“MEIOFAUNAL DIVERSITY OF PUTHUVYPU BEACH, VYPIN”

Dissertation submitted to Mahatma Gandhi University

In partial fulfillment of the requirements for the award of the degree of

BACHELOR OF SCIENCE IN ZOOLOGY

DEPARTMENT OF ZOOLOGY

BHARATA MATA COLLEGE

THRIKKAKARA

2019-2020

Date: **Submitted by,**

Teacher in charge: Dr. PRIYALAKSHMI. G. **ALIYA JALAL**

Examiner: 1. **REG NO: 170021037704**

2.

DEPARTMENT OF ZOOLOGY
BHARATA MATA COLLEGE
THRIKKAKARA

Date: .0 .2020

CERTIFICATE

This is to certify that the project entitled "**MEIOFAUNAL DIVERSITY OF PUTHUVYPU BEACH, VYPIN"** is a bonafide work done by **ALIYA JALAL** with Register No. **170021037704** during 2019-2020 in partial fulfillment of the requirement for the award of the Bachelor Degree of Science in Zoology of M G University, Kottayam.

Head of the Department
Dr. Priyalakshmi G

DECLARATION

I do hereby declare that the work embodied in the dissertation entitled "**MEIOFAUNAL DIVERSITY OF PUTHUVYPU BEACH, VYPIN"**, submitted to Mahatma Gandhi University, Kottayam in partial fulfillment for the award of Bachelor of Science in Zoology is record of bonafide dissertation done by me under the supervision of **Dr. Priyalakshmi G**, Head of Department of Zoology, Bharata Mata College, Thrikkakara, and that no part of this work has been submitted for the award of any other degree/diploma/associate ship/fellowship or any other similar title to any candidate of any university.

Place: Thrikkakara

Date:

Signature of Candidate

Name: ALIYA JALAL

Reg No: 170021037704

ACKNOWLEDGEMENT

First and foremost, praises and thanks to the God, **the Almighty**, for His showers of blessings throughout my project work to complete my work successfully. I would like to express my deep and sincere gratitude to my project guide, **Dr. Priyalakshmi. G**, Associate professor, Head of the Zoology Department, Bharata Mata College, Thrikkakara, for giving me the opportunity to do the project and providing invaluable guidance throughout this work. Her dynamism, vision, sincerity and motivation have deeply inspired me. It was a great privilege and honor to work and study under her guidance. I thank other teachers of our department **Dr. Simi Joseph P, Dr. Sherin Antony** and Ms. **Aswini Venugopal**, for their valuable support and guidance throughout the project. I thank our lab assistant, Mr. **Joshy Thomas** for providing me with all the necessary lab equipment when required. I would like to express my sincere gratitude to my project group members, **Annmaria Joge, Chantal Meril Michael** and **Nikhil .R**. Also I express my thanks to my parents for their love, prayers, caring and sacrifices for educating and preparing me for my future.

TABLE OF CONTENTS

SYNOPSIS

The marine environment has two major provinces viz; benthic and pelagic. Pelagic environment mainly consists of plankton and nekton, however, the benthic community consists of sessile forms. The benthic organisms are classified based on their 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, and environmental disturbance, has been identified as an important member of the benthic community ie., converting the energy from basic to higher trophic levels. Since it is sensitive to the environment, abundance and diversity of these in the environment is considered as a yardstick to measure the health.

I did a project entitled **"MEIOFAUNAL DIVERSITY OF PUTHUVYPU BEACH, VYPIN".** Puthuvypu is a part of the Vypin Island, Kochi. The diversity study of meiofauna of this area, using sampling techniques was done as part of my project. Various meiofaunal groups have been found which revealed the diversity of the Puthuvypu beach. The groups which I studied were ARCHIANNELDA, NEMATODA, POLYCHAETA, OLIGOCHAETA, OSTRACODA, COPEPODA, and HALACAROIDEA. Environmental factors including temperature, salinity, dissolved oxygen and pH of the water are estimated. The diversity of meiofaunal groups along the coastal areas of Kerala and India are reviewed. Problems affecting the diversity of meiofauna like pollution, trawling is also reviewed.

INTRODUCTION

The oceans in their vast expanse cover seven-tenths of the Earth's surface. The mean depth of the ocean has been estimated at about 4000 meters considerably greater than the mean height of land above sea level. Living things inhabit all this tremendous expanse and depth. (Priyalakshmi and Menon, 2014).

Coastal zone is the most thickly populated region of the Indian subcontinent, especially its southwest coast. Consequently, the bordering beaches are heavily utilized for a variety of purposes and are under considerable human influence. Sewer system, holidaying crowd of fair weather season and recreational pursuits, bring forth wastes from a wide area of the hinterlands and deliberately introduce these on to the beaches. Debris and waste from different sources find their way to and accumulate in these environs. Rafts of salvinia are common in the monsoon season and contribute to the debris load. A variety of wastes, perishable to persistent, thus arrive at the beach and coastal environs during all times of the year.

One of the main challenges in beach ecology is to understand how the biological communities are adapted to the extreme environmental conditions and to identify the main factors controlling such adaptations. Benthos represents a major component of the marine environment and plays a vital role in the overall food chain in the sea (Ganesh and Raman, 2007). The study of interstitial fauna in beach ecology is important for the understanding of trophodynamic process (Moreno et al., 2006). Zoological investigations and taxonomic descriptions of minute benthic animals were being published by the mid-19th century. The importance of the study of interstitial ecology was fully realized only after Remane's work (1933) on the distribution and the organization of the micro-fauna in the Kiel Bay.

The seashore has long been a subject of fascination and study. This region is better known as the 'Intertidal zone', where the land meets the water. The sandy beaches harbor diverse and abundant assemblage of marine organisms. All the macroorganisms inhabiting this area are burrowing animals. (Priyalakshmi and Menon, 2014).

Besides macrofauna, the sandy beaches are profusely inhabited by microscopic organisms belonging to the lower and higher invertebrate taxa. The ecological realm where these animals exist is known as the interstitial environment, which in principle includes the pore spaces in between sand grains containing copious supply of nutrient rich oxygenated seawater.

The general term 'interstitial' for the meiofauna in the interstitial water of sand was introduced by Nicholls(1938); Remane(1940) used the word 'mesopsammon' and the term 'meiobenthos' was coined by Mare(1942).

The meiofauna (or meiobenthos) are the smallest metazoans dwelling in the substratum of streams and other stationary surfaces, such as tree root wads and other large debris. They are roughly defined as metazoans that can pass through a 500-mm sieve, but are retained on a 40-mm sieve (Higgins and Thiel, 1988). Meiofauna are diverse, numerically dominant, and act as trophic intermediaries between micro- and macroscopic organisms in stream ecosystems (Schmid et al., 2000; Schmid-Araya et al., 2002a).They include small microscopic animals and protists, operationally defined based on the standardized mesh size of sieves with 500 micrometer as upper and 44 micrometer as lower limits(Giere 2009), living in aquatic sediments. A lower size limit of 31 or 20 micrometer has been suggested in order to retain even the smaller meiofaunal organisms in the deep sea (Giere 2009; Danovaro 2010).

In streams, the ecological role and importance of the benthic meiofauna might be similar to that of the zooplankton for lakes and large rivers. Meiofauna can be distinguished as permanent (fully benthic species that remain in the meiofaunal size-range during their whole lifespan), or temporary (species that start off as meiofauna but grow into macrofauna, or emerge out of benthos during their lifespan). Owing to their high abundance and diversity, wide spread distribution, rapid generation times and fast metabolic rates, meiofaunal organisms are important contributors to the ecosystem processes and functions, including nutrient cycling and provision of food to higher trophic levels, among many others (Woodward 2010; Schratzberger and Ingels 2017). Several studies have shown that meiofauna can adapt to extreme environments. The discovery of abundant and well adapted meiofaunal communities in several environments with extreme conditions has provided new insights into the ecology and physiology of species thriving in very challenging settings (Danovaro et al. 2010; Fontaneto et al. 2015).

Animals belonging to various phyla, from Protozoa to Echinodermata occur in marine interstices. Practically, all groups of invertebrates are represented in the interstitial fauna. Invertebrate groups with very small bodies (copepods, tardigrades) or which by their normal type of organization are pre-adapted for life in an interstitial environment are usually represented by many species in interstitial biotopes. Other groups of invertebrates like Coelenterata, Bryozoa etc. are instead represented by small number of morphologically aberrant forms (Halammohydra, Monobryozoan). It is in the interstitial fauna the smallest representatives of most of the invertebrate phyla are found. Interstitial meio-faunal sandy species reside within the space between the sand grains. Protozoa and metazoa in this environment have about the same dimensions.

Nematodes, Rotifers, and Harpacticoid copepods often dominate permanent meiofaunal communities, although curious animals such as tardigrades (also coined “water bears”), Ostracods, cladocers, gastrotrichs and microturbellarians can be found in some habitat. Temporary meiofauna are typically dominated by the youngest instars of aquatic insects (especially chironomids), but also comprise oligochaetes and water mites (Walter Traunspuger and Nabil Majdi, 2017).

In sands coarser than 200 µm median particle diameter, virtually all the meio-fauna are interstitial forms. Harpacticoids can remain interstitial down to a particle size of 160 to 170 µm and nematodes down to 100 to 125 µm mean particle diameter. Below 100 to 125 µm mean particle diameter, the interstitial fauna is absent. Purely interstitial forms like Gastrotricha are thus excluded from very fine sands and mud. In sands of 200 to 300 µm, nematodes are usually dominant, whereas in sand coarser than 350µm, copepods are usually more abundant, while in sand of 300 to 350 µm these two groups are equally abundant. Nematodes regularly dominate the meiofauna in sediment biotopes comprising less than 50 % of the total meiofauna. Harpacticoid copepods are usually second in abundance but may dominate in some coarse grained sediments.

According to Wieser (1959) a mean grain size of 200µm represents a critical threshold with the exception of nematodes, which easily tolerate smaller grain size. Species, which easily glide in the interstices of particles, are more abundant in the coastal sands while those able to displace the particles predominate in finer sands. Fenchel (1969) lowered the upper threshold to 90 - 100µm in the case of nematodes in well-sorted sands. Generally enough ciliates also live abundantly in this grain sized sorted sand and could dominate in the total biomass of smaller metazoans. Crisp and Williams (1971) attributed porosity and size of interstices to control the body size of the inhabitants. The composition of meio-fauna also varies based on sediment type. In well-sorted sands with particle diameter greater than 100 µm with the interstices filled with water rather than silt or clay, there would be a rich interstitial fauna comprising of turbellarians, gastrotrichs, oligochaetes, archiannelids, Ostracods and others, apart from nematodes and herpaticodes.

A significant factor in the nutritional biology of the interstitial fauna is the availability of organic matter in the sand. Their food mainly consists of organic detritus, bacteria, diatoms and protozoans. Major groups of animals like nematodes, gastrotrichs, archiannelids and tribulations are reported as detritus feeders (Swedmark, 1964). The organic debris is either absorbed to the sand grains or remains as colloidal suspension after bacterial decomposition. The adsorbed organic matter may serve as food for the scavenging microfauna while colloidal suspensions may be made use of by the suspension feeders. The organic debris while undergoing bacterial decomposition affects the pH and oxygen concentration of the medium, which in turn may alter the characteristics of the population (Krishnaswamy, 1957). Benthic bacteria have long been thought to be a major food source for meiofauna (Boucher and Chamroux, 1976).

The temperature of intertidal sediments is regulated by more general factors such as seasonal and climatic weather conditions and time of day. These in turn are frequently modified by more specific and local factors such as slope of the beach, moisture held in sedimentary spaces, the temperature of both air and seawater, and insulation of the sediment (Bruce, 1928a, b; Pennak, 1942; Jansson, 1967c; Johnson, 1965; Salvat, 1967).

In tidal beaches, seawater conditions dominate the chemistry of interstitial water. Except in areas of unusually concentrated precipitation, interstitial salinity remains approximately comparable to that of the seawater (Ganapati and Rao, 1962; Johnson, 1967) , in a few cases slightly higher (Fenchel and Jansson, 1966; Ganapati and Rao, 1962) , and in most cases somewhat lower (Jansson,1967c; Kuhl and Mann, 1966; Renuad-Dedyser,1963; Salvat, 1967).

The abundance of oxygen within a beach is related to the permeability of sediments to water (Brafirld, 1964). Oxygen is present within interstitial spaces in decreasing abundance from the water's edge toward the shore and from the sand surface toward greater depth (Jansson, 1967d; Pennak, 1951). Several investigators have studied the pH of interstitial water and reported readings similar to those from adjacent seawater (Bruce, 1928b; Ganapati and Rao 1962). Bruce (1928) observed that pH changes are moderated by an alkali reserve buffering effect of calcareous material in the sand.

Though the terms Nematoda, Polychaeta, Oligochaeta etc. are familiar, the term 'Meiofauna' or 'Interstitial fauna' was something new and this fascinated me in taking up this project so that I would be able to acquire new knowledge of this ecologically important group of minute organisms which forms an essential part of the ecological food chain.

AIM AND OBJECTIVES

AIM: The aim of the present study is to find out the **MEIOFAUNAL DIVERSITY OF PUTHUVYPU BEACH, VYPIN.**

OBJECTIVES:

- To find out the various meiofaunal groups inhabiting the coastal areas of Puthuvypu beach.
- To find out the various environmental factors affecting the diversity of the area.

REVIEW OF LITERATURE

The term "MEIOBENTHOS" was introduced and defined in1942 by Mare in her accounts of the benthos of muddy substrates off Plymouth, England. Meiofauna define a diverse assemblage of minute invertebrates generally associated with the benthos, or bottom, of many streams and rivers. Meiofauna can be considered intermediaries between microbes and macroscopic organisms in stream food webs. The size boundaries of meiofauna are generally based on the standardized mesh apertures of sieves with 500 µm (or 1000 µm) as upper and 63 µm (or 42 µm) as lower limits. Meiofauna are ubiquitous, inhabiting most marine substrata, often in high densities. Meiofauna are highly diverse, and several phyla are only known to occur as meiofauna.

Moore (1931) and Rees (1940) in Great Britain as well as Krogh and Sparck (1936) in Denmark quantitatively investigated meiobenthos and enumerated all the taxa. But it was Remane, "the father of meiofaunal research", first recognized the rich populations in intertidal beaches, sub tidal sands, and muds and algal habitats as definable ecological assemblages (Bruce C. Coull and Olav Giere). In 1940 Pennak published a comprehensive monograph, "Ecology of the microscopic metazoan inhabiting in sandy beaches of some Wisconsin Lakes". In 1951 he compared the freshwater and marine interstitial fauna.

The abundance or biomass values, vary according to the size, habitat etc. Highest values typically come from intertidal muddy estuarine habitats, lowest values from deep sea. Environmental factors such as temperature, salinity, water movement, O2 content, seasonality also affect the abundance of meiofauna. (Higgins and Thiel, 1988).

Role of meiofauna in estuarine soft bottom habitats was explained by Bruce C. Cuoll in 1999. In estuarine sediments meiofauna facilitate bio mineralization of organic matter and enhance nutrient production. It serves as a food for various higher trophic levels and exhibit high sensitivity to anthropogenic activities.

The study of meiofaunal diversity in shallow water hydrothermal vent in the Pacific Ocean showed that nematodes can thrive in conditions typically hostile to the metazoan life (Daniela Zeppalli, Roberto Danovaro, 2009).

Molecular tools have revolutionized the exploration of biodiversity especially for microscopic organisms. Higher diversity of meiofauna was found in Antarctic sediments using metabarcoding. Earlier it was found that only mega and macrofauna were inhabited in the Antarctic region (Fonseca, Sinniger 2017). Sediments of three different sub tidal areas of the Adriatic and Ionian Sea of the Italian coasts were investigated to study meiofauna and nematode composition. The nematodes were in abundances followed by copepods. (Leonardis, Sandulli, Vanaverbeke, 2008). The studies conducted by Tang, Alexander Kieneke in 2012 came to a conclusion that using 18S ribosomal subunit as a marker for biodiversity surveys and COI (Cytochrome c oxidase subunit) for eDNA surveys provide more accurate estimates of species richness in the future.

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).

The diversity of meiofauna of three stations (Pulicat, Royapuram, Marina) along with coast of Chennai was investigated from January 2003 to January 2005. One hundred and four species of meiofauna were recorded. Nemertina, Gastrotricha, Sipuncula, Thermosbaeneacea, Cumacea, Halacaroidea, Insecta, Gastropoda and Holothuroidea are the groups reported for the first time from the Chennai coast (Sugumaran, Naveed and Altaff, 2009).

A two year investigation of meiofauna and its related major ecological parameters was made in the sandy beach of Manamelkudi, Palk Bay, South East Coast of India. Samples were collected from January 2016 to December 2017. Eighty species of meiofauna belonging to 19 taxas were recorded (Sugumaran and Padmasai, 2019).

A study of ecology of interstitial fauna and environmental variables were carried out in the 4 main sandy beaches of west coast of India. Species of 9 interstitial taxa of which nematodes, Harpacticoid copepods, turbellarians and polychaetes constituted the bulk of the population. (Geetha Priyalakshmi and Menon 2014).

In the south west coast of India in the Poonthura estuary, the diversity of meiobenthic nematodes were studied. From this study the station close to sewage outfall shows a decrease in the abundance as well as species diversity and an increase in the species dominance were recorded (Anila Kumary, 2008).

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 benthic meiofaunal density of Pichavaram mangrove, along with environmental variables like temperature, salinity, dissolved oxygen, organic carbon and sediment characteristics were made during September 2000 to August 2001, and concluded that meiofaunal density was highest in sediments with Avicennia cover followed by Rhizophora cover. (Chinnadurai and Fernado 2003).

A comparative study of diversity, distribution and abundance of meiofauna in Kochi and Thiruvananthapuram coast was done and found that nematodes and foraminiferans were abundant (Jisha Kumaran and AV Saramma, 2014).

Preliminary studies on epibiotic Protista in the mangrove ecosystem of Ayiramthengu, Kerala coast evaluates the distribution and abundance of these protists in the prop roots of mangrove Rhizophora apiculata and in submerged litters also. A total of 15 genera of epibiotic protists were identified (Chitra and Sunil Kumar 2015). The studies conducted in the mangrove forest in north eastern Malaysia shows that mangrove diversity and leaf litter decay promote meiofaunal diversity (Michael Gee and Paul J Somerfield 1997).

Meiofauna are the biological indicators of marine environmental health and is a neglected benthic component. Then use of meiofauna (benthic metazoan 45 to 500 µm in size) as biological indicators for monitoring marine environmental health. Meiofauna increases bacterial denitrification in marine sediments. In sediments with abundant and diverse meiofauna, denitrification is double than in sediments with low meiofauna, suggesting that meiofauna bioturbation has a stimulating effect on nitrifying and denitrifying bacteria. (Bonagli, F J A Nascimento 2014). Nematode assemblages provide more particular differences between sea grass and unvegetated habitats than meiofaunal communities on small spatial scales. Both seagrass beds and adjacent unvegetated sediments harbor specific meiofaunal communities, and hence, the conservation strategy for seagrass should also consider the bare area of seagrass beds. (Jian-Xiang Liao and Hsin Ming yeh 2015).

Some meiofauna are sensitive to pollutants, and should be useful as indicator species because they are “frontline” organisms, facing sediment pollution during their whole life cycle and for several generations (Traunspurger and Drews, 1996; Bongers and Ferris, 1999).

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.

Meiobenthos are key indicators of aquatic environmental pollution and stress and can be used as effective tools in bio monitoring programs to assess the overall health of oceans. The dynamics of meiobenthic assemblages in relation environmental variables along the coast of Arthunkal in Kerala was studied by (Sinu J Varghese, MTP Miranda 2015). These diversity indices indicate moderate pollution and uneven distribution. The relation between pollution and meiofauna was investigated by BC Coull, GT Chandler 1992. Several meiofaunal indices in sediments of three Mediterranean harbors differing in environmental contamination are used to evaluate their usefulness. Meiofaunal taxa demonstrated a significant relation with the concentration of contaminants, especially the polycyclic aromatic hydrocarbons was studied by Moreno, Vezzulli, 2008.

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, Nemertina, 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).

Abundance of foraminifera was observed from the post tsunami shore of Indian coast. Studies done in the prior to tsunami and post tsunami showed a significant increase in foraminiferal number, organic matter, and calcium carbonate content. This is due to the large scale transportation of deeper water, offshore sediment to intertidal zone. (Subhadra Devi Gadi and KP Rajashekha 2007).

Impacts of trawling on the diversity, biomass, and structure of meiofauna assemblages were studied on the real fishing grounds in the southern North Sea. After various investigations it came to a conclusion that meiofauna are more resistant to disturbances by beam trawling than are macrofauna, and they also have the potential to withstand the effects of chronic trawling on real fishing grounds and to retain a key role in energy cycling (Schratzberger, Dinmore and Jennings 2002). Immediate effects of trawling on sea bottom and living communities along the Kerala coast was studied in 2004. Several studies have been conducted on the impact of trawling on a sea bottom and its living communities (Walting and Norse 1999, Churchill 1989, Gibbs et al., 1980), however no concerted attempt has so far been done to find its real impacts on Indian coast. Trawl fishes with more than 5000 units, is the most widespread method of capturing marine fishes and invertebrates in Kerala, the southernmost state of India with a coastline of 590km (Raveendran, 2001). Menon (1996) reported that trawling operations in a climatically limited coastal habitat slowly resulted in the disproportionate destruction of non-targeted groups along with juvenile/sub adults of homogenous species of commercially important fishes and shell fishes and a wide spectrum of benthic organisms. (B Madhusoodana Kurup, 2004). Dissolved oxygen, organic matter content, and water flow may be the most important abiotic factors regulating meiofaunal populations at small scales in streams and rivers (Swan and Palmer, 2000; Beier and Traunspurger, 2003; Caramujo et al., 2008; Majdi et al., 2011, 2015).Most stream meiofauna are obligate aerobes, and several studies have found a correlation between oxygen and meiofaunal populations (Boulton et al., 1991; Beier and Traunspurger, 2003). Because dissolved oxygen and interstitial water flow are influenced by sediment grain size and depth, these latter variables should be good predictors of meiofaunal abundance and composition in many cases (Ward and Voelz, 1990; Caramujo et al., 2008; Reiss and Schmid-Araya, 2008; Rae, 2013). For instance, gravel harbors an abundant and diverse meiofauna, particularly rotifers, copepods, and tardigrades, whereas sands and silts are inhabited chiefly by worm-shaped oligochaetes, chironomids, and nematodes. Other physicochemical factors (e.g., temperature and pH) may also be important regulators at regional scales (Rundle and Ramsay, 1997; Zullini et al., 2011).

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.

FAUNAL DIVERSITY OF INDIA.

India has some of the world's most biodiverse regions. The political boundaries of India encompass a wide range of ecozones- desert, high mountains, highlands, tropical and temperate forests, swamplands, plains, grasslands, areas surrounding rivers, as well as island archipelago. It hosts 4 biodiversity hotspots: the Himalayas, the Western Ghats, the Indo-Burma region and the Sunderland. These hotspots have numerous endemic species.

India, for the most part, lies within the Indomalaya ecozone, with the upper reaches of the Himalayas forming part of the Palearctic ecozone; the contours of 2000 to 2500m are considered to be the altitudinal boundary between the Indo-Malayan and Palearctic zones. India displays significant biodiversity and is one of the seventeen megadiverse countries.

The richness of the fauna of the country and need for their exploration was recognized a long time ago. It has become absolutely essential to obtain the information on the identity, distribution, interactions and population levels of animal species. Major constituents of marine meiofauna are Nematoda, Kinorhyncha, Annelida, Cnidaria, Isopoda, etc.

METHODOLOGY

The intertidal region of the Kerala coast is mainly sandy with some rocky patches. In some regions the sub tidal region bottom following the sandy intertidal is composed of very fine mud which is not a usual phenomenon. Kerala coast is unique in the formation of the mud banks. The study was done on the Puthuvypu beach. Puthuvype is a part of Vypin Island. It borders Vembanad Lake to the east, Arabian Sea to the west and South and Njarakkal to the North. The main thoroughfares in the area are Vypin-Munambam Road and LNG Terminal Road.

Meiofaunal organisms are mobile multicellular animals that are smaller than macrofauna and larger than micro fauna. Meiofauna are ubiquitous, inhabiting most marine substrata, often in high densities. Meiofauna are highly diverse, and several phyla are only known to occur as meiofauna. Owing to their small size and high densities, specialized techniques are required to collect, preserve and examine meiofauna. Their small size also makes them useful candidates for manipulative experiments, and culturing of individual species and approaches to experiments on whole communities.

SAMPLING METHOD

Sample collections and observations were done during the low tide, when the whole intertidal belt was accessible for sampling. Three different samples each of very low tide, low tide and mid tide were collected from the Puthuvypu Beach. Sampling was done by thrusting a glass corer of 2.5 cm diameter into the sand. The undisturbed sediment sample was immediately transferred into a bottle and a little of sea water was added followed by 7% $MgCl_2$ prepared in filtered seawater to anaesthetize the interstitial organisms. After 15 minutes, the sample was fixed and preserved in buffered formalin diluted to 4% by filtered seawater. The fixed samples were stained with .1% Rose Bengal (Pfannkuche and Thiel, 1988) for efficient faunal extraction.

HYDROGRAPHY

Interstitial water samples were collected and analyzed for temperature, salinity, pH and dissolved oxygen. Temperature was measured with a high precision mercury thermometer; salinity was noted immediately after collection using a calibrated Salinometer; pH was found with pH paper, dissolved oxygen was estimated by Winkler's method (Strickland and Parsons, 1972).

Winkler's method is based on the reaction between dissolved oxygen and Mn2+ ions in a strong alkaline medium. Mn2+ is oxidized to Mn3+ and is precipitated. It is then acidified to a pH range 1-2.5 and is again reduced to Mn2+ by excess I2- and I2 is liberated. The liberated I2 corresponds to dissolved oxygen and is estimated by sodium thiosulphate solution, using starch indicator.

PROCEDURE FOR THE ESTIMATION OF DISSOLVED OXYGEN

Siphon the interstitial water sample to the 250Ml bottle with precaution to reduce the contact with air. The siphoning tube should reach the bottom of the bottle. Do not allow the water to flow turbulently but allow water to flow over so that no air bubbles are trapped in it. Close the bottle with the stopper. Then remove the stopper and add 1Ml of MnSO4 solution followed by 2Ml of alkaline iodide to the water sample using separate pipette. The reagents should be added to the bottom of the sample. Now a white precipitate is formed. Replace the stopper of the bottle, shaken vigorously for one minute and allow the precipitate to settle down. Then add 1-2 Ml of H2SO4 just below the sample of water. Close the bottle with the stopper without any air bubbles. Shake the bottle vigorously and acid will digest all the precipitate. It is then titrated against standardized sodium thiosulphate.

Take 50Ml from the sample water into the conical flask and run the standardized sodium thiosulphate from the burette until the brown color of the sodium is almost disappeared or more correctly a pale straw color appear. At this point, add two or five drops of freshly prepared starch solution as an indicator. Then the color turns blue and completes the titration quickly by adding sodium thiosulphate from the burette. The end point is the complete disappearance of blue color. Repeat the experiment till the concordant values are obtained. The readings are taken and tabulated.

From the normality, amount of oxygen in the sample was calculated.

Oxygen concentration (mg/l) = y X x 8 X (1000/ s X (b-c) b)

Where: y= normality of sodium thiosulphate.

x= volume of sodium thiosulphate.

s= volume of sample taken for titration.

b= volume of BOD bottles.

c= volume of reagents added (Winkler A and B).

EXTRACTION OF THE MEIOFAUNA

Meiofauna was separated by suspension- decantation method (Wieser, 1960) with a few modifications (Neira and Rackemann, 1996). The sample was transferred into a large conical flask containing filtered seawater. It was stirred well and kept for 5 seconds for the denser sand particles to settle down. The supernatant was then carefully poured into a thin cloth. This process was repeated 6-8 times for the maximum extraction of the fauna. The sediment in the flask was examined under a stereomicroscope to ensure that no organisms were left behind. The organisms retained in the sieve were transferred to a small petridish containing minimum quantity of filtered seawater. The obtained organisms were observed under the stereomicroscope.

PUTHUVYPU BEACH, VYPIN

SAMPLING

RESULTS

Meiofaunal organisms belonging to various phyla were identified by the studies conducted on the coastal areas of Puthuvypu beach, Vypin. Environmental factors like Temperature, Salinity and pH was noted, and the amount of dissolved oxygen of interstitial water sample was determined.

MEIOFAUNAL GROUPS OBTAINED:

- **Archiannelida**
- **Nematoda**
- **Polychaeta**
- **Oligochaeta**
- **Copepoda**
- **Ostracoda**
- **Halacaroidea**

ARCHIANNELIDA

- KINGDOM – ANIMALIA
- PHYLUM - ANNELIDA
- CLASS – POLYCHAETA
- ORDER - ARCHIANNELIDA

The name Archiannelida was erected in the last quarter of the 19th century. Archiannelid is a small primitive marine worm. The term archiannelida was applied to the genus Polygordius because of the belief that these worms represented the primitive ancestors of annelids.

A class of small, simple, annelid, worms which are metamerically segmented and most of which have narrow, tube-like bodies. In some, the nervous system is primitive. Parapodia and tentacles may be present. Separate male and female forms generally occur. The group was formerly regarded as a distinct phylum; most authorities now suggest it represents an assortment of largely unrelated annelids, most of which are marine and members of the meiofauna of the sand grains. There are three families, all found in aquatic habitats.

It was Westheide (1985) is of the opinion that the category “Archiannelida” should be eliminated from the modern zoological systems and should no longer be used when referring to the families which are well adapted for the interstitial life.

(ARCHIANNELIDA)

NEMATODA

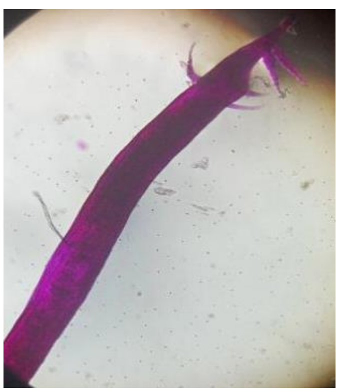
- KINGDOM - ANIMALIA
- PHYLUM – NEMATODA

Nematodes are one of the most highly diversified and perhaps the largest group of invertebrates. The organisms belong to this phylum are also known as “roundworms”. They are long thin worms with transparent and typically curled bodies. They are unsegmented vermiform animals. They are cylindrical in shape and exhibit tissue level of organization. Their body is bilaterally symmetrical and triploblastic. Nematodes are free living or parasite and shows sexual dimorphism.

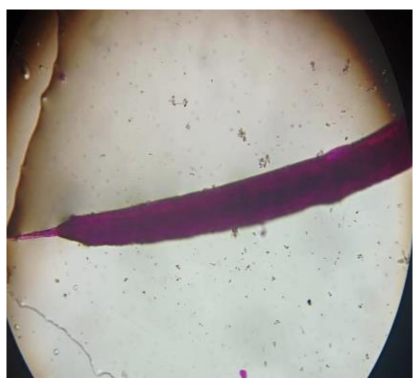
According to Platt and Warwick (1983), nematodes occur in a wide range of habitats, which is unsurpassed by any other metazoan group. There are two classes: the Secernentea and Adenophorea.

Nematodes can colonize virtually every moist habitat that can sustain metazoan life. Free living nematodes have comparatively short and simple gonads, the number and position of which can be easily assessed in whole mounts. These characters have received high importance in the classification (Lorenzen, 1981). The length of marine nematodes is usually around 1-3mm but sizes well over 10mm may be attained.

The main diagnostic characters are the presence of caudal glands (secreting a sticky fluid), bristles, and conspicuous amphids (cephalic multifunction sense organs) in the majority of Adenophore, being either absent or inconspicuous (amphids) in the Secernentea.



(ANTERIOR END)



(POSTERIOR END)

POLYCHAETA

- KINGDOM - ANIMALIA
- PHYLUM – ANNELIDA
- CLASS - POLYCHAETA

The class Polychaeta is a heterogeneous group, however no real distinction can be made between the larger benthic forms and the smaller ones found in the meiofauna. Only those Polychaetes, which are able to live in interstices of sediments, are considered “interstitial”. Many of the larger than the pore spaces of coarse sandy sediments, also are considered to be interstitial animals, since they move through the pore space by pushing the sand grains.

Polychaeta are relatively primitive annelids, apparently very close to the stem species of the Articulata. They are “worm like”, soft bodied invertebrates with a metamerically organized body. There are more than 10000 species of polychaetes can be arranged in to about 80 well defined families.

The meiofaunal polychaetes do not represent a single taxonomic group. They evolved in several independent lines from larger species which may have lived in or on top of the sediment. Among them are many highly derived, secondarily reduced or distinctly paedomorphic (= progenetic) species. Segmental Parapodia or cirri as well as head appendages which are so characteristic for most polychaete species may be lacking in these forms. Even chaetae may be completely absent.

(ANTERIOR END)

(POSTERIOR END)

OLIGOCHAETA

- KINGDOM - ANIMALIA
- PHYLUM – ANNELIDA
- SUB CLASS - OLIGOCHAETA

Oligochaeta make up about half of the phylum Annelida. They are important ‘recyclers’ because they eat dead and decaying material and turn it in into usable, nutrient rich soil for other organisms to use. These worms usually have few setae or bristles on their outer body surfaces, and lack Parapodia, unlike polychaeta. Oligochaetes are well segmented worms and most have spacious body cavity used as a hydroskeleton. Terrestrial oligochaetes are commonly known as earthworms and burrow in the soil, whereas aquatic oligochaetes are called microdriles.

Microdrile oligochaetes are generally slender and flexible, and they often exhibit jerking movements. Several species are reddish, brown or orange due to the coloration of the blood or the chloragogen tissue covering the gut. Some species are colorless and transparent, others are conspicuously white. The segmentation is often indistinct as many septa are either thin or incompletely developed.

All sexually reproducing oligochaetes are hermaphrodites. The genital system consists of testes, ovaries, male and female efferent ducts, and spermathecae. The segmental arrangement of sexual organs constitutes the most important feature used for the distinction of different families; the principal morphology of genitalia provides the fundamental generic characters, whereas particular details in the genitalia and setal characteristics are used to distinguish species.

(OLIGOCHAETA)

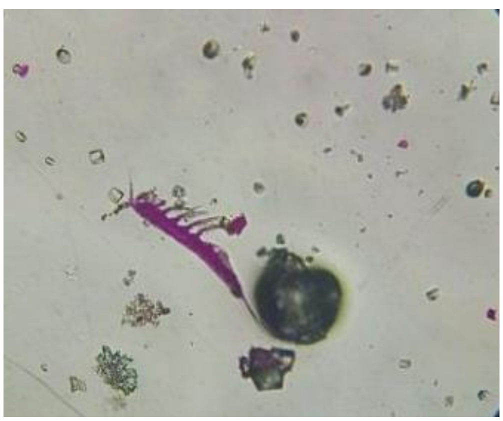
COPEPODA

- KINGDOM - ANIMALIA
- PHYLUM – ARTHROPODA
- SUB CLASS – COPEPODA

In terms of the meiofaunal abundance the Copepoda are second only to the Nematoda in sediments. In terms of the biomass they are often the most important taxon. There is considerable species diversity and copepods inhabit all available benthic habitats in the sea, freshwater and inland saline waters. They are also common in damp terrestrial habitats.

The copepod body consists of three tagmata: the cephalosome, the metasome, and the urosome. The cephalosome consists of head and first thoracic segment. The tergites and pleurites of these segments fused together to give a continuous head shield. The cephalosome bears head appendages. The metasome primitively consists of the thorax, except for the first segment, and bears the first five pairs of “swimming legs” or pereiopods. The urosome is the narrowest part of the body.

The life cycle typically includes six nauplius larval stages and always includes five sub-adult copepodid stages during which there is a progressive addition of cephalosome, metasome and urosome segments and development of their appendages. All species of copepods are sexually dimorphic.



(COPEPODA)

OSTRACODA

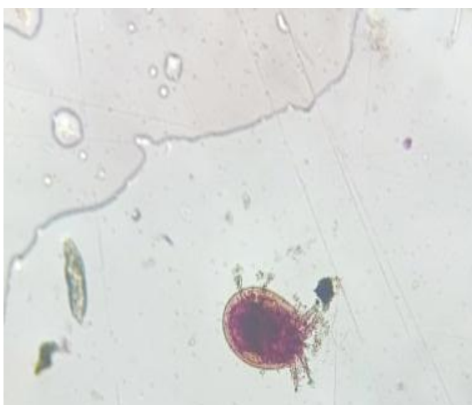
- KINGDOM - ANIMALIA
- PHYLUM – ARTHROPODA
- CLASS - OSTRACODA

Ostracods are found in nearly all aquatic environments. Most groups are marine, some are collected as planktons, and some benthic communities crawl on grains of sediment and on the algae.

They are small crustaceans ranging in length from 0.8 to 32mm. Their entire body is enclosed in a bivalve, calcified carapace which can be smooth to variously ornamented. The body is unsegmented and has reduced number of limbs. The gut is divided into an atrium, esophagus, midgut (intestine), and rectum which terminates either infront of or behind the furface.

Most Ostracoda possess naupliar eyes. Ostracoda can be bisexual or parthenogenetic. Sexual dimorphism is often made obvious by the presence of a very large penis or distinct brood chamber.

The Ostracoda are one of the few groups which have been easily fossilized because of their calcified valves. They have long fossil records, (Hartmann, 1975). Ostracods are found back to early Cambrian times.



(OSTRACODA)

HALACAROIDEA

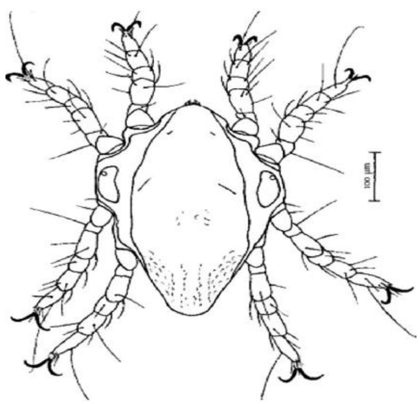
- KINGDOM - ANIMALIA
- PHYLUM – ARTHROPODA
- CLASS – ARACHNIDA
- SUPER FAMILY - HALACAROIDEA

The superfamily Halacaroidea includes several subfamilies and genera. In almost 700 species are described, the majority lives in marine and brackish water habitats, 40 species are known from freshwater.

The Halacaroidea are part of the marine, brackish and freshwater benthos. The halacarid body is divided into an anterior gnathosoma and a posterior idiosoma. They are usually flattened, slender, and almost sub cylindrical in interstitial forms.

Males and females are very similar in the general appearance, with marked differences in the genital region only. In the middle or in the posterior half of the genital plate there is the genital opening. There are 4 pairs of the legs attached marginally or dorsomarginally. Legs I and leg II are directed forwards and leg III and leg IV are directed backwards. Leg IV is absent in the larvae and the legs of the adult are six segmented.

Most halacarids are dioecious, probably all are oviparous. The lifecycle runs from the eggs through 1 larval and 1-3 nymphal stages.



(HALACAROIDEA)

RESULTS OF HYDROGRAPHY

The salinity of the sea water is noted using Salinometer. The salinity obtained from the sea water of the Puthuvypu beach is 35‰. pH was measured using pH paper and is about 8.0 and temperature noted using thermometer is about 26°C . The value of dissolved oxygen is 0.32 mg/L.

DISCUSSION

Sandy beaches have been regarded as marine deserts by many biologists and were largely neglected until Remane (1933) began studies on the coasts of Germany. The work of Pearse., et al (1942) was also pioneering and represented the first qualitative attempt to evaluate a whole beach system. Since then sandy beach ecology has advanced considerably, though it has always lagged behind other aspects of coastal marine ecology in the attention it has enjoyed. The sandy beach occupies a dynamic interface position between sea and land, its boundaries with the adjacent terrestrial and marine environments are not always clear and the functional extent of the beach itself has seldom been discussed.

Biodiversity investigations aim to integrate species checklists and the compilation of databases that represent a regional and global benefit for researchers worldwide.

As a comparatively young area of study most research on meiobenthos has remained taxonomic and descriptive. While the list of known intertidal meiofauna includes representatives of nearly every phylum of invertebrates, many investigators have attempted thorough ecological studies in this area. But, this is the first study on the meiofaunal diversity occurring along the coast of Puthuvypu, beach, Kerala. A preliminary study of the diversity of meiofauna is carried out using sampling techniques. Samples are collected and are examined to find out the various organisms inhabiting in the coastal areas. Sample collection was mainly done on the three levels, such as low tide, very low tide and mid tide. Organisms were analyzed from these areas to get into the conclusion. Studies of various environmental factors of this area are also conducted. Temperature, Salinity, Dissolved oxygen and pH were also found. This study suggests the diversity of meiofauna in the Puthuvypu beach. Various groups obtained were Archiannelida, Polychaeta, Oligochaeta, Nematoda, Copepoda, Ostracoda, and Halacaroidea.

Nematodes belonging to the phylum Nematoda and Copepods of the phylum Arthropoda are found in larger numbers, thus it shows the abundance of these organisms. Perhaps there is no taxon of metazoans so commonly obtained in sediment samples as marine nematodes. Their great abundance, adaptation to a wide variety of habitats and diverse morphology suggest that nematodes play a complex and significant role in the ecology of the marine environment. They are considered to be the most dominant water film fauna that inhabit the capillary water in pores between and within the soil aggregates (Bamforth, 1985). The biology of nematodes especially about free living, plant parasitic and animal parasitic nematodes was explained by Donald L Lee (2002). Van der Linde (1938) describes and figures a number of nematodes collected from around the roots of various plants. Nematodes present in the soil feed on the bacteria, fungi, and other nematodes and play an important role in nutrient recycling. They also attack the insects and control the pests.

Polychaeta are known as the bristle worms or polychaetes, which comes under the phylum Annelida. About 8000 living species are known. Polychaetes include rag worms, lugworms, bloodworms, sea mice, and others, are marine worms notable for well-defined segmentation of the body. Several workers have reported the occurrence of polychaetes along the Madras coast, Waltair and Orissa coast (Aiyar & Alikunhi, 1940, 1944; Alikunhi, 1941, 1947; Gnanamuthu, 1954; Krishnaswamy, 1957; Rao & Ganapati, 1962, 1968, 1969). A study on the occurrence and distribution of interstitial polychaetes on the west coast of India was pioneered by Govindankutty (1966).

The oligochaeta are considered a class, sometimes a subclass within the Annelida. Oligochaetes are both terrestrial as well as marine. Marine oligochaetes are called microdriles. An account of external and internal morphology of aquatic oligochaetes has been given by Cook (1971). The number known species of oligochaeta has increased rapidly, especially with the growing evidence of the diverse oligochaeta fauna in sub littoral biotopes (Erseus, 1980).

Ostracodes live in fresh, brackish, saline, and hyper saline waters, and rarely even in extra aquatic environments. In the sea, they are found from the shoreline down to hyperabyssal depths. The planktonic species, due to their weakly calcified shells, are generally rare in fossil assemblages, and play a minor role in paleontology. The majority of Ostracodes have a length between 0.15 and 12mm. Recent marine swimming forms attain up to about 25mm in length and the largest Paleozoic species up to 80mm. (Vladimer Pokorny, 1998).

Copepods are one of the most abundant metazoans on Earth. During their diversification, these small aquatic crustaceans have colonized almost all benthic and planktonic aquatic ecosystems, from deep sea oceans to the crevices of the Himalayan glaciers. The pioneering work in India on marine interstitial copepod was that of Krishnaswamy (1951; 1957) who made a systematic study of the group inhabiting the beach sands of Madras coast.

Archiannelids have been mostly recorded from the European coasts, especially from the coast of the Mediterranean. Archiannelida is an order of primitive polychaete worms. Zoologist Ray Lankester gave it the name Haplodrili, while zoologist Berthold Hatschek later named it as Archiannelida. Once, considered to be a class under Annelida, and even a separate phylum, Haplodrili is now widely accepted to be an order under Polychaeta. Species in this order are known for completely lacking external segments. The occurrence of Archiannelids in the inter tidal zone of the Madras coast was first observed in 1938 by R. Gopala Aiyer and K.H Alikunhi (1943).

The family Halacarid includes marine, brackish and freshwater species occupying areas from littoral to the deep sea (Bartsch, 2006). The first marine halacarid mite recorded in 1758 by Baster. To date about 1200 species of Halacarid have been reported worldwide (Bartsch, 2009).

CONCLUSION

Meiofauna constitute the best studied component of the interstitial biota. The density and diversity of the groups presented is low as the sampling method is done only once in an area. The review presented includes the history, distribution and various factors affecting the meiofaunal groups.

Sampling techniques are used to extract the various meiofaunal groups of this area. The meiofaunal groups present in the sample included Archiannelida, Nematoda, Polychaeta, Oligochaeta, Copepoda, Ostracoda and Halacaroidea. The density of the individual groups was generally found to be low in this study. Along with this meiofaunal groups, the environmental factors were also analyzed like temperature, salinity, pH and amount of dissolved oxygen. This study revealed that innumerable microscopic metazoan organisms live in the sandy beaches of Puthuvypu beach, Vypin though the beach appears to be barren sand.

REFERENCES

1. Andrew D Kennedy, Charles A Jacoby (1999); Environmental monitoring and assessment 54.
2. Andrew J Gooday, Brian J Bett, Rizpah Shires, P John D Lambshed (1998); Deep sea research part II: topical studies in Oceanography 45
3. Anilakumary KG (2008); Diversity of meiobenthic nematodes in the Poonthura estuary, Mar. Biol. Ass. India 50, 23-28.
4. Burton SM, SD Rundle, MB Jones (2001); the relationship between trace metal contamination and stream meiofauna, Environmental biology.
5. Bruce C Coull, Susan S Bell (1979); Perspectives of marine meiofaunal ecology, Ecological processes in coastal and marine systems, 189-216.
6. Bruce C Coull (1999); Role of meiofauna in estuarine soft bottom habitats, Australian journal of ecology 24(4).
7. Brusca, R. C., and G.J Brusca, (1990); Invertebrates, Sinauer associates.
8. Chinnadurai G. OJ Fernado (2003); Meiofauna of Pichavaram mangroves along southeast coast of India, Journal of the Marine biological association of India.
9. Chithra P, R Sunil Kumar (2015); Journal of the marine biological association of India.
10. Cuong Q Tang, Francesca Leasi, (2012); The widely used subunit 18S rDNA molecule greatly underestimate true diversity in biodiversity surveys of meiofauna, Proceedings of the national academy of sciences.
11. Cristiana De Leonardis, Roberto Sandulli, Jan Vanaverbeke (2008); Meiofauna and nematode diversity in some Mediterranean sub tidal areas of the Adriatic and Ionian sea, Scientia Marina 72(1).
12. Daniela Zipelli, Roberto Danovaro (2009); Meiofaunal diversity and assemblage structure in a shallow water hydrothermal vent in the Pacific ocean, Aquatic biology 5 (1).
13. Fonseca VG, F Sinniger, JM Gasper, C Quince, S Creer, Deborah M Power(2017); Revealing higher than expected meiofaunal diversity in Antarctic sediments; a metabarcoding approach, Scientific reports 7.

14. Geetha Priyalakshmi, NR Menon, (2014); Ecology of interstitial faunal assemblage from the beaches along the coast of Kerala, India, International journal of oceanography.
15. Gopala R. and Alikunhi K H (1943); On some archiannelids of the Madras coast.
16. Hector M Guzman, Vilma L Obando, Jorge Cortes (1987); Meiofauna associated with Pacific coral reefs, Coral reefs 6.
17. Hickman, C. P, and L.S. Roberts, (1994); Animal diversity, Wm. C. Brown, Dubuque, IA.
18. Higgins, R. (1978) Echinoderes gerardi n.sp. And E. reidli from the Gulf of Tunis, Transactions of the American Microscopical Society, 97/2: 171-180.
19. Jisha Kumaran, AV Saramma (2014); Diversity, disturbance and abundance of meiofauna in Kochi and Trivandrum coast- a comparative study, Climate change and marine ecosystems, 104.
20. Manylov, O. (1999) first finding of a microsporidian parasite in the gastrotrich, Protistology, 1:17-19.
21. Mariapaola Moreno, Luigi Vezzulli, Valentina Marin, Poala Laconi (2008); The use of meiofauna diversity as an indicator of pollution in harbors, ICES Journal of Marine Sciences 65.
22. Mark Blaxter, Ben Elsworth, Jennifer Daub (2004); Proceedings of the Royal Society of London. Series B: Biological sciences 271.
23. McLachlan A (1977); Composition, distribution, abundance, and biomass of the macrofauna and meiofauna of four sandy beaches, African zoology 12 (2).
24. Michael Gee J, Paul J Somerfield (1997); Mangrove diversity and leaf litter decay promote meiofaunal diversity, Journal of experimental marine biology and ecology 218(1).
25. Patrick JS Boaden, (1975); Anaerobiosis, meiofauna and early metazoan evolution, Zoologica Scripta.
26. Paul J Somerfield, Richard M. Warwick (2013); Meiofaunal techniques.
27. Robert P. Higgins and Hjalmar Thiel, (1992); Introduction to study of meiofauna.
28. Sabine Gollner, Barbara Riemer, Pedro Martinez Arbizu (2010); Diversity of meiofauna from the East Pacific Rise ocean, Plos one 5(8).

29. Schratzberger M, T Dinmore, S Jennings (2002); Impacts of trawling on the diversity, biomass and structure of meiofauna assemblages, Marine biology 140(1), 83-93.
30. Si Creer, VG Fonseca, DL Porazinska (2010); Ultra sequencing of the meiofaunal biosphere; practice, pitfalls and promises, Molecular ecology 19, 4-20.
31. Sinu J Varghese, MT Miranda (2015); Meiobenthic diversity and abundance along Arthunkal coast in Kerala, Journal of marine biological association of India.
32. Subhadra Devi Gadi, KP Rajashekha (2007); Changes in the intertidal foraminifera following tsunami inundation of Indian coast, CSIR.
33. Sugumaran J, MS Naveed, K Altaff (2009); Diversity of meiofauna of Chennai, East coast of India, Journal of aquatic biology.
34. Sugumaran J, R Padmasai (2019); Meiofaunal diversity and density of manamelkudian intertidal sandy beach of Palk Bay India, Res. J. Life Sci.Bioinform. Pharm. Chem. Sci.5.
35. Vladimir Pokorny (1998); Ostracodes, Introduction to marine micropaleontology, 109-149.
36. Warwick RM (1981); Feeding and survival strategies of estuarine organisms.