Chapter 1.
Introduction

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The term “benthos” is derived from the Greek word meaning ‘depth of the sea’. When organisms live in, or on are occasionally associated with aquatic sediments, their mode of life is referred to as benthic and collectively they form the ‘benthos’. According to Bostwick (1983), benthos are defined as those organisms live in or on the bottom of any water body. The benthic organisms play an important role in the marine food chain at the primary, secondary and tertiary levels. The demersal fishery especially in the coastal waters depends mainly on benthic productivity. As benthic animals lead a relatively sedentary mode of life, any change in the environment is reflected in the benthic organisms of the region.

1.1. The marine environment

The marine environment may be conveniently divided broadly into primary and secondary biotic divisions based either on physico-chemical attributes or on the nature of the biota (Sverdrup et al., 1942). The two primary divisions of the sea are the pelagic and the benthic realms. The former includes the entire water column while the latter includes all the ocean floor.

Benthic division includes all the bottom terrain from water-washed shore line at flood-tide level to the abyssal depths. It supports a characteristic type of life that not only lives upon, but also contributes to and markedly modifies the characters of
Ekman (1935) described the boundaries of the vertical zones from a geographic standpoint, and divided the benthic system into two, namely the littoral and the deep sea. The dividing line between these has been set at a depth of about 200 m on the arbitrary supposition that this represents the approximate depth of water at the outer edge of the continental shelf and also roughly on the depth separating the lighted zone from the dark portion of the sea. The littoral system is subdivided into the eulittoral and the sublittoral zones. The deep sea system is divided into upper archibenthic and lower abyssal benthic zones. The limits of the benthic subdivision are hard to define and are variously placed by different authors because uniform boundaries that fit all requirements cannot be drawn. For general biological studies, the different boundaries may be based on the peculiarities of the endemic plant and animal distributions and follow the region of most distinct faunal and floral change. The biotic zones thus delineated will be characterised by a more or less clearly defined range of external ecological factors which have given character to the population.

The eulittoral zone extends from the high tide level to a depth of about 40 to 60 m. The sublittoral zone extends from this level to a depth of about 200 m, or the edge of the continental shelf. The dividing line between these subdivisions varies greatly between extremes, since it is determined by penetration of light. It will be relatively shallow in higher latitudes and deep in the lower latitudes. In the upper part of the eulittoral zone a relatively well-defined tidal or intertidal zone is recognised.

The benthic environment from shore to abyssal depths is covered, to a greater or lesser degree by sedimentary deposits that may be classified as terrigenous deposits, organic or pelagic oozes and red clay. As far as the biology of benthic animals is concerned, the most important feature of these oozes are their physical charastericts and the amount of digestible organic material they contain. Most deep sea benthic forms are detritus feeders and mainly dependent upon the rain of detrital matters of pelagic organisms that falls to the bottom. The production of pelagic food
generally decreases markedly with increasing distance from the coast and the amount reaching the bottom in areas of very deep water is further reduced by its disintegration while sinking. Hence the littoral muds are most rich in organic food content, and the red clay at greater depths and far from the shore is the poorest in organic matter. These differences in the organic carbon are reflected in the numerical abundance of the fauna inhabiting in different areas.

The size of the sedimentary particles is of obvious importance in determining the distribution of marine benthic species. Sand particles are coarser fractions while silt and clay are finer particles. The nature of fauna in the benthic environment varies according to the types of deposits. The suspension and filter feeders predominate in the sandy bottom and deposit feeders dominated the fine particle substratum. (Harkantra et al, 1980). The interstitial space and porosity of the sediment are also considered to be important especially for meiofauna which facilitate to modify their shape and movement through the sediment (Crisp and William, 1971; Swedmark, 1971). The nature of bottom fauna in an area depends on the prevailing water movement. When there is vigorous water movement the bottom will be hard. Coarse gravel and shell fragments occur in places where the water movement is limited and in calmer waters smaller particles of sand, mud or silt occurs. A decrease in particle size will be associated with an increase in proportion of the organic matter. Mean grain size and sediment sorting distribution, which is a function of hydrodynamic regime played a role in benthic population (Snelgrove and Butman, 1994; Harkantra and Rodrigues, 2004).

1. 2. Benthos-definition and classification

Animal communities in the ocean can broadly be divided into different groups according to their ecological mode of life such as planktonic, nektonic, and benthic. Planktonic organisms are drifting or passively swimming organisms, nektons are large actively swimming organisms and benthic communities are those, which
live at or near the bottom. Many Benthic organisms have the power to swim and can change their position, while some live wholly or partially buried in the sediment and have limited ability to move around. They collectively form benthos or bottom communities. Benthos (both moving and sessile forms) represents a major component of the marine ecosystem and plays a vital role in the transfer of energy through food chain in the sea. Demersal fishes, crustaceans, molluscs, worms, echinoderms etc. are the larger forms coming under first category (moving forms). Sessile organisms are those, which stay at one place either fixed to the substrata or anchored at a suitable site. Corals, barnacles, encrusting sponges, anemones and seaweeds are sedentary in nature and belong to this group. However it must be noted that the distinction between pelagic and benthic is purely ecological and arbitrary as certain molluscs and crustaceans, living close to the bottom can adopt temporarily a pelagic mode of life. Larval forms of these organisms spent part of their life in the pelagic realm and are referred to as meroplankton. Three functional groups of benthos could be recognized namely the infauna, epibenthic fauna and hyper benthic fauna i.e., organisms living within the substratum, on the surface of the substratum and just above it, respectively (Pohle and Thomas, 2001). The infauna is much more restricted than the epifauna and only one-fourth as rich in species as the epifauna. The epifauna is represented by a maximum number of species in the tropical regions and they show decrease in number of species towards the poles. Based on the habitat, benthic organisms could be divided into two major groups namely soft-bottom benthos, and hard-bottom benthos. Depending upon the size, all large organisms retained by 0.5mm (500μ) sieve are generally referred to as macrobenthos; organisms which pass through a sieve of 0.5mm but retained by 63μ sieve are known as meiobenthos and those which pass through 63μ sieve are known as microbenthos. The dominant groups of organisms that constitute the macrobenthos are the sublittoral soft bottom inhabitants belonging to 4 major taxonomic groups-polychaetes, crustaceans, molluscs and echinoderms. Among these, polychaete
worms are the most abundant group and represented by numerous tube dwelling and burrowing species. Among meiobenthos, nematodes and foraminifers are the predominant ones. Other meiobenthic forms include harpacticoid copepods, ostracods, isopods, cumaceans, coelenterates, turbellarians and juveniles of larger invertebrates, gastrotrichs, kinorhynchs and tardigrades. The microbenthos include bacteria, protozoa, yeasts, fungi, diatoms, dinoflagellates, blue-green algae, euglenoids, cryptomonads etc. (Mare, 1942). This distinction of benthos into three size categories is rather arbitrary and it has no biological significance and varies according to the researchers and also on the pore size of the sieve used. Demersal fishes, which browse and burry themselves in the sediment surface, are grouped as megafauna. All feeding types from selective feeders to carnivores and omnivores are represented in this group. Based on their trophic status benthos are classified as phytobenthos which are represented by plants and algae seen on the sea floor and zoobenthos which include all consumers.

Of all the marine animals, a great many live on firm substrate, good numbers occur on sandy or muddy bottoms and a small percentage remains planktonic throughout their life. Benthic forms develop chitinous exoskeleton, calcareous shells and several other adaptations in the form of appendages and body musculature, enable them to live, move and propagate into the sediments or substrata they select to live. Animal representatives of most of the phyla are generally found in benthos, but a particular habitat is characterised by a few dominant species.

1.3. Importance of benthos

Estimation of benthic abundance is necessary for the assessment of demersal fishery resources, as the benthos form an important source of food for demersal fishes (Longhurst, 1958, Harkantra et al., 1980). According to Spark (1935) the average weight and number of benthic organisms have a correlation with primary production in the water column, climatic factors and also with demersal fish
production. Demersal fishery has a role in supporting the food requirements of man. Marine fish production in India shows that demersal finfish, crustaceans and molluscs together contribute about 49% of the total landings (CMFRI Annual Report, 1999). Besides their role in human diet, benthos especially mussels and clams are also used as an important sentinel organisms for pollution monitoring studies and are being used as indicators of pollution. The main reason of choice of benthic organisms for pollution monitoring are that they have the ability to bioaccumulate many pollutants like heavy metals, hydrocarbons and pesticides. Their ability to metabolise pollutant is very low, so it is easy to measure the body load of pollutants and also the amount that is depurated. They are tolerant to wide ranges of temperature and salinity, and can be easily grown in captivity for experimental studies. They can be easily sampled from inshore areas due to their sedentary habit.

Microbenthos are important since they are considered as the decomposers of the environment. They degrade the organic matter and enrich or get back the nutrients to the environment. Microphyto-benthos like diatoms are autotrophs and can prepare the food by means of photosynthesis. This food can be utilised by the meiobenthic forms. The meiobenthic organisms form the food for macrobenthic forms and act as a connecting link between the micro and macro forms, i.e primary producers and secondary consumers. Macrobenthic forms are later consumed by megabenthic forms like fishes and therefore the small benthic forms in turn regulates the demersal fishery potential.

1.4. Review of literature

The major oceanographic efforts to study the organism and their environments initiated as expeditions under the leadership of different investigators using various research vessels from time to time. Italians, Marsigli and Donati were the first to study the benthos, using dredge around the year 1750 (Murray and Hjort, 1965). British – Antarctic expedition in HMS Erebus and HMS Terror (1839-43) under the
leadership of Sir James Clark Ross, used a dredge showing that there was abundant and varied benthic fauna down to 730 m. The great marine expedition by H.M. S. Challenger (1872-76) during its course of study, made investigations on benthic invertebrates of the Pacific, Atlantic and Antarctic Oceans. The earlier works were on qualitative aspects and pioneering studies on the quantitative aspects of benthos were by Peterson (1911, 1913, 1914, 1915 & 1918) who developed a concept about community structure of benthos. Nicholls (1935) introduced the term ‘interstitial fauna’ to denote organisms, which inhabited the space between the sand particles. Remane (1940) coined the term ‘mesopsammon’ for these organisms and Thorson (1957) proposed ‘isocommunity concept’, which was the seed of vertical zonation in addition to Peterson’s (1918) community concept. Sanders (1958) studied the benthos of Buzzards Bay and its positive correlation to the type of substratum. Sanders (1968, 1969) collected the benthos of the coastal and deep-sea areas and studied the population density and diversity of the organisms. Gerlach (1972) studied the bottom fauna and sediment characteristics and its influence on the burrowing resistance and filter feeding conditions. Buchanan et al. (1978) studied the temporal variations and observed that seasonal changes in abundance and biomass appeared to be independent of the composition of the assemblage. Gaston (1987) studied the feeding and distribution of polychaetes of Middle Atlantic Bight and found that proportion of carnivorous were greatest in coarse sediments and decreased significantly with water depth across the continental shelf. Graf (1992) investigated the benthic – pelagic coupling and developed an energy flow equation for marine sediments. Service and Feller (1992) while studying the sub-tidal macrobenthos from the sandy and muddy sites in the North inlet and noticed significant fluctuations in faunal abundance and high variability between replicate samples.

Powellite and Kube (1999) studied the effect of severe oxygen depletion on macrobenthos in the Pomeranian Bay and concluded that hypoxic and anoxic conditions have a major role in the distribution and abundance of benthos. Desrosiers

Pioneering works on benthos in India were by Annandale (1907) on the macrobenthos and their ecology of Gangetic delta followed by Annandale and Kemp (1915) on the fauna of the Chilka Lake. Panikar and Aiyar (1937) studied the bottom fauna of the brackish waters of Madras and Samuel (1944) studied the animal communities of the Madras coast. Kurian (1953) and Seshappa (1953) studied the benthos of Trivandrum and Malabar coasts respectively while, Ganapati and Rao (1959) studied the benthos of the continental shelf of the north east coast of India. The Soviet research vessel ‘Vityaz’ collected samples during the Indian Ocean Expedition and the results has published by Beljaev and Vinogradova (1961) and Sokolova and Pasternak (1962). Later, Kurian (1967 & 1971) made an extensive study on the bottom fauna of the south west coast of India. A comparative study of marine and estuarine fauna of near shore regions of the Arabian Sea has done by Desai and Krishnankutty (1967) and Sanders (1968) studied the bottom fauna and species diversity along the east and west coast of India. Neyman (1969) made an extensive study on the benthos of northern Indian shelf and was the first study, which covered the entire length of northern Indian coast. The work on benthos of mud banks of Kerala coast was done by Damodaran (1973) and correlated the benthos with prawn fishery. He also included seasonal variations of macro and meiofauna in his study, which was the first quantitative study on meiofauna along the Indian coast. Ganapati and Raman (1973) investigated the role of Capitella capitata as an indicator species of Visakapatanam harbour. Parulekar and Wagh (1975) made studies on the quantitative distribution of benthic macrofauna of northeastern Arabian shelf and noticed a gradual decrease of biomass with depth and also in north-south direction. Parulekar et al., (1976) have worked on the distribution and abundance of macro and meiofauna off Bombay in relation to the environmental characteristics.
Ansari *et al.*, (1977b) carried out observations on the distribution of macrobenthos in five shallow bays of the central west coast of India and described the seasonal variations in benthic distribution. Ansari *et al.*, (1977a) also conducted a study on the quantitative distribution of benthos in the depth range of 20-1700m from the Bay of Bengal and stated a clear relationship between type of sediment and density of animals.

Harkantra *et al.*, (1980) studied the distribution and abundance of benthos of the shelf region along the west coast of India and correlated a definite relationship between benthic biomass, organic carbon, nature of substrata and demersal fish catch. Divakaran *et al.*, (1981) reported the distribution, abundance and ecology of benthic fauna from Vizhinjam harbour and its seasonal variations. Harkantra and Parulekar (1981) studied the qualitative and quantitative differences in the spatial and temporal distribution and production of macrobenthos during the pre-monsoon and post-monsoon seasons emphasising their relation to the environmental factors in the coastal zone of Goa. Parulekar and Ansari (1981) examined the benthic macrofauna of Andaman Sea and pointed out that distribution of macrofauna was substrate specific and environmental factors like temperature and oxygen also influence its distribution. Quantitative study on macro and meiobenthos and the relationship with demersal fishery resources in the Indian seas were done by Parulekar *et al.*, (1982) and concluded that exploitation of demersal fisheries can increase without adversely affecting the resources. They also pointed out the decrease in the abundance of macrobenthos as depth increased and dominance of meiofauna in the slope and deep sea.

Devassy *et al.*, (1987) studied the effect of industrial effluent on biota off Mangalore, west coast of India and found that effluent discharge did not cause any noticeable damage to the inshore areas. Varshney *et al.*, (1988) studied the qualitative and quantitative aspects of benthos of Versova (Bombay), west coast of India and stated that coastal areas were more polluted than off shore and high species diversity
indices of foraminifers and polychaetes in pollution stressed area revealed their tolerance to the pollutants.

Harkantra and Parulekar (1991) using the multivariate analysis showed the dependence of distribution and abundance of sand dwelling fauna on more than one ecologically significant environmental parameters rather than one ecological master factor. Salinity, dissolved oxygen, grain size and availability of food together formed significant factors in the distribution and abundance of benthos.

Vizakat et al., (1991) have made observations on the population ecology and community structure of sub-tidal soft sediment dwelling macro invertebrates of Konkan, west coast of India and postulated that sediment composition, organic carbon content of the sediment and salinity of the bottom water were the key factors determining the population and community structure. They observed an increase in faunal abundance from pre-monsoon to post-monsoon and suggested that colonization of shallow water macrobenthic communities get enhanced with cessation of south west monsoon associated with stability of salinity in coastal waters. Prabhu et al., (1993) observed significant spatio-temporal variations in the qualitative and quantitative distribution of benthos in the nearshore sediments off Gangolli, west coast of India.

Ansari et al., (1994) made a survey of the macro invertebrate fauna in the soft sediment of Mormugao harbour and revealed the spatial heterogeneity based on the environmental parameters and benthic assemblage. Harkantra and Parulekar (1994) also stressed the monsoon impact, which plays an important role in the density and diversity of soft sediment dwelling macrobenthos of Rajapur Bay, west coast of India and its replenishment after the monsoon. Ansari et al., (1996) studied the macro and meiobenthos of the EEZ of India and pointed out the relevance of benthic data in the assessment of potential fishery resources.

Saraladevi et al., (1996) studied the bottom fauna and sediment characteristics of the coastal regions of southwest and southeast coasts of India.
Gopalakrishnan and Nair (1998) conducted study on the sub tidal benthic macrofauna of the Mangalore coast, west coast of India and found the dominance of molluscs over polychaetes in the study area and also pointed out the increase in benthic abundance as moving towards greater depths (5 m to 15 m). Sheeba (2000) studied the distribution of benthic fauna in the Cochin backwaters, the south west coast of India in relation to the environmental parameters and Joydas and Damodaran (2001) studied the diversity and abundance of macrobenthic polychaetes along the shelf waters of west coast of India. Ingole et al., (2002) have done a study on the macrobenthic communities of the coastal waters of Dabhol and suggested that coastal waters of Dabhol provide favourable environmental conditions for feeding and breeding of commercially important prawn and crab species. Joydas (2002) studied the macrobenthos of west coast of India.

Quantitative studies on meiofauna from west and east coast of India were taken up by Thiel (1966), Mc Intyre (1968), and Sanders (1968); and central Indian Ocean by Ingole et al., (2000) and Sommer & Pfannkuche (2000). Works of meiofauna from the west coast were that of Damodaran, 1973; Ansari et al., 1977a, 1980; Ingole et al., 1992; Ansari and Parulekar, 1993). Pollution and its impacts on meiofauna were reported by many workers (Varshney, 1985; Rao, 1987, Ingole et al., 2000). Sajan (2003) studied the meiofaunal fauna of the west coast of India.

1.6. Scope and objectives

Benthic studies in India were rather neglected till 1970 due to lack of infrastructure and the laborious nature of the work, though scattered attempts had been made to understand the quantitative nature and community structure of benthos from different regions (Kurian, 1953&1967; Neyman, 1969). Later, many workers (Neyman et al., 1973; Kurian, 1971; Damodaran, 1973; Parulekar, 1973; Parulekar and Wagh, 1975; Parulekar et al., 1976; Ansari et al., 1977 a&b; Ansari et al., 1980; Harkantra et al., 1980) reported on benthos and most of the information pertains to
regional studies on macrobenthos. Damodaran (1973) and Harkantra et al., (1980) have attempted to correlate the benthic standing crop as an indication of the potential resources of demersal fish and the prawns.

Most of the earlier studies were directed towards the qualitative and quantitative aspects, but during the beginning of the present century, interest in the benthos has been directed more on the ecology, with particular reference to benthos as a source of fish food. Since 1973, National Institute of Oceanography has collected extensive data on various aspects of bottom organisms in different regions of the Indian Ocean and some of the results have already been documented (Parulekar, 1973; Parulekar and Wagh, 1975; Parulekar et al., 1976; Ansari et al., 1977 a&b; Ansari et al., 1980). Most of the studies pertaining to the seasonal changes on benthos were in the estuaries and backwaters and a few in the shallow subtidal regions of west coast (Ansari et al., 1977a; Harkantra and Parulekar, 1981; Vizakat et al., 1991, Prabhu et al., 1993; Harkantra and Parulekar, 1994; Gopalakrishnan and Nair, 1998) and all are from the very shallow coast of 5-20 m depth. However no attempt has been made to project the role of environmental factors on the benthic community structure and their distribution and abundance off the coast between 30-200m except that of Joydas (2002), which lacks any seasonal comparison. The northern part of Indian Ocean is peculiar with its land locked water body, which separates the Indian Ocean from the other two major oceans. The northwest coast of India experiences different climatic changes under the influence of monsoonal regime. Winter cooling is a special feature observing in the study area. It is therefore necessary to investigate various environmental factors and their role in structuring the infaunal benthic community, variation in their biomass, population density. With this view the present study was taken up to investigate the seasonal changes in the northwest coast of India and its impact on benthic organisms and the key factors that controls the benthic production.
Major objectives:-

1. To understand the distribution and abundance of marine benthos in relation to the prevailing environmental conditions.

2. To evolve latitudinal and depthwise variations of benthos.

3. To assess the community structure, species composition and diversity of benthic organisms.

4. To evaluate hydrography and the sediment characteristics of the northeastern Arabian Sea and its influence on benthic community.
1.6. References


monitoring committee (Atlantic Maritime Ecological Science cooperative, Huntsman Marine Science Centre) to the ecological Monitoring and Assessment Network of Environment Canada. www.cciw.ca/eman-temp/research/protocols/benthos/intro.html


