas. Benthic communities typically respond to adverse conditions through biological and morphological adaptations (Coull & Chandler, 1992).

The interstitial water temperature ranged from 29°C (Station 1, November 2023) to 32°C (Station 2, February-March 2024). Temperature serves as a crucial physical factor influencing chemical and biological processes in aquatic ecosystems; including photosynthesis rates (Manikannan *et al.*, 2011). The observed seasonal variations align with findings from multiple studies (Gupta *et al.*, 2008), showing higher temperatures during summer months (March-June) due to increased solar radiation and lower temperatures during monsoon season (November-January) because of cloud cover and rainfall. Notably, surface water temperature consistently exceeded



Punnakayal Tiruchendur  
**Fig.2 Air Temperature**



**Fig.3 Water Temperature of two sampling sites**

atmospheric temperature across all stations, reflecting water's greater heat retention capacity (Srilatha *et al.*,2012). These temperature patterns confirm established seasonal trends along southeast coastal ecosystems and demonstrate how thermal regimes influence physicochemical characteristics and biological distributions in coastal waters.

### 3.2 Environmental Parameters and Ecological Impacts

The study assessed key environmental parameters (temperature, salinity, pH, dissolved oxygen and organic carbon) in interstitial water alongside meiofaunal sampling. Temperature showed distinct seasonal variation, ranging from 29°C (Station 1, November 2023) to 32°C (Station 2, March 2024), with higher values in summer months due to increased solar radiation and lower values during monsoon from rainfall and cloud cover. These fluctuations significantly influence aquatic chemical/biological processes, including photosynthesis and species distribution patterns (Manikannan *et al.*,2011).

Anthropogenic activities (industrial discharge, dredging and sewage) introduce pollutants that alter sediment chemistry and dissolved oxygen levels, creating ecological stress. Benthic communities respond through adaptive changes in abundance and composition, with meiofauna serving as sensitive bioindicators (Balsamo *et al.*, 2012). Notably, surface water temperatures consistently exceeded atmospheric readings, reflecting water's higher heat retention capacity—a trend documented in similar coastal ecosystems (Srilatha *et al.*,2012). The findings align with prior studies on tropical coastal systems (Santhanam & Perumal, 2003; Gupta *et al.*, 2008), confirming temperature's role in shaping physicochemical dynamics. Such data are critical for monitoring ecosystem health amid growing anthropogenic pressures.

### 3.3 Salinity and Water Quality Parameters



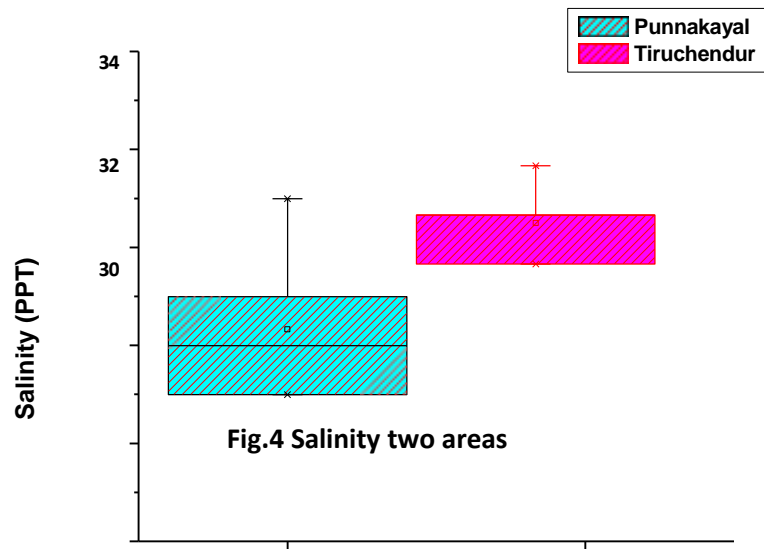


Fig.4 Salinity two areas

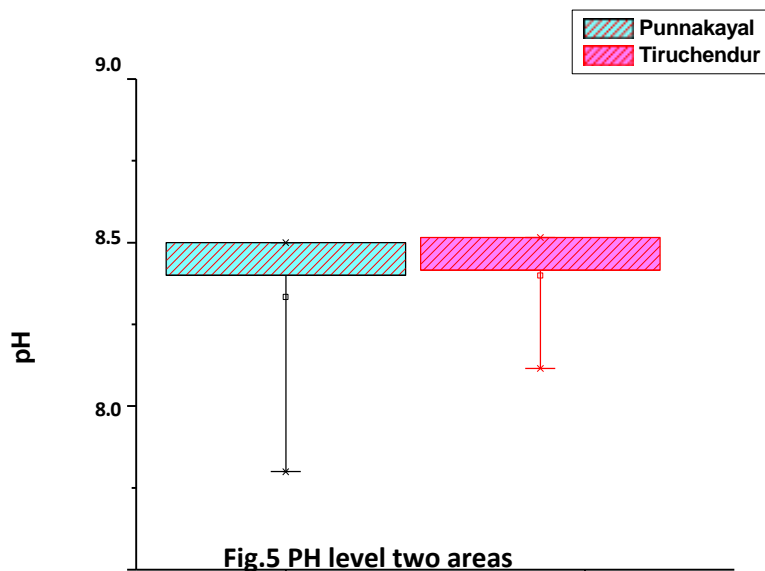


Fig.5 PH level two areas

Significantly, the **salinity** influenced meiofaunal distribution across the study sites, ranging from 29‰ (Station 1, Nov'23) to 34‰ (Station 2, Mar'24). Seasonal variations followed established patterns, with higher values in summer (increased evaporation) and lower values during monsoon (freshwater influx), consistent with findings from Srilatha *et al.*, (2012) and Rao *et al.*, (2012). **pH** measurements revealed alkaline conditions (7.6-8.5) at all stations except Station 2, which showed acidic values (6.0-6.8) likely due to industrial pollution. The alkaline nature correlated with higher salinity, while seasonal fluctuations reflected monsoon-driven freshwater inputs and organic matter decomposition (Manikannan *et al.*, 2011; Trivedy & Goel, 1984). **Dissolved oxygen** levels varied inversely with temperature and salinity, ranging from 3.4 ml/l (Station 2, Feb'24) to 4.5 ml/l (Station 1, Nov'23). Lower summer values resulted from increased respiration and organic decomposition, as documented by Saravanakumar *et al.*, (2008). Notably, the **Organic carbon** content was highest in Station 2 (0.911 mgC/g, Mar'24), attributed to sewage inputs. This enrichment



corresponded with depressed oxygen levels, demonstrating the cascading effects of anthropogenic pollution on benthic conditions.

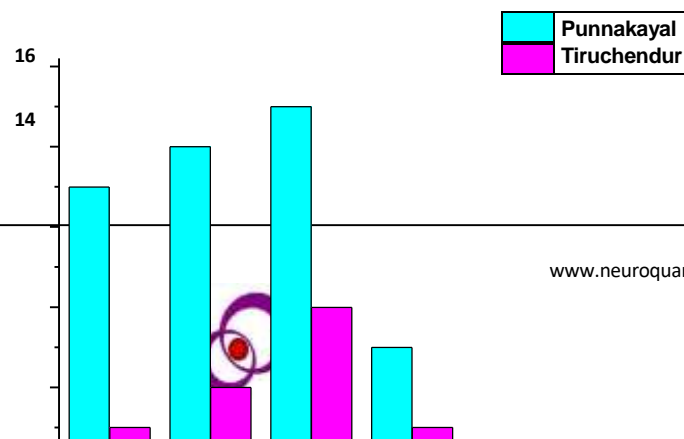
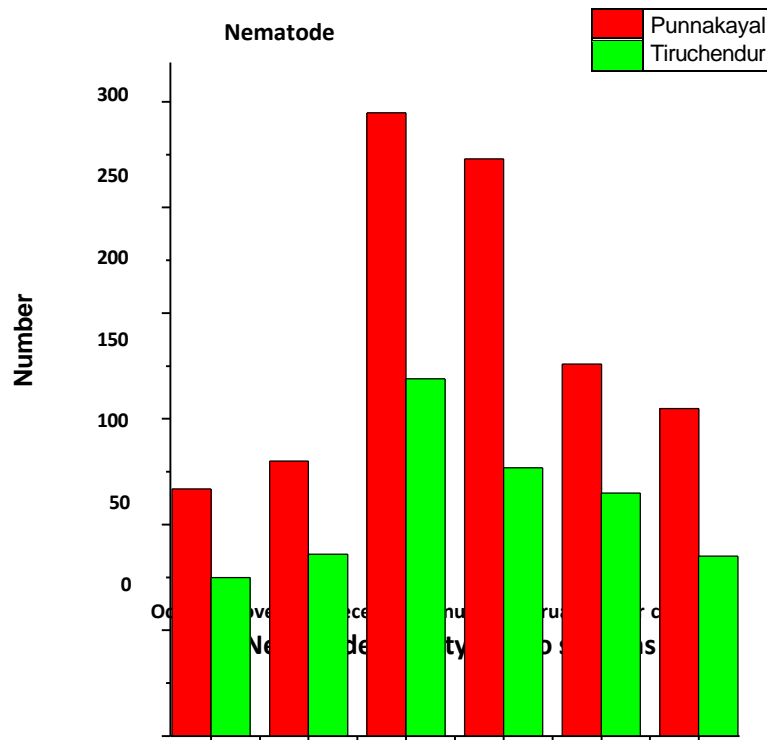
### 3.4 Meiofaunal Distribution Patterns and Anthropogenic Impacts

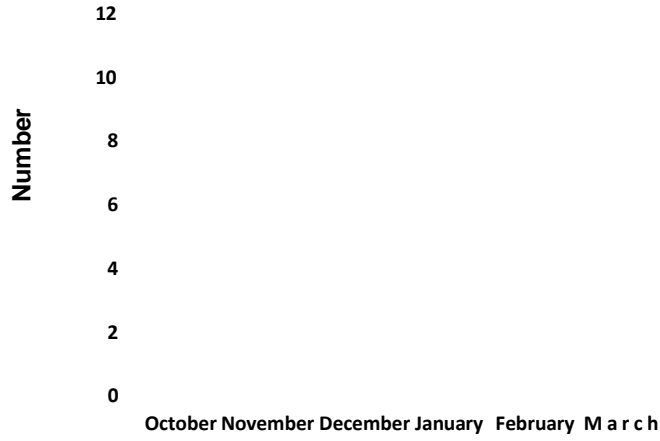
The study revealed distinct spatial and temporal patterns in meiofaunal assemblages, particularly nematodes, across stations. Station 1 showed higher nematode abundance with clear seasonal variation - peaking during monsoon (November-March) across all sediment layers. In contrast, Station 2 exhibited decreased abundance during monsoon, likely due to abnormal rainfall and pollutant influx from Buckle Canal, followed by partial recovery post-monsoon. This pattern aligns with findings by Arieli *et al.*, (2011) on thermal pollution impacts, suggesting temperature thresholds ( $\geq 30^{\circ}\text{C}$ ) critically affect benthic communities.

Organic enrichment from sewage discharge at Station 2 created oxygen-deficient conditions, reducing overall meiofaunal density. As observed by Balsamo *et al.*, (2012), excessive organic input leads to ecosystem imbalance, where only tolerant species persist.

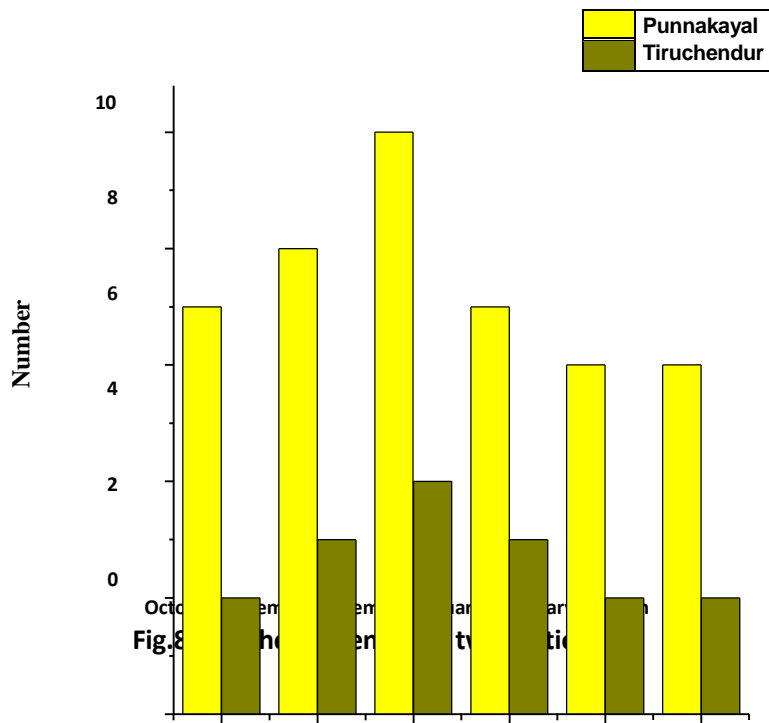
Thermal pollution near Station 3 (proximate to Thoothukudi Thermal Power Station) resulted in elevated interstitial temperatures and significantly reduced nematode, copepod and polychaete abundances. While Kailasam and Sivakami (2004) reported better conditions at a similar location, the current study demonstrates worsening conditions, possibly indicating cumulative stress from prolonged thermal exposure and other anthropogenic factors

### 3.5 Ecological Impacts on Meiofaunal Communities

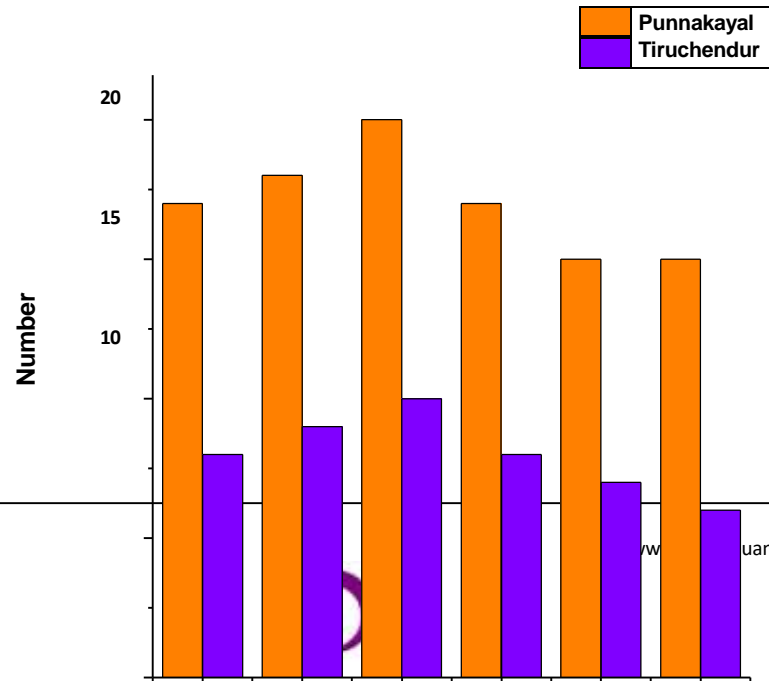




**Fig.7 Copepode density in two stations**



**Fig.8**



5

0

October November December January February March

**Fig.9 Foraminifera density in two stations**

The study documents severe anthropogenic impacts on meiofaunal assemblages along the Thoothukudi coast, particularly through thermal and organic pollution. Elevated seawater temperatures near the thermal power station (Asha, 2002) and ash deposition have significantly degraded benthic habitats, supporting Kinne's (1963) observations about temperature-induced physiological stress. This aligns with Ahmed *et al.*'s (1992) findings at Kalpakkam, where thermal effluent reduced benthic populations, creating low-diversity, high-stress ecosystems (Kailasam & Sivakami, 2004).

Nematodes demonstrated characteristic pollution responses, with abundance patterns reflecting organic enrichment gradients. While Nanajkar and Ingole (2010) reported increased nematode diversity near sewage outfalls, our Station 2 showed reduced abundance, likely due to extreme organic overload creating hypoxic conditions (Austen & Warwick, 1995). This confirms nematodes' value as pollution indicators (Heip, 1980; Coull & Chandler, 1992), though responses vary with stressor intensity (Schratzberger *et al.*, 2008). Notably, these Copepod populations showed alarming declines compared to earlier studies (Sivaleela & Venkataraman, 2014), BOPA index findings and Surugiu's (2009) observations of oxygen-limited, toxic conditions near outfalls.

#### **4. SUMMARY AND CONCLUSION**

The study examined meiofaunal abundance and diversity in relation to environmental parameters across two coastal stations in Thoothukudi district from October 2023 to March 2024. Station 1 (Punnakayal) served as a reference site with minimal anthropogenic disturbance, while Station 2 (Tiruchendur) was influenced by sewage discharge and industrial activities. Environmental parameters such as temperature, salinity, pH, dissolved oxygen, and sediment organic carbon were assessed alongside meiofaunal groups—primarily nematodes, copepods, polychaetes, and foraminifera.

Interstitial water temperatures ranged from 29°C to 32°C, with consistently higher values at Station 2, likely due to effluent from thermal power plants. Salinity varied between 29‰ and 34‰, while pH ranged from 7.6 to 8.5, indicating a trend toward acidification compared to historical data. Generally, the Dissolved oxygen levels (3.4–4.5 ml/l) were observed to be lower at Station 1, suggesting higher organic load. Sediment organic carbon ranged from 0.138 to 0.911 mgC/g, with elevated levels at Station 2. Nematodes dominated the meiofaunal community across both stations, particularly in the upper 5 cm sediment layer. Their abundance was higher at Station 1 during most months, except during November and December 2023. Copepod densities were consistently low, reflecting their sensitivity to pollution stress. Station 2 exhibited reduced meiofaunal abundance, indicating environmental stress likely induced by anthropogenic pollution.

Overall, the study highlights the impact of localized pollution and thermal discharge on meiofaunal communities in the Gulf of Mannar. The observed decline in sensitive taxa such as copepods reinforces the need for long-term monitoring and management interventions to mitigate ecological degradation and preserve benthic biodiversity in these coastal ecosystems.

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