Review Article

A REVIEW ON MEIOFAUNAL STUDY IN INDIA

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Abstract

The marine environment has two major provinces *viz*. pelagic and benthic. Pelagic environment mainly consists of plankton and nekton, however, the benthic community consists of vagile and sessile forms. The benthic organisms are classified based on the size, as Macrofauna (> 0.5mm), Meiofauna (0.5 to 0.063mm) and Microfauna (< 0.063mm). The meiofauna for its small size, short life span, absence of planktonic stages, sensitive to the natural, anthropogenic, environmental disturbance and along with it production it has been identified an important member of the benthic community *i.e.* converting the energy from basic to higher trophic level. Since it is sensitive to the environment and availability of these in the environment is considered as a yardstick to measure the health. However, in India, that also in Andaman and Nicobar Islands to understand the status of meiofaunal study, this review work was carried out in general to the International level and in-depth in national scenario. The review divided in to history of meiofauna study, meiofaunal taxa and distribution, meiofaunal ecology, importance of meiofauna, food for higher trophic levels, demineralization of organic matter, responses of meiofauna to perturbations, pollution indicator as a whole. In particular to Indian scenario the study was classified based on the available literature in to inter tide study, mangroves, salt marsh, continental shelf, deep sea meiofauna, nematode, studies in Andaman and Nicobar Islands and tsunami and its impact on meiofauna. The review of meiofaunal study with reference to India suggested that this is an infant study and need a lot of manpower to understand this science. Even though the different marine environments study such as beach, tidal flat, nearshore, continental shelf, deep sea, salt marsh, mangrove and other related environment distribution and diversity have been documented, the whole scenario has not been revealed till date. The existing studies were also not undergone to level of species in all the twenty meiofaunal groups. In India, meiofaunal study mainly concentrated nematode and harpacticoida (copepoda) and certain extend in polychaeta. Further, the biomass study, interrelation ship with tropic level, pollution monitoring systems, culture aspects with reference to aquaculture and mariculture related activities, drug from the sea, etc. also area where the marine biologist should concentrate and work for the developmental activities for the humankind.

INTRODUCTION

The marine environment has two major provinces *viz*. pelagic and benthic. Pelagic environment mainly consists of plankton and nekton, however, the benthic community consists of vagile and sessile forms. The organisms (Fauna, Flora and Micarobes) that live on or in the seabed (Benthic zone) referred as benthos (Hedgepeth, 1957). The word of benthos derived from the Greek, "*Depths of the Sea*". It lives all along the shore, tidal pools, continental shelf and then down depths also. The dead, decaying matter utilize and disintegrated by the benthos because the organisms in the benthic zone are scavengers or detrivores. Coral reef, Seagrass, and Seaweed are the major benthic community covers the coastal areas. The study on benthos of marine organisms and their environment was initiated by the Italians during 1750.

In marine ecosystem, the benthic organisms are classified based on the habitat namely, Epiphyta or Epifauna (live on the seafloor) and infauna (within the sediment), they are heterotrophs. According to size, infaunal organisms are usually divided into following types, Macrofauna (> 0.5mm), Meiofauna (0.5 to 0.063mm) and Microfauna (< 0.063mm). Meiofaunal organisms have been known and studied since 1700's long before the name 'Meiofauna' was established.

The small size, short life span, absence of planktonic stages, sensitive to the natural, anthropogenic, environmental disturbance and along with it production (Austen *et al*., 1994; Kennedy and Jacoby, 1999). This has been identified an important member of the benthic community *i.e.* converting the energy from basic to higher trophic level. Since it is sensitive to the environment and availability of these in the environment is considered as a yardstick to measure the health. However, in India, that also in Andaman and Nicobar Islands to understand the status of meiofaunal study, this review work was carried out in general to the International level and in-depth in national scenario.

History of meiofauna study

The study on marine and fresh water meiofauna were initiated during the eighteenth century. First work was carried out by Loven (1844) who described the worm under new genus. Later Dujardin (1851) was identified kinorhyncha. The next significant revolution was done by Nicholls (1935) to introduce the term "interstitial fauna". The term interstitial fauna were denoted that the animals living in the interstitial spaces between all types of sediment particles. During the year 1940, Remane proposed the equivalent term "Mesopsammon".

The term "Meiofauna" was derived from Greek and introduced by Mare (1942), means "smaller fauna" for the benthos of muddy substrates. In nineteenth century several methodology and devices were developed for study the meiofauna. Earlier days, to study the benthic animal fine meshed plankton net was used to filter the coastal ground waters. During the years 1911 to 1935, it was noticed that effective sampling techniques were developed and this differentiate the distribution of meiofauna from intertide to subtidal range. Petersen (1913) and Mortensen (1925) were developed the sediment sampling devices of grabs and dredges, respectively, for subtidal sample collection. The pioneers of meiofaunal research field are Moore and Neil (1930), Moore (1931), Nicholls (1935), Remane (1940) and Mare (1942).

Remane (1952) reported extensive work on the distribution of gastrotricha, rotifer, archiannelida, kinorhyncha, and other taxa in the shore line of Helogoland Island, Germany. Remane the "Father of Meiofaunal Research" who first recognized the rich populations of meiofauna in intertidal beaches, subtidal sands and mud, algal habitats and started the International Association of the Meiobenthology (IAM) and German School of Meiobenthology. These works was introduced numerous students on meiobenthic studies.

Moore (1931), Krogh and Sparck (1936) and Rees (1940) were studied the meiofauna quantitatively and enumerated all taxa. Holme and McIntyre (1984) had been discussed the work of McIntyre (1969) and Hulings and Gray (1971) in the handbook of 'Methods for the Study of Marine Benthos' for the sample collection, treatment and sorting of samples. Meiofaunal sample collection required minimum quantity of sediment samples provides more number of meiofauna than macrofaunal collection and these samples conveniently obtained by core sampling. In order to examine the meiofauna, the animals must be extracted from the sediment sample by decantation, elutriation and seawater ice method.

For the meiofaunal separation from the collected sediment samples, Petersen (1911) established the concept of 1mm sieve size had to be used to separate the macrofauna from meiofauna for the quantitative studies. 1mm lower limit was not a measure of organism size but sieve mesh size. Latter, Higgins and Thiel (1988) reported that the mesh size of 42µm to 1mm for meiobenthos and 2-42µm for nanobenthos. Giere (2009) reported that the formal size boundaries of meiofauna are 500µm as upper and 63 µm as lower limits and deep sea meiobenthologist suggested that 42 µm has the lower limit for the deep sea meiofaunal studies.

Meiofaunal taxa and distribution

Meiofauna occur in all aquatic (freshwater, marine and estuarine), terrestrial habitats and polar region (Giere, 2009). In marine environment, it occurs from splash zone to the deepest part of the ocean and found in all types of sediment texture (clay to gravel). This is common epiphytes on sea grass, algae, sea ice and various animal structures like coral crevices, worm tubes and echinoderm spines (Vincx, 1996). According to Higgins and Thiel (1988), out of thirty three metazoan phyla twenty two were meiofaunal taxa and latter, it was reclassified into twenty phyla by the International Association of

Meiobenthologist (IAM). Gastrotricha, gnathostomulida, kinorhyncha, loricifera and tardigrada are exclusive meiofauna (McIntyre, 1969) and the remaining taxa are comes under the temporary meiofauna. In general the meiofaunal distribution has patchy (Vitiello, 1968; McLachlan, 1978; Thistle, 1978 and Findlay, 1981) and not shows similarity in a particular environment. Further, their abundance mainly depends on season (Coull, 1985), latitude (Kotwicki *et al*., 2005a), water depth, tidal exposure, grain size (Williams, 1972; Conrad, 1976; Coull, 1985; Schratzberger *et al*., 2000; Schratzberger *et al*., 2004) and habitat (Funch *et al*., 2002). The highest density noticed in muddy intertidal habitat. The physical environmental factors of temperature (McIntyre and Murison, 1973), Salinity, pH, Redox Potential Discontinuity layer (RPD), inorganic nutrients and pollutants and the biotic factors of Particulate Organic Matter (POM), Dissolved Organic Carbon (DOC), mucus, exopolymers, biofilms, bacteria, microphytobenthos and predators of macrofauna (Giere, 2009) were control (abiotic and biotic factors) the meiofaunal distributions from intertidal to deep sea environment.

Different habitat such as intertidal (McLachlan *et al*., 1977a; Ellison, 1984) and sub tidal sandy and muddy substratum (McLachlan *et al*., 1977b; Vidakovic, 1984), deep sea (Ansari and Parulekar, 1981), phytal habitats of mangroves (Dye, 1983 and Armenteros, 2006), seagrass (Decho *et al*., 1985; Fisher and Sheaves, 2003 and Armenteros, 2008a), salt marsh mud (Smith *et al*., 1984), hydro thermal vents (Vanreusel *et al*., 1997 and Thiermann *et al*., 1997) and sea ice (Bick and Arlt, 2005) consists of specific ecosystem composition of meiofaunal assemblages. The meiofaunal taxa showed the symbiotic and commensalism relationship with the phytal habitats (Vincx, 1996). Gambi *et al*. (2003) had been reported meiofaunal abundance was reduced by sediment organic matter accumulation, but was not resulted by salinity gradients and conversely influenced microphytobenthos distribution.

More often, the upper sediment layer of 2 to 5 cm exhibited the maximum density of meiofauna (70 to 71 per cent) than in deeper layers (Yingst, 1978 and Kotwicki *et al*., 2005b). The vertical zonation always controlled by Redox Potential Discontinuity (RPD) layer (McLachlan,

1978; Diaz and Rosenberg, 1995 and Wu, 2002). Some of the meiofaunal taxa tolerating the anoxic condition (Wieser *et al*., 1974) however, the RPD level reach below +200mV, the metazoan densities greatly decrease (McLachlan, 1978). Mostly the horizontal distributions have controlled by salinity gradients (Barnett, 1968; Coull and Bell, 1979; Blome, 1983).

The fauna of sandy beaches initially studied in the European waters by Elmhirst (1931), Stephen (1929, 1930, 1935), Pirrie *et al*. (1932) Southward (1953) and Colman and Snelgrove (1955). Vertically the sandy beach meiofauna able to live in 50 cm or more deep (McLachlan, 1978) but in the muddy sediments which has restricted to upper few centimeters or millimeters (Coull and Bell, 1979). Estuarine intertidal habit has more meiofaunal communities and serves as the food to the higher tropical levels (Warwick, 1987; Ellis and Coull, 1989). This high rate of meiofauna production in mudflats is a function of high nutrient availability (Vicente, 1990).

In mangrove environment, the nematode and harpacticoid are the dominant meiofauna usually constitutes 90 per cent of the animal component. Many studies were carried out on the temporal and spatial distribution of the mangrove meiofauna (Hopper *et al*., 1973; Alongi, 1988; Vanhove *et al*., 1992; Olafsson, 1992, 1995; Fisher and Sheaves, 2003). Epiphytic algae influence meiofauna abundance on seagrass blades (Hall and Bell, 1993) and in the seaweed holdfast sample shows more abundant meiofaunal groups than in front and bottom samples (Arroyo *et al*., 2004).

Most often the nematode was the dominant meiofauna in sediment biotopes comprised >50 per cent of the total meiofauna and harpacticoid copepods are the second dominant in the coarse grained sediments. The nematodes were indeed dominant phyla in almost all sediment habitats and the second dominant is harpacticoid copepod (Vincx and Heip, 1987). Turbellaria were the dominant meiofaunal group recorded in tropical mangrove estuaries by Alongi (1987). The organic content, bacteria and protists of the sediments shows biogenic parameters to play a key role in meiofaunal density and distribution (McLachlan *et al*., 1981, Olafsson *et al*., 2000 and Moreno *et al*., 2006). Occasionally some other meiofaunal taxa also dominant in some places *i.e.* gastrotricha were dominant in sandy south

Caroline over an 11 year period (Galhano, 1970), isopod were dominant in the Portuguese sandy beach and Ostracoda found as a second dominant taxa in the Delaware sandy beach (Hummon *et al*., 1976). Gastrotricha and tardigrada were typically excluded from the muddy substrates (Higgins and Thiel, 1988). The harpacticoid copepod was dominant meiofaunal taxa in coarse sandy beach (Moore, 1973) and silty substratum supports number of nematodes. Foraminifera show a quick response to the sudden changes of environmental parameters (Albani *et al*., 2007).

Meiofaunal ecology

During the year 1950 to 1980 the studies on the approach for ecological experiments were carried out to know the meiofaunal distribution from the wild to laboratory conditions i.e. tolerance level for environmental parameters such as temperature, salinity, dissolved oxygen, measuring the respiration rates and the life history of the meiofaunal taxa were studied under the laboratory conditions (Giere, 2009). This study leads to understand the macro and meiofaunal interactions, role of meiofauna as food for higher trophic levels, effects on macro benthic structure on meiofaunal distribution and microfauna as food for meiofauna (Fenchel, 1978).

Temperature, salinity and dissolved oxygen were the primary important factors of the tropical and subtropical environment (Armenteros *et al*., 2008). Salinity was the important factor in the estuarine condition for the meiofaunal distribution (Alongi, 1990 and Richmond *et al*., 2007). The entrainment of meiofauna was passive but it clearly exerts considerable behavioral influence over their susceptibility to entrainment (Fegley, 1987). Josefon and Widbom (1988), reveals that the permanent meiofauna exhibited no clear signs of being influenced by the hypoxia and the temporary meiofauna of polychaetes seemed to be negatively affected. The response of macrofauna has more sensitive than meiofauna to low oxygen concentration. The tidal environment shows higher abundance of meiofauna than the deeper waters (Vanreusel *et al*., 1995). The study reported that water content, porosity and grain size were the predictor variables of meiofaunal density in the tidal environment. The sandy beach shows highest rate of desiccation during the neap

tide, so the meiofauna are migrating along the tides and this migration is high in the summer than in the winter (McLachlan and Turner, 1994). Among the tidal range the highest meiofaunal densities and biomass occurred at the mid-shore levels. Individual cores from the sandy site were significantly less diverse than the muddy site. The species patterns in some environments set by habitat selection by larvae and by juvenile colonization from the surrounding community (Snelgrove *et al*., 2001). The across-shore variability in densities and community assemblage structure of the meiofauna decreased through the dissipative state (Rodriguez, 2004).

Sublittoral to deep sea sediment encompass a lesser amount of food availability reduces the meiofaunal abundance. The typical deep sea meiobenthic organisms are highly adapted in biological and ecological terms to the scarcity of food (Giere, 2009). The intertidal ecosystem is important ecotones between the terrestrial and marine environment (Gheskiere *et al*., 2005). The zonation of intertidal meiobenthos of Australian estuaries revealed that seasonality of meiobenthic communities was influenced by rainfall (Alongi, 1987). The community structure of meio and macro benthos indicates selective post-recruitment mortality on different macrofaunal species.

Disturbance

Frequent disturbance was one of the main characteristics of coastal ecosystems (Hall, 1994 and Gremare *et al*., 2003). The losses were occurred in the coastal ecosystem like coral reef, seagrass (Kendall *et al*., 2009), seaweed (Prathep *et al*., 2008) and mangrove by tsunami. Several studies were carried out in tropical (Grzelak *et al*., 2009), deep sea (Gray *et al*., 2003) and polar (Brown *et al*., 2004; Meredith and King, 2005; Peck *et al*., 2006; Gutt and Piepenburg, 2003) regions to understand the patterns of disturbance, colonization and development. Lewis *et al*. (2003) identified new vectors of colonization and hierarchical competition structure leading to disturbance-mediated high diversity (Barnes, 2002). The meiofauna recolonization in the beach was quick and highly resilient to this disturbance (Grzelak *et al*., 2009). The colonization is less when the dispersion rate is long (Sousa, 1985).

Importanc of Meiofauna

Benthic food web mainly controlled by the meiofauna and act as an intermittent tropical level from micro to macrofauna. Meiofauna mainly serve as food (energy) to higher trophic levels, remineralization of organic matter, responses to perturbation and pollution indicator.

Food for higher trophic levels

The important food source of meiofauna are bacteria, diatoms and other microalgae (Coull, 1988) but the effect of meiofaunal grazing on the microbial community is largely unknown (Montahna, 1984). Pinckney and Sanduli, (1990) suggested that meiofauna and microalgal populations share nearly identical spatial patterns. Coull (1988) summarize the relationship of meiofauna to different tropical levels as a feed. The meiofauna are responsible for about five times of total benthic metabolism than the macrofauna. The rapid reproduction stabilizes the trophic level from micro to macrofauna (Giere and Pfannkuche, 1982; Hicks and Coull, 1983, Coull, 1990; Heip *et al.*, 1985; Smith and Coull, 1987, Nelson and Coull, 1989). Meiobenthic prey were consumed by meiobenthic predators which leads to limiting factor for total proportion of meiofauna entering into the higher trophic levels (McIntyre and Murison, 1973; Heip and Smol, 1975; Gee, 1987; Pratts and Schizas, 2007). It is an important prey for some metazoan and variety of endo and epi- benthic macrofauna as well as benthic juveniles and commercially important fish (McIntyre and Murison, 1973; Kennedy and Jacoby, 1999). Fluctuation of meiofaunal population could have the impact on lower and higher trophic levels (Speybroeck *et al.*, 2007).

Remineralization of organic matter

Meiofauna enhances the rate of carbon mineralisation by stimulating microbial activity through predation and consumption of detritus by larger deposit-feeding invertebrates facilitate biomineralization of organic matter and enhance nutrient regeneration (Alongi, 1989, 1990; Gee and Somerfield, 1997). Bacteria, fungi and other microorganisms living in sand are able to decompose organic matter efficiently (Rees *et al.*, 1991). McIntyre (1964) and Marshall (1970) reported that meiofaunal communities act as a major catalyzing nutrient regeneration by the way of organic matter decomposition.

Responses of meiofauna to perturbations

Consequences of perturbation prediction are based on understanding of animal-sediment interaction (Heip, 1980). Coull and Palmer (1984) identified meiobenthos are responsible to perturbations from the field experimentation. In any form of disturbances influence the substratum leads to decrease the abundance and diversity of meiofauna. Parker (1975) and Raffaelli and Mason (1981) proposed that ratio of nematode and copepod (N/C ratio) used for understanding sediment changes and to measure of environmental perturbations. Hinnig *et al.* (1983) reported that psammolittoral meiofauna as a perturbation indictor of sandy beaches in South Africa. Mechanical perturbation increased the harpacticoid copepods but did not concern nematode densities. The perturbation in sewage increased the number of nematode and copepod taxa.

Pollution indicator

Meiofauna are known to be sensitive indicators to pollutants. Because their large numbers, relatively stationary life habitats and short lifecycles has assess the effects of contaminant within a short duration made meiofauna as pollution indicator (Higgins and Thiel, 1988, Giere, 2009). Hinnig *et al.* (1983) found that contamination by chemical effluent depressed numbers of the nematodes and harpacticoids drastically. Oil in beaches decreased the harpacticoids but nematode density remains the same. Organic enrichment increased the nematodes and harpacticoid numbers remained normal. Fenchel (1978) and Kennedy and Jacoby (1999) had been reported that meiofauna are the biological indicators for monitoring marine environmental health. Schratzberger *et al.* (2000) reported that deposition of sediment in large dose caused severe changes rather than the type of sediment or the degree of contamination in nematode assemblage structure.

Indian Scenario

Major benthic work was initiated in Indian subcontinent by Annandale (1907), followed by Panikkar and Aiyar (1937), Kurien (1953, 1967 and 1972), Seshappa (1953), Ganapati and Rao (1959) and Ganapati and Rao (1962). Quantitative studies on meiofauna in west coast of India have been carried out by Thiel (1966), McIntyre (1968) and Sanders (1968).

Even though meiofaunal study had a long history, it has been the neglected sciences due to its laborious process. Latter, numerous workers studied meiofauna of different coastal areas and backwaters of east coasts of India (Ganapati and Sarma, 1973; Ganapati and Raman, 1973; Sharma and Ganapati, 1975; Ansari and Parulekar, 1981; Ansari *et al*., 1982, Rao, 1986a & b; Rao and Murthy, 1988; Vijayakumar *et al*., 1991, 1997; Chatterji *et al.*, 1995) and west coast (Damodaran, 1973; Ansari et al., 1977; Ansari *et al*., 1980; Aziz and Nair, 1983; Reddy and Hariharan, 1985, 1986; Ingole *et al*., 1992; Ansari and Parulekar, 1993; Mani *et al*., 2008 and Nagelkerken *et al*., 2008), respectively. The important Indian works were in this section to understand and delineate meiofaunal studies in the recent past in India.

Inter tide

McIntyre (1968) had been reported that sand bar beach Porto Novo exhibited meiofaunal densities such as 420 to 3815 nos./10cm^2, 395 to 1010 nos./10cm^2 and 968 to 1960 nos./10cm^2, respectively in sand bar, marine sandy beach and exposed sand beach. Rao (1969) studied the distribution of interstitial fauna of Orissa coast. Munro *et al*. (1978) enumerated meiofaunal community in sandy beach (Shertallai, India) and reported that 215 to 1337 nos./10cm^2 density. Ansari et al. (1980) reported that significant vertical decrease in densities of meiofaunal distribution in the sublittoral meiobenthos of Goa coast. Sarma and Chandramohan (1981) studied in Bhimilipatnam coastal environment of coarse sandy beach (Bay of Bengal) exhibit meiofaunal population in the range of 118 to 318 nos./10cm^2.

The freshwater cladoceron *Diaphanosoma oxcisum* were noticed in the intertidal regions of Balrangari, Orissa coast due to low environmental values and high mean grain size during the southwest monsoon (Chatterjie *et al*., 1995). Observed meiofaunal community with relation to season not shows any significant trend. The meiofaunal study and the environmental parameters of the Bhimillipatnam, east coast of India, was revealed that a top 5 cm of the beach had an temperature increment of 0.5 to 4.0°C due to convection heat through the deeper layers of the sand bed increase the salinity (34.67 PSU) of interstitial waters than the surrounding waters (Sarma and Chandramohan,

1981). Nematodes, copepod, polychaetes, archiannelids, oligochaetes, foraminifera, turbellaria, nemertinea and gastrotrichs were identified throughout the year and kinorhyncha, isopod, mysidaceans, tardigrada and coelenterates found sparse in numbers intermittently. Ostracoda and rotifers noticed in the calm and fairly stable environment and mid tide shows favourable environment to copepods, annelids and nematoda. The environmental factors had influences on species inhabiting in the intertidal environment for its survival (Ansari and Parulekar, 1993; Ingole and Parulekar, 1998). Ansari and Ingole (2002) was studied the meiofaunal distribution after the result of oil spill at off Goa. The nematode trophic groups found out that the values were lower than the earlier to the spill in the marine sediments. The Index of Trophic Diversity (ITD) was calculated and suggested that no changes in the index of trophic diversity due to oil spillage.

Estuary

Interstitial organisms study was carried out by Aiyar and Alkunhi (1944), Gnanamuthu (1954), Krishnaswamy (1957), Rao and Ganapati (1968) and Rao and Mishra (1983). Ganapati and Rao (1962) explained the ecology of the interstitial fauna of the Waltair, east coast. Kutty and Nair (1966) and Panikkar and Rajan (1970) reported the distributions of interstitial organisms in the west coast of India and Cochin backwaters, respectively. Murthy and Rao (1987) studied the ecological aspects of meiofauna from an estuarine environment.

Rao (1970) reported the occurrence of salt water *Halacarus anomalus* Trouessart in the interstitial sands on Indian coast. The geographical distribution of interstitial fauna of beach sand was reported by Rao (1972). According to McIntyre (1962), Ansari (1978) and Dalal (1980) was reported that muddy substratum exhibit abundant meiobenthos. Kurein (1972) studied the ecology of benthos of the Cochin backwaters showed that meiofauna were more in the finer sediments and their abundance is not affected by the tidal changes. Ansari (1978) reported that Karwar estuarine environment had a density of 1022 to 1250 nos./10cm^2 meiofaunal population. Nematodes and foraminifera were dominant taxa among the observed meiofaunal communities. Upper sediment layers of 0 to 6cm had nematodes, foraminifera and

polychaetes. Copepods, ostracods, lamellibranches, kinorhyncha and turbellarians were restricted only 0 to 4cm of upper layer. Varshney *et al*. (1981) studied the Narmada estuary sandy and muddy environment and reported that the population of meiofaunal community fall in the range of 0 to 3164 nos./10cm^2.

The marine mud in off Krishna, Godavari, Mahanadi and Hooghly rivers of East Coast of India exhibited 502 to 2149 nos./10cm^2 of individuals in meiofaunal community (Ansari *et al*., 1982). Khondalarao (1988) reported that 245 to 2194 nos./10cm^2 density of meiofaunal community existed in the Gauthami-Godavari estuarine muddy sand environment. Kutty *et al*. (1983) reported that sandy to muddy estuarine environment of south Gujarat exhibited 0 to 5334 nos./10cm^2 individual population of meiofaunal community. Fernando et al. (1983) studied the sandy bottom of Vellar estuary and reported maximum concentration of meiofaunal communities of nematodes, harpacticoids, copepod nauplii and foraminifera was observed. Rao (1983) reported the distribution of meiofauna in the intertidal environment of Lakshadweep. The upstream sediments were silt and clay dominated with abundance of foraminifera as a largest taxon. Estuarine muddy sands show 475 to 310 nos./10cm^2 and 71 to1495 nos./10cm^2 of meiofaunal density for pre-monsoon and post-monsoon conditions in the Goa Coast, India (Harkantra and Parulekar, 1985). Datta and Sarangi (1986) reported that the west Bengal estuarine sandy environment exhibit meiofaunal community individuals in the range of 100 to 2420 nos./10cm2. Bhat and Neelakandan (1991) study the distribution of meiobenthos in relation to environmental parameters in the Kali estuary, Karwar.

Ansari and Parulekar (1993) studied the Mandovi estuary of Goa and reported that deposit feeders of nematodes in fine muddy substratum and epi-growth feeders in sandy substratum were dominant. The second abundance of meiofauna was harpacticoids followed by turbellaria, polychaeta and ostracoda in sub tidal environment. Vellar estuarine sandy environment exhibited meiofaunal density in the range of 33 to 213 nos./10cm^2 (Fernando *et al*., 1983).

A study during the year 1991 to 1992 in estuarine intertidal beach at Siridao, Goa, was found out that mid tide level exhibit 3.6 to 211 individuals for every 3cm^2 and highly influenced by salinity fluctuation in this environment. Minimum density was recorded in monsoon (July - August) and peak density were noticed in pre and post monsoon seasons. Nematode is the dominant taxa of this study shows highest density (59.2 per cent) followed by turbellarians, oligochaetes, harpacticoids, gastrotrichs, halacaroids, ostracods, tardigrades, kinorhynchs, isopods, polychaetes and tanaids as reported by Ingole and Parulekar (1998). Ansari et al. (2001) reported that intertidal mudflat of the Mandovi estuary, Goa exhibit nematode was dominant (589 to 1457 nos./10 cm^2) followed by turbellaria (259 to336 nos./10 cm^2) and harpacticoid copepod (90 to 160 nos./10 cm^2). The other taxa available in this environment were tardigrada, gastrotricha, foraminifera, oligochaeta and crustacean nauplii. Ansari and Parulekar (1998) studied the community structure of meiobenthos from a tropical estuary. Rao and Sarma (1999) studied the patterns of numerical abundance of meiofaunal variation with the sediment during different seasons in a tropical estuary.

Mangroves

Very limited Indian mangrove meiofaunal research work was carried out by Ali *et al*. (1983); Krishnamurthy *et al*. (1984); Varshney *et al*. (1984); Rao (1986a); Sinha *et al*. (1987); Fernando (1987); Sinha and Choudhary (1988); Kondalarao and Ramanamurty *et al*. (1988); Harkantra and Parulekar (1989); Alongi (1990); Ansari *et al*. (1993); Sarma and Wilsanand (1994, 1996); Goldin *et al*. (1996); Ansari and Gauns (1996), Ingole *et al*. (2006) and Mohan *et al*. (2012a,b) in the last 40 years. Kumar (2000) carried out a detailed review on the biodiversity of soil dwelling organism in Indian mangroves, found seven works of meiofaunal studies between 1983 to 1996 periods. Further, this work also reported that distribution of the major taxa of meiofauna and its ecology.

The energy flow of mangrove ecosystem in Pitchavaram was studied by Ali *et al*. (1983) using the nematodes distribution. The energy flow through the benthic photosysnthesis was utilized by nematode was in the range of 4 per cent in mangrove environment of Pitchavaram, South India. Sinha *et al*. (1987) identified the new species *Anoplostoma macrospiculum* from the mangrove environment of deltaic Sundarbans, West Bengal region. Ansari *et al*. (1993) was studied the mangrove

environment of Goa and reported that the nematodes, turbellaria and harpacticoids were reduced with increasing sedimentation in this environment. Kumar (2001) had been made a check list of polychaetes annelids from Indian mangrove environment. The study confirmed the 62 species of Indian record and it shows higher diversity among the Asian countries.

The study on Pichavaram mangrove, south east coast of India, states that 6 species of nematode under 2 orders and 7 families was recorded by Chinnadurai and Fernando (2006a) as first time record in mangrove environment of India. Chinnadurai and Fernando (2006b) study on the relationship between the mangroves and meiofaunal distribution in Cochin, Southwest Coast of India suggested that *Avicennia marina*, *Sonneratioa caseolaris* and *Rhizophora apiculata* cover consists of 7 major taxa of meiofauna (nematodes, copepods, foraminifera, polychaetes, oligochaetes, ostracods and turbellarians). Nematode (Comesomatidae) was abundant in *Avicennia marina* (48.2 per cent) and *Sonneratioa caseolaris* (30.3 per cent) with 16 genera belonging to 23 species. *Avicennia marina* had highest genera (11) distribution than *Sonneratioa caseolaris* and *Rhizophora apiculata* (9 genera). *Daptonema oxycerca* was the commonest species exited in all the studied five stations and *Therstus flevensis* was present occasionally at Mangalavanam. Meiofaunal density was higher in *Avicennia marina* than *Rhizophora apiculata* due to high mud concentration in the sediments.

The mangrove leaves of *Avicennia marina* available environment exhibit high concentration of meiofauna than the *Rhizophora apiculata* in Vellar estuarine environment (Chinnadurai and Fernando, 2007a). The nematode species in the environment of *Avicennia marina* and *Rhizophora apiculata* from Pichavaram, South east coast of India suggested that 44 species of nematodes belongs to 36 genera and 20 families were occurred in this environment. Fifteen species restricted to *Avicennia marina* and 13 species bound to *Rhizophora apiculata* environments (Chinnadurai and Fernando, 2007b). Muthupettai mangrove forest, east coast of India located in Sethukuda exhibit 106 species of meiofauna with 12029 to 23493 nos/10cm^2 with a diversity index of 3.515 to 3.680. Foraminifera were the dominant group followed by nematodes, harpacticoid, ostracods, rotifer, ciliophora, cnidaria, gnathostomulida, insecta, propulida, bryozoa and polychaeta larvae were observed (Thilagavathi *et al*. 2011).

Saltmarsh

Ingole *et al*. (1987) were studied the distribution of meiobenthos in the Saphala salt marsh, west coast of India.

Continental shelf

Ansari *et al*. (1977) reported the distribution of meiofaunal community in Bay of Bengal as a preliminary report of offshore and continental shelf region at a depth of 20 to 170 m. Ansari *et al*. (1980) studied the off Goa coast, India at a depth of 20 to 840 m reported that the meiofaunal community concentration in the range of 250 to 2925 nos./10cm^2.

Ansari and Parulekar (1981) and Parulekar and Ansari (1981) had been reported in the continental shelf region the meiofaunal community exhibits 68-438 no./10cm2 individuals with a biomass of 3.6 to 32.8 g WW/m^2. However, Rodreiguez *et al*. (1982) reported that continental shelf of Andaman Sea, at a depth of 10 to 250m exhibits 0.9g DW/m^2 of meiofaunal biomass. Arabian Sea and Bay of Bengal shelf regions, at a depth of 10 to 250m, 1.4 and 0.2g DW/m^2 of meiofaunal biomass were reported, respectively. Rao and Veeryya (2000) and Nanajkar *et al*. (2011) had been reported that the high hydrodynamic stress around the continental slope preventing phytoplankton as a food source reach to deep waters. Sebastian (2003) studied the meiobenthos of west coast shelf waters reported that 80 per cent of the nematode recorded in upper 4cm of the sediment core. The environmental factors, silt and feed are control the vertical distribution of nematode. Jayaraj (2006) studied the dynamics of in infaunal community of the continental shelf of north eastern Arabian Sea and reported that benthic biomass was positive to environmental parameters but it was not a limiting factor. Sajan *et al*. (2010) studied the meiofaunal composition in west coast continental shelf of India.

Deep sea meiofauna

Ansari and Parulekar (1981) and Ansari *et al*. (1980) studied the meiofaunal composition at a depth of 840-2000 m in Goa and Andaman Sea, respectively. Deep sea

meiofaunal community generally concentrated to the relatively thin surface layers (Ingole *et al*. 2000). Ingole *et al*. (2005) studied on deep sea metazoan meiofaunal assemblage to understand the re-colonization process in Central Indian Ocean Basin (CIOB) at a depth of 5000 to 5500 m depth. The density value of meiofaunal ranges from 8 to 52 nos. in 10 cm^2 area. Nematode (36.8 per cent), Nermertina (34.6 per cent), Turbellaria (11.4 per cent), Gastrotricha (8.8 per cent), Polychaeta (4.4 per cent), Harpacticoida (1.3 per cent), Kinorhyncha (0.4 per cent) and unidentified (2.2 per cent) were the major taxon identified in this region. The abundance of nematodes was reduced to 50 per cent level after disturbances. From this study it was concluded that the deep sea mining affect the benthic communities, however the re-colonization occurs at temporal level.

The organic constituents available as a labile stage in deep sea sediments play a significant role in meiofaunal food cycle (Ingole *et al*., 1992; Raghukumar *et al*., 2001). The benthic biomass populations were closely associated with bacterial growth in deep-sea sediments (Alongi and Pichon, 1988; Raghukumar *et al*., 2001). To study the deep sea meiofaunal assemblage the experimental design was reported by Sharma (1999) and Sharma *et al*. (2001). Ingole *et al*. (2000; 2001) reported that approximately 40 per cent of reduction in the benthic population taxon and community level immediately, if the sediments were disturbed.

The Central Indian Ocean Basin (CIOB) were studied the meiofaunal assemblage in siliceous ooze sediments and low manganese nodules environment (Sharma, 1999). After 44 months of disturbance on the deep sea floor, the dissolved nutrients in the sub surface layer and freshly churned organically rich sediments layer on the sediment become the food source for the epibenthic animals (Ingole *et al*., 1999). The nematode: copepod (N: C) ratio was used to estimate the environmental conditions as an indicator in deep sea environment (Ingloe *et al*., 2000, 2005; Ansari and Ingole, 2002; Ingole and Koslow, 2005). Further, it was also reported that micro-crustaceans (Harpacticoid copepods) were sensitive to environmental changes and nematode shows resistant to rapidly changed environment (Ansari, 2000; Ansari and Ingole, 2002).

Mohan *et al*. (2011) studied the distribution of meiofauna on the continental shelf off Nicobar group of islands reported that eleven meiofaunal taxa were identified such as foraminifera, nematoda, copepoda, polychaeta, halacaroidea, amphipoda, kinorhyncha, tardigrada, ostracoda, syncarida and isopoda. All the 100 m stations show low concentration of meiofauna than 50 m and 200 m depths. The foraminifera, nematode and copepod were occurs in all the depths of 50 to 200 m which is considered as common group of meiofauna. However, kinorhyncha, ostracoda, syncarida and isopoda exhibit only in 50 m depth. Polychaeta and amphipoda were absent only in the stations of Great Nicobar. Further, it was also noticed that from the north to south of Nicobar group of islands, the diversity show a significant reduction. However, in the deeper stations of 200m, the minimum temperature 13.56 to 16.44°C, dissolved oxygen 0.59 to 0.87 ml/L and high salinity 34.67 to 34.96 PSU not play a major role to concentrate any significant meiofaunal group. Further, it also infer that the amphipod needs 0.80 ml /L and polychaetes need 0.60 ml/L of minimum oxygen for their existence.

Nematode

Sinha and Choudhury (1988) reported that nematodes present mainly in medium and fine sediments. Nematode was the abundant taxa followed by foraminifera where the sediment was fine sandy texture (Setty and Nigam, 1982; Varsheny *et al*., 1984; Nigam and Cahturvedi, 2000). Nematode is a large fraction of marine benthic community (Rao, 1986a). Sinha *et al*. (1987) recorded a new species of nematode (*Anoplostoma macrospiculum*) in Sundarbans, West Bengal. Nanajkar *et al*. (2011) had been reported that nematode was dominant among the meiofaunal population (ostracods, turbellarians, polychaetes, harpacticoid copepods, bivalves, oligochaetes, hydroids, nauplii and gastropods) in the sediments of Ratnagiri to Mangalore coast of India. This species distribution correlated with high content of organic matter and silty sediment. The species *Desmoscolex spp.* and *Polysigma spp.* were dominantly distributed in these stations.

Sarma and Rao (1980) reported that Chilka lake brackish water lagoon consist of high concentration of nematodes in their meiofaunal distribution groups. Aziz

and Nair (1983) reported the high concentration of nematodes in Edava-Nadayara Paravur backwater system of south west coast of India. The Karwar Bay has high meiobenthic production and in turn increases the total productivity of water column in this environment (Sudarsan and Neelakantan, 1986). Chinnadurai and Fernando (2006c) reported five new records of nematodes (*Anoplostoma viviparum, Darylaimopsis punctata, Desmodora (Pseudochromadora) pontica, Desmoscolex falcatus* and *Metalinhomoeus typicus*) in the artificial mangrove environment developed at Parangipettai, India.

Andaman and Nicobar Islands

In Andaman and Nicobar Islands a few studies on the meiofauna were attempted by Rao during the period of 1970 to 1993. Marine sandy environment exhibited 600 to 800 nos./10cm^2 of meiofaunal population in Andaman and Nicobar Island, India (Rao, 1975). Higgins and Rao (1979) had been identified kinorhynchs from the Andaman Islands.

Polluted beaches intertidal environment was studied by Rao (1987a) in Great Nicobar Island, India and found that turbellarians, gastrotrichs, nematodes, archiannelids, polychaetes, oligochaetes, copepods, isopods and amphipods as a major groups and nemertines, ostracods, mysids, mites, larvae of insects and mollusks as a minor group of meiofauna. Unpolluted beach dominated by nematodes, annelids and copepods (1164 Nos./10 cm^2) and polluted beach has less concentration of turbellarians, nematodes, chaetonotid, gastrotrichs, oligochaetes, copepods, mites and insect larvae (104 Nos./10 cm^2). Further, it was identified that the copepods were sensitive to the pollution and nematodes exhibit tolerance. Rao (1989) studied the sandy and muddy beaches at Port Blair and reported that density and diversity were higher in the sandy beach and lower in the muddy environment, that also only for the few dominant species. The total population consists of turbellaria, nematoda, gastrotricha, kinorhyncha, archiannelida, polychaeta, oligochaeta, ostracoda, copepoda, amphipoda and halacaroida groups of meiofauna with the 2 to 412 nos / cm^2. Nematodes followed by copepods were the dominant fauna of this study area. The sediment temperature increased from low water to high water level. In the low water mark the sediment temperature closely related to open water.

Rao (1987b) collected meiofaunal species and analyzed the same for thirty islands of Andaman and Nicobar group of islands. The study was conducted during the low tide of February and April. Temperature varies between 28.0 to 32.0 ºC, salinity 32.0 to 35 PSU, dissolved oxygen 0.3 to 4.8 ml/L and grain size varies silt to clay size (520 to 120 µm). The meiofauna groups such as turbellarians, nematodes, ostriches, archiannelids, polychaetes, copepods, hydrozoans, nemertines, kinorhyncha, oligochaetes, ostracoda, isopods, amphipods, tardigrades, gastropods, holothurians, larval forms of annelids, crustaceans and mollusks were also observed in these study areas. The total meiofaunal density reduced from 1600 indi./cm^2 to 80 indi./cm^2 from non polluted to polluted environment. Nematodes, copepods and annelids were dominant in sandy non polluted environment. Nematodes, oligochaetes and copepods were available in reduced numbers. .

Rao (1988) carried the survey on intertidal sediments of Great Nicobar Islands and included 124 new records out of 1282 species. Nematodes, annelids and copepods were identified as a major groups and ciliates, turbellaria, hydrozoans, gastrotricha, kinorhyncha, ostracoda, isopoda, amphipoda, tardigrada, halacaroida and gastropoda as minor groups. Coarse sandy sediments exhibit copepods and annelids and fine sandy and muddy sediments exhibits nematodes. Sandy habitats have more diversity than the muddy one. The highest density of meiofauna noticed in mid water level (51 per cent). Nematodes occurs all the tidal levels and the lower level of the beach exhibits annelids and copepods (coarse and muddy sediments). The low availabilities of meiofauna in high tide level due to low water content in this environment. Out of 182 species recorded in these islands 34 species were cosmopolitan and 88 were eurytopics, 36 were Indian Ocean forms and 24 were endemic to the fauna of Andaman and Nicobar Islands.

As suggested by Rao (1968), Low Water Mark (LWM) exhibits unfavorable for the distribution of the interstitial waters meiofauna due to the more turbulence and High Water Mark (HWM) environment represent less porous and anoxic condition which also not favourable for meiofauna. The zoogeography of interstitial fauna was elucidated by Rao (1980) for the beach sands of Andaman

and Nicobar Islands. Sarma and Chatterjee, (1993) reported halacarids species *Atelopsalis pacifica* (Halacarinae: Halacaridae) obtained from the coralline algae of *Jania rubens*, near Chatham Island, Port Blair. The species *Copidognathus eblingi* from the seaweed of *Acetabularia sp.* in Ross Island of Andamans, India had been reported first time Indian water as well as a new species by Chatterjee (1991). The species *Copidognathus krautzi* collected in the *Halimeda opuntia* from Mus Island (Nicobar), India identified as new species of Halacaridae (Acari) by Chatterjee (1992), occurrence of *Copidognathus longispinis* in sea grass beds from the Bay islands (Chatterjee, 1995a).

Three species of *Rhombognathus* such as *R.papuensis, R.scutulatus and R.similis* of Halacaridae (Acari) was reported from different parts of Indian coast from the different algal attachments (Chatterjee, 1995b). The *Copidognathus tamaeus* and *Copidognathus pseudosidellus* were identified as a new species from the sea grass beds of Andaman Islands (Chatterjee, 1996; 1997). *Copidognathus fabuli* reported first time as a new female specimen from *Halimeda opuntia* from Mus Island (Chatterjee 1999a). The intertidal environment of Chiriatapu and Chatham Island located in Andaman groups of islands exhibits *Copidognathus greeni sp nov* which had been reported as a new species represent holotype and allotype (Chatterjee, 1999b).
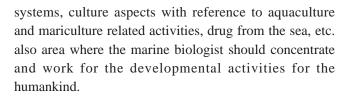
The species *Copidognathus andamanensis sp. n.*, reported as a new marine Halacaridae (Acari) from Chiriatapu, Andaman Island, India sediments associated with the coral algae *Halimeda opunita* (Chatterjee and DeTroch, 2003). On two species of *Stygarctus bradypus, Batillipes carnonensis* marine interstitial tardigrada from the east coast of India (Rao, 1970). Mohan and Dhivya (2010) studied the meiofaunal review in the Andaman and Nicobar islands. Mohan *et al*. (2012c) studied the status of meio and macrobenthos and its environment in Jolly Buoy Island, Mahatma Gandhi Marine National Park, Andaman, reported that the coral reef environment had more meiofaunal concentration and nematode and copepod was the dominant taxa of this study area. Mohan *et al*. (2012b) studied the organic matter and carbonate distribution and its significance with meiofaunal distribution in Junglighat Bay and Car Nicobar, suggested that the

positive correlation was noticed in nematode and organic carbon.

Distribution of mangrove meiofaunal composition to sediment organic carbon and carbonate in Port Blair reported that the *Avicennia marina* exhibited highest diversity and density and the lowest were found in *Acrosticum aureum*. The higher amount of carbonate (0.2 per cent) and moderate amount of organic carbon (2.5 per cent) was essential for wide level distribution of meiofauna. The higher concentration of organic carbon affects the diversity and density of meiofauna. Among the observed meiofaunal communities the nematodes were dominant taxon followed by foraminifera and copepod (Mohan *et al*., 2011).

Tsunami

Meiofauna of Marina beach, Chennai was studied for its distribution immediately after the tsunami occurred in December 2004 for a period of 25 days and found that oligochaetes, nematodes and harpacticoids reduced their population while polychaetes and turbellarians occurred at high density due to their sustainability on these high disturbances. Further, it was also noticed that the recolonization process for the meiofaunal groups of foraminiferans, cnidarians, nemertines, gastrotrichs, rotifers, kinorhynchs, ostracods, isopods, halacarids and insects had in high response. Another fact noticed on this study was that those species normally occupy in 10 to 15 cm had migrated to upper layers of the sediment due to the favorable condition existed on this layer after tsunami (Altaff 2005; Altaff *et al*., 2005).

The review of meiofaunal study with reference to India suggested that this is an infant study and need a lot of manpower to understand this science. Even though the different marine environments study such as beach, tidal flat, nearshore, continental shelf, deep sea, salt marsh, mangrove and other related environment distribution and diversity have been documented, the whole scenario has not been revealed till date. The existing studies were also not undergone to level of species in all the twenty meiofaunal groups. In India, meiofaunal study mainly concentrated nematode and harpacticoida (copepoda) and certain extend in polychaeta. Further, the biomass study, interrelation ship with tropic level, pollution monitoring

systems, culture aspects with reference to aquaculture and mariculture related activities, drug from the sea, etc. also area where the marine biologist should concentrate and work for the developmental activities for the humankind.

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