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A review on Meiobenthic assemblage and its significance in the ecosystem.

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ABSTRACT

Meiobenthic assemblages are crucial components of the aquatic community, particularly in marine and estuarine ecosystems playing significant roles in nutrient cycling, sediment stabilization, and food web structures. Their abundance and diversity can be indicators of ecosystem health thus, making them an important focus for environmental monitoring and conservation efforts. Understanding and preserving meiobenthic communities are essential for maintaining the overall functionality and resilience of aquatic ecosystems.

Keywords: Meiobenthos, Assemblage, Abundance, Ecological indicators, Nutrient cycling, Sediment stabilization, Functional traits.

INTRODUCTION

Benthos is derived from the Greek word 'Depths of the Sea'. Benthos' term was introduced by the German naturalist Ernst Haeckel (1834-1919). The seafloor of the benthic region consists of rocks, stones, gravel, sand, and mud from the extreme water mark of spring tides to the deepest abysses of the open ocean. Intertidal, subtidal, and deep-sea environments are the three major zones in the benthic region. Benthos constitutes the organisms which live on or in the seabed which include flora, fauna, and microbes. Benthic organisms are classified based on the habitat namely, epifauna (live on the seafloor) and infauna (within the sediment). Benthic organisms can be differentiated into two major groups. They are differentiated based on their habitat. The two major groups are soft bottom benthos and hard bottom benthos. Benthic organisms which are found in sand, mud, and which inhabit soft substrates are known as soft bottom benthos. Higher proportions of faunal species composition are found in soft bottom benthos. Benthic organisms which are present on hard substratum and attach themselves firmly to rocks is known as hard bottom benthos. They are mostly found on rocky shores. The major communities which cover the coastal areas are the Seagrass, Coral reef, and Seaweed. Infaunal organisms live within the sediments and are classified based on their body size- Mega benthos, Macrobenthos, Meiobenthos, Microbenthos and Nanobenthos. Megabenthic organisms are the larger group of animals with their body size of more than 3000 µm (e.g.sea turtles, holothurians, etc). Macrobenthic organisms are the organisms which reside in sea bottom sediments and are greater than 500 µm size (e.g., polychaeta, amphipods etc). Macrobenthic animals can be easily identified up to a certain level with naked eyes. The meiobenthos is smaller than macrobenthos with size ranging between 43 µm to 500 µm (e.g., nematodes, foraminiferans, harpacticoida etc.). They have been studied since the 1700's before the name meiofauna was established. The microbenthos are smaller than meiobenthos, their body size falls below 43 µm (e.g., dinoflagellates, ciliates etc). Organisms in the benthic zone are scavengers or detritivores which feed upon the dead, decaying matter. (Higgins and Thiel, 1988). *Introduction to the study of meiofauna).*

Meiofauna : The biomass and abundance of meiofauna varies depending on the season, latitude, water depth, tidal exposure, grain size, habitat, etc. The standards coming from the intertidal muddy estuarine habitats are mostly higher when compared to deep sea. The assemblage of meiofauna differs with differences in habitat such as muddy, sandy or phytal habitats. Temperature, salinity, water movement, oxygen content, seasonality, and others can temper the diversity of meiofauna.

Diversity and abundance of meiofauna- As meiofauna have very short generation time, which is less than 1 month and due to their direct benthic development, they are considered to show possible environmental effects over very small spatial and short temporal scales (Kennedy and Jacoby 1999).

Horizontal distribution- The salinity also majorly affects the horizontal gradients of meiofauna mostly in estuaries (Warwick 1971, Horn 1978) across the intertidal sandy habitats (Harris 1972, Platt 1977, Moore 1979), across intertidal muddy habitats (Coull *et al*., 1979) and onto continental shelf and into deep sea with increasing water depth (Soyer 1970, Coull *et al*, 1982). This relationship can be observed in abundance, species diversity, and composition.

Dispersion-patchiness - Distribution of meiofauna is patchy (Gray and Rieger 1971, Findlay 1981). Small scale dispersion is mostly due to animal habitat whereas large scale dispersion is influenced by physical factors such as salinity, tidal exposure, sediment granulometry, oxygen concentration (Findlay 1981).

Spatial and Temporal variations in meiofauna- Spatial patterns of meiofauna density and community structures are controlled majorly by hydrodynamic stress (Covazzi *et al*., 2001). According to the season, the faunal distribution varies in the year (Hicks and Coull 1983) and marine organisms can make daily or tidal migrations (Joint *et al*., 1982). Seasonal variation can be seen in meiofauna; their peak abundances can be seen in the warmer months of the year with some exceptions.

Ecological significance of Meiofauna: There are several roles of meiofauna but majorly there are some important roles of meiofauna in benthic processes highlighted below:

Meiofauna can be said to be a homogeneous ecological group. They are the most phyletic diverse fauna on planet earth. Meiofauna is found in freshwater as well as marine ecosystems in a varied range of habitats. They can also thrive in a broad range of salinity. The production rate of meiofauna is equal or higher than macrofauna from shallow waters to deep sea (Coull 1999).

Remineralization of organic matter- meiofauna feed upon dead and decaying matter as they are detritivores and indiscriminately, they feed on diatoms and bacteria. They also play an important role in providing detritus to macroconsumers (Tenore *et al*., 1977).

Productivity of meiofauna- meiofauna has an important role in benthic energetics. Benthic metabolism is increased five times more by meiofauna when compared with macrofauna. Meiobenthic invertebrates such as nematodes, polychaetes, oligochaetes, ostracods, tardigrades are frequently present in soft sediments whereas the most diverse shelled meiofaunal organisms in the oceans are foraminiferans. Simultaneously, nematodes are present in ample amounts (Balsamo *et al*., 2012).

Life- history parameters such as reproductive potential, fecundity, rate of development are very important to understand to study the production. Along with that, the effect of physical factors upon the above reproductive parameters is also important to be known.

Meiofauna is food for higher trophic level organisms- meiofaunal prey is also eaten by meiofaunal predators thus it leads to the competition between macrofauna and meiofauna for food. (McIntyre and Murison 1973) and meiofauna is a nutrient regenerator which serves them as their food. (Marshall 1970). The ratio of meiofauna as food for higher organisms is observed to be greater in mud when compared with sands. Meiofauna consumes diatoms, bacteria, detritus, protozoans and dissolved organic matter whereas meiofauna is consumed by swimming predators (e.g. shrimp, fish etc.) and by suspension feeders if meiofauna is in suspended form.

The response of meiofauna towards perturbations- the sensitivity of meiofauna towards environment is great because of this they are used as environmental indicators. As they are ubiquitous organisms they have numerous qualities such as large numbers, relative stationary of life habitats, short generation times, benthic larvae and great association with the sediments. They can also be studied to determine the pollution ratio of the area. They also play an important role in aquatic ecosystems. Meiofauna performs a varied range of activities such as bioturbation, feeding or moving through or along the sediment (Cullen 1973). They secrete sticky mucus which helps to stabilize burrows and provides support to attachment of eggs to the sediment (Reimann and Schrage 1978). The meiofaunal organisms also produce extracellular polymeric substances (EPS) which helps in bounding the sediment particles together (Chandler and Fleeger 1984; Nehring *et al*., 1990; Reichelt 1991; Nehring 1993). They are also known as Vertical conveyors within the sediments and also between the sediments and overlying waters due to their bio-turbating properties. (Coull 1999).

There are various environmental factors on which distribution patterns, diversity, abundance, structure of meiofauna is dependent such as- OMZ (oxygen minimum zone), coastal upwelling, ENSO events etc. along with abiotic factors which are- geography, geology, hydrography, physiography, light, pH, pollutants. Anthropogenic activities such as industrialization, agriculture, mining, dredging and dumping leads to huge numbers of pollutants entering into marine areas, causing disturbance to meiofaunal assemblage and also creating an impact on the ecosystem. Offshore pollution through the drilling of oil rigs and oil platforms is of major concern.

Benthic organisms are widely affected due to this adverse condition and shows following issues such as – extinction of local meiofauna in an area, modification in assemblage of meiofauna biological, morphological and cytological differences, reproduction capability is changed (Balsamo 2012). Meiofauna can tolerate high levels of anoxia as compared to macrofauna, and among the different meiofaunal groups the most surviving group under anoxic condition is nematode (Giere 1993). Many species of nematode tend to survive up to 2 weeks in total anoxia (Wieser and Kanwisher 1961), (Ott and Schiemer 1973). (Higgins, R.P., Thiel, H. (1988) *Introduction to the study of meiofauna).*

History of Meiofaunal Study: The study on marine and freshwater meiofauna commenced during the eighteenth century. The first person to start the work and describe the worm under a new Genus named Chaetoderma was Loven in 1844. Later, Dujardin in 1851 identified that as Kinorhyncha which is a meiobenthic group. The term interstitial fauna was introduced by Nicholls in 1935. Animals or marine organisms that lived in the interstitial spaces between all types of sediment particles are termed as "Interstitial fauna". In the year 1940, Remane projected the commensurate term "Mesopsammon". The term "Meiofauna" was derived from a Greek word, and it was introduced by Mare in 1942. Meiofauna means smaller fauna in benthos found mostly in muddy substrates.

In previous years, benthic animals were studied by collected them with fine meshed plankton net which filtered the coastal ground waters but due to ineffective sampling in the year 1911 to 1935, more effective sampling techniques were used which differentiated the distribution of meiofauna from intertidal to subtidal range. Instruments such as grabs and dredges were developed for subtidal sample collection by Petersen (1913) and Mortensen (1925). The inventors of the meiofauna research field are Moore and Niel (1930), Moore (1931), Nicholls (1935), Remane (1940) and Mare (1942). Remane is known as "The Father of Meiofaunal research" because he was the first person who recognized the diverse and rich populations of meiofauna in subtidal sands and mud, intertidal beach, and algal habitats. He also initiated the International Association of Meiobenthology (IAM) and German School of Meiobenthology. Quantitatively, meiofaunal taxa was enumerated and studied by Moore (1931), Krogh and Sparck (1936) and Rees (1940). The work done by McIntyre (1969) and Hulings and Gray (1971) is discussed by Holme and McIntyre (1984) in the handbook named "Methods for the study of Marine benthos". Meiofaunal separation from the collected core samples is important, Petersen (1911) entrenched the phenomenon of 1 mm sieve size that had to be used to separate the meiofauna from macrofauna for the quantitative studies. Higgins and Thiel in 1988 noted that 1 mm was the sieve mesh size used for meiofauna separation, but it was not a proper measure for sieving of organism size therefore, they noted that the mesh size to be used for meiofauna separation is 42 µm to 1 mm and 2-42µm for nano benthos. Later, in the year 2009 Giere proposed formal size limitations of meiofauna which are 500 µm upper and 63µm as lower limits, whereas deep-sea meiofauna benthic experts suggested that 42 µm as the lower limit for meiofaunal separation in deep sea. Meiofaunal community structure and their distribution pattern with respect to environmental disturbances have been studied several times. Meiofauna also is an essential biomass for the food chain and in consumption of food. This was studied by Gerlach (1971). Macrofaunal research started much previously as compared to meiofauna, but later scientists discovered that meiofauna plays a better role in an ecosystem than macrofauna (Balsamo *et al*., 2012). These studies state that meiofauna plays an essential role in ecosystem monitoring.

International review:

Internationally, most of the Meiobenthos research has been done in coastal temperate regions. Presently, deep sea and coastal tropical ecosystems have been focused on meiobenthos studies. In Buzzards bay, the occurrence of nematode species with respect to the sediment distribution was studied by Wiser, 1960. The amount of organic matter in the sediment in relation to the meiofaunal density was studied by Meyer and Fauvel (1980), Tenure (1983), Varshney (1985). Coull in 1973 carried out a study which showed the mechanism which controls the abundance of biomass of the meiofaunal organisms in the temperate of sub - tropical estuarine ecosystem. Benthic study in Arctic and sub- Arctic seas was carried out by Curtis (1975). Ecology of free-living nematodes from an intertidal sand flat in Northern Ireland was studied by Platt (1977). In subtidal zones, most of the studies are done with respect to meiofaunal presence by (Moore 1931; Wiser 1960; McIntyre 1964; Muss 1967; Tret Jen 1969; Coull1970; de Bovee and Soyer 1974) which status that more than 95% of the fauna is present in the upper 7 CM and among them about 60% - 70% of meiofauna is present in the upper 2cm layers. Perspectives of marine ecology of meiofauna was explained by Coull and bell in 1979. Meiofaunal community structure was studied by Gray in 1978. Resilience of the benthic roots after an external physical disturbance is expected only in a few cases was advised by Sherman and Coull in 1980. The drifting mechanism intertidal meiobenthos was studied by Palmor in 1984 and he advised that erosion is the main cause of drifting and abundance and diversity of meiobenthic drift fauna depends on species to species behavior. Dispersion of meiofaunal in tidal creeks was studied by Palmer and Gust in 1985. In Gullmar Fjord basin, differential response of benthic meiofauna and meiofauna with respect to hypoxia was studied by Josefson and Widbom in 1988. Meiofauna as food for fish was described by Gee in 1989. Heip in 1990 studied the meiofaunal composition, distribution, biomass and production in North Sea. The zoogeography, ecology and biology of continental benthos along the arctic coast of northern America was reviewed by Carey (1991). Abundance of nematodes at oxygen minimum zone in Arabian Sea was studied by Cook 1999. In coral sandy beaches of Moorea, the survey of intertidal meiobenthos was done by (Gourbault *et al*., 1995; Soltwelded *et al*., 1996) discovered an indication of fractionated sedimentation of organic matter on the seafloor due to meiobenthic abundance in relation to sediment bound pigment continental margin. Meiofauna is the efficient indicator of environmental perturbations as concluded by Kennedy and Jacoby (1999). Polluted mudflats were studied by Coull in 1999. Gooday in 2000 studied the oxygen minimum zone in the Arabian Sea with respect to foraminifera. He also explained the taxonomic composition and diversity along with the relation with other foraminiferans. Overview of the hypoxic conduction around the world explained by Diaz in 2001. Mediterranean region with respect to the response of the deep-sea ecosystem to climate change. In the sandy beach of South America spatial and temporal effects on interstitial meiofauna were studied by Albuquerque in 2007. Carbon utilization, modification and sequestration was studied by

Klanges *et al*., 2004. In East Antarctica Ingole and Singh in 2010 carried out a study on biodiversity and community structure of free - living nematodes. Nematode ecological status of the soft sediments was investigated by (Hoss *et al*., 2011). Semprucci in 2014 studied the spatial pattern of distribution of meiofauna and nematode assemblage huvadhoo lagoon in Maldives, Indian Ocean and explained the temporal changes of meiofauna is used as a tool to monitor ecological quality status. Stimulating effects on nitrifying and denitrifying bacteria due bioturbation by meiofauna communities was recently studied by Bonaglia in 2015. Vertical distribution of the benthic organisms and their community structure is mainly affected by the presence of OMZs. Rosenberg *et al*., 1983; Arntz *et al*., 1991 and Levin in 2003.

National Review: The Initiation of Meiobenthic work in Indian subcontinent was carried out by Annandale (1907), Later it was followed by Panikkar and Aiyar in 1937, Kurien in 1953, 1967 and 1972, Seshappa 1953, Ganpati and Rao in 1959 and Ganpati and Rao in 1962, Thiel in 1966. The distribution patterns of the benthic fauna were investigated by Neyman *et al*., 1969. Meiofauna abundance with respect to seasonal changes and physico-chemical parameters was studied. In the Central West Coast of India along Thane creek in mangrove mudflats, meiobenthic was studied by Goldin *et al*., 1996. Ingole and Parulekar in 1998 studied the absence and presence of dominant meiofaunal species during a season, influenced by salinity. Alongi and Piclion 1988; Raghukumar *et al*., 2001 reported that the bacterial growth in deep sea sediments is closely associated with the biomass of benthic populations. The study of meiofaunal assemblage in siliceous ooze sediment and low manganese modules environment in Central Indian Ocean Basin (CIOB) was studied by Sharma in 1999. Experimental design to study the meiofaunal assemblage was reported by Sharma in 1999 and Sharma *et al*., 2001. Organic constituents present in deep sea sediments at a labile stage play a significant role in meiofaunal food cycle Ingole *et al*., 1992; Raghukumar *et al*., 2001. The Meiofaunal community existing in the deep sea generally concentrated on the relatively thin surface was studied by Ingole *et al*., 2000. Ingole *et al*., 2000; 2001 also reported a 40% decline in benthic population if sediments were distributed. To estimate the environmental conditions in deep sea environments, the Nematode: Copepod (NiC) ratio was used as an indicator (Ingole *et al*., 2000; 2005; Ansari and Ingole, 2002; Ingole and Koslow, 2005). Furthermore, (Ansari, 2000; Ansari and Ingole 2002) also reported that nematode shows high resistance to environmental conditions whereas (harpacticoid, copepod) were sensitive to environmental disturbances. Re-colonization process in Central India Ocean Basin (CIOB) at a depth of 5000m to 5500m to understand the meiofaunal assemblage was studied by Ingole *et al*., 2005. Whereas the 50% level decline in nematode abundance was observed after disturbances. It was concluded that re-colonization occurs at a temporal level whereas deep sea mining affects the benthic communities. Changes in the benthic biota due to external physical disturbances soon after the impact was observed and recovery are expected to be very slow stated by Ingole *et al*., 2005. Several meiofaunal studies in the west coast of India was done (P. Dhivya and P.M Mohan 2013). Meiofaunal of different coastal areas and backwaters of east of India was studied later by (Ganpati and Sharma,1973 ; Ganpati and Raman, 1973 ; Sharma and Ganpati, 1975 ; Ansari and Parulekar, 1981; Ansari *et al*., 1982; Rao 1986a & b ; Rao and Murthy, 1988 ; Vinjayakumar *et al*., 1991; 1997; Chattage *et al*., 1995 by Damodaran 1973 ; Ansari *et al*., 1977 ; Ansari *et al*., 1980 ; Aziz and Naik, 1983 ; Reddy and Hariharan 1985, 1986; Ingole *et al*., 1992 ; Ansari and Parulekar , 1993 ; Mani *et al* ., 2008 and Nagelkarkam *et al* ., 2008), respectively. Several national review studies in conducted along the east and west coast of India to investigate in the faunal associations at community level of organization to identify links to the key environmental factors (Ganpati and Lakshahman Rao 1959; Radhakrishna and Ganpati 1969; Kurian 1971; Domodaran 1973; Ansari *et al*., 1977; Harkantra *et al*., 1980, 1982; Parulekar *et al*., 1982; Raman and Adiseshasai 1989).

Nematode Review

Nematoda concentration is high in the brackish water lagoon Chilika lake Sharma and Rao in 1980; Savdarshan and Neelakantam, 1986 stated that due to high meiobenthic production the productivity rate in the water column also increases. Nematoda are faunal, majorly in medium and fine sediments was reported by Sinha and Choudhury in 1988. The abundance of nematodes was high followed by foraminiferans in the sediment with fine sand texture, Shetty and Nigam, 1982; Varsheny *et al*.,1984; Nigam and Chaturvedi, 2000. Five new records of Anoplostoma viviparum, Darylaimopsis punctata, Desmodara (pseudochromadora) pontica, Desmoscolex falcaxtus and Metalinhomoeus typicus) was deported by Chinnadurai fernando in 2006c from the artificial mangrove environment developed at Parangipettai. India density, Biomass, and distribution pattern of nematode species along the western Indian shelf depend on various factors like depth, organic matter (OM), latitude and amount of clay (Sajan *et al*., 2010).Comparative study on the tropical nematode communities from three harbors in west coast of India was conducted by Nanajkar and Ingole in 2010.The dominance of nematode among the meiofaunal population in sediments from Ratnagiri to Mangalore coasts of India was reported by (Nanajkar *et al*., 2011).The distribution pattern of meiofauna especially nematodes is affected by the nature of the sediment (Sediment texture)., Ansari in 2012. Desmoscolex falcatus is a nematoda species which is firstly recorded in Rushikulya estuary, Odisha, India by Baliarsingh et al., 2015). Increase in Bacterial denitrification due to influence of Meiofauna in marine sediments was studied by (Bonaglia *et al*., 2014). Recently, tree-living nematode diversity along the Indian west coast was studied by (Ghosh and Mandal 2016). The respective study states that Nematofaunal community is higher in east sector as compared to west sector and the highest species richness is observed in continental shelf, followed by the intertidal areas. Study on a severely polluted area was done where defaunation of meiofauna in Mumbai Bay (India) was studied by (Sahoo *et al*., 2017). The relevance of Meiobenthic research with focus on Indian perspective was also stated by Chakraborty and Datta (2018).

CONCLUSION

Meiobenthic assemblages exhibit high biodiversity, with a variety of functional traits contributing to the ecosystem. Recent surveys have shown that even in disturbed habitats, meiobenthos can remain diverse, although species composition may shift in response to environmental pressures. The ecological functions and responses of meiobenthic communities to anthropogenic impacts are the subject of an expanding body of research. To learn more about meiobenthic diversity and distribution, new approaches have been employed, such as molecular techniques. Meiobenthic assemblages are increasingly being studied in the context of climate change, particularly concerning shifts in temperature, sea level rise, and ocean acidity. These factors can affect both the abundance and diversity of meiobenthic organisms. Meiobenthos contribute to nutrient cycling and decomposition processes in sediments. They play a role in controlling primary production by grazing on microbes and detritus, reinforcing their importance in benthic-pelagic coupling. Research has revealed complex food web dynamics involving meiobenthos, highlighting their roles as prey for macrofauna and other higher trophic levels. Studies underscore the importance of conserving meiobenthic habitats for maintaining ecosystem health and functioning, especially in areas affected by human activities. These themes represent just a few of the ongoing research efforts focusing on meiobenthos. The field continues to evolve as scientists seek to better understand the ecological importance of meiobenthic communities and their responses to changing environmental conditions.

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