DYNAMICS OF INFAUNAL BENTHIC COMMUNITY OF THE CONTINENTAL SHELF OF NORTH-EASTERN ARABIAN SEA

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K. A. Jayaraj, M.Sc.

NATIONAL INSTITUTE OF OCEANOGRAPHY
Regional Centre, Kochi - 682018

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Certificate

I hereby certify that the thesis entitled **"Dynamics of Infaunal Benthic Community of the Continental Shelf of North-eastern Arabian Sea"** submitted by K. A. Jayaraj, Research Scholar (Reg. No. 2269), National Institute of Oceanography, Regional Centre, Kochi -18, is an authentic record of research carried out by him under my supervision, in partial fulfilment of the requirement for the Ph.D degree of Cochin University of Science and Technology in the faculty of Marine Sciences and that no part thereof has previously formed the basis for the award of any degree, diploma or associateship in any university.

Dr. Saramma U. Panampunnayil

Supervising Guide & Scientist -F
National Institute of Oceanography
Regional Centre, Kochi-18
Kerala, India.

Kochi-18
22.03.06

Acronyms and Abbreviations

AS	Arabian Sea
ASHSW	Arabian Sea High Salinity Water mass
BOB	Bay of Bengal
CTD	Conductivity - Temperature – Depth
DO	Dissolved oxygen
EEZ	Exclusive Economic Zone of India
EICC	East India Coastal Current
et al.	et alii (Latin word meaning 'and others')
e.g.	exempli gratia (Latin word meaning 'for the sake of example')
etc	et cetera (Latin word meaning 'and other similar things; and so on')
Fig.	Figure
N	North
NE	Northeast
NW	Northwest
NEC	North Equatorial Current
psu	Practical Salinity Unit
SW	Southwest
Sp.	Species
viz	videlicet (Latin word meaning 'namely')
WICC	West India Coastal Current
St.	Saint

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Chapter 1.
Introduction

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 the bottom. 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 seperating 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 sublitttoral 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 partickles is of obvious importance in determining the distribuion 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 oranic 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, crypomonads 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 (Longhrust, 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 showes that demersal finfish, crustaceans and molluscs together contribute about 49% of the total landings (CMFRI Anaual Report, 1999). Besides their role in human diet, benthos especially mussels and clams are also used as an important centinel 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 demerasal 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 differentr 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 – Anractic expedition in HMS Erebun 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 coarse 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.

Powelleit 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 *et al.,* (2000) studied the trophic structure of Macrobenthos of Gulf of St. Lawrence and Scotian shelf using multivariate analysis and Martin *et al.*, (2000) investigated the polychaetes and its spatial distribution and trophic structure of Alfacs Bay.

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 meiobenthos in his study, which was the first quantitative study on meiobenthos along the Indian coast. Ganapati and Raman (1973) investigated the role of *Capitella capitata* as an indicator species of Visakapatanm harbour. Parulekar and Wagh (1975) made studies on the quantitative distribution of benthic macrofuana 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 macrofuana of Andaman Sea and pointed out that distribution of macrofuana 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 meiofuana 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 macro fauna of the Mangalore coast, west cost 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 infuana 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 meiobenthos 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 meiobenthic 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 Arabain Sea and its influence on benthic community.

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Chapter 2.
Materials and Methods

2.1. Study area

The area selected for the present study is the continental shelf of the northwest coast of India. Samples were collected onboard the *Fishery and Oceanographic Research vessel (FORV) Sagar Sampada* (Plate1) as part of benthic productivity studies of a multidisciplinary project 'Marine Research on Living Resources (MR-LR) Progamme', funded by Department of Ocean Development (DOD), Govt. of India through the Centre for Marine Living Resources and Ecology (CMLRE). The present study is based on the samples collected along 6 transects (October, 1999) and 5 transects (February, 2002).

Study area extended from Mormugao to Dwaraka located between latitude 14° to 22° N and longitude 68° to 74.5° E and covered an area of ~ 55000 sq. km. The transects were off Mormugao, off Ratnagiri, off Mumbai, off Veraval, off Porbander and off Dwaraka (Fig. 1). At each transect (limited to the shelf) samples were collected from 30, 50, 75, 100, 150 and 200 m depths depending on the shelf width and other factors such as the distance between two successive stations in order to study the depth wise variation of fauna. Care had been taken to limit the distance between the stations in each transect to 30 nautical miles. Wherever required an additional station was fixed if the distance between two locations exceeded 60 km. Because of the restriction for the entry to the 'Mumbai High' region, one transect was added near Mumbai High which was named as 'off Mumbai' and another, along this area was named 'off Veraval'. For convenience of analysis and presentation of transect wise variation, the data is presented as 30 m, 50 m, 75 m, 100 m, 150 m and >150 m depths. The location of the stations sampled is presented in the figure 1.

2.2. Collection of the samples

2.2.1. Hydrographic parameters

Hydrographic parameters such as temperature, salinity and dissolved oxygen were estimated from each station. Water samples were collected using 1.8 l Niskin bottles attached to the rosettes of a Sea-bird CTD (Plate 2) (model: SBE-911 USA) with remotely operated closing mechanism.

CTD was used to measure the temperature-salinity profiles. Salinity values from CTD were corrected against the values obtained from autosal (model: 8400 A) onboard. Dissolved oxygen was determined by Winklers method as described by Grasshoff (1976). Water samples were carefully collected in glass bottles (125 ml) without trapping air bubbles. Samples were immediately fixed by adding 0.5 ml of Winkler A (manganous chloride) and 0.5 ml of Winkler B (alkaline potassium iodide) solution and mixed well for precipitation. The dissolved oxygen was later analysed after acidification by titration against standard sodium thiosulphate using starch as indicator. The concentration of oxygen in the sample was calculated as,

Dissolved oxygen (ml/l) = 5.6*N*(S-Bm)* V/ V-1)*1000/A

Where,

N = Normality of thiosulphate in solution

S = Titre value for sample

Bm = Mean titre value for blank

V = Volume of the sample bottle

A = Volume of sample titrated (50 ml)

2.2.2 Sediment and benthic samples

Sampling was done for the estimation of sediment parameters like texture and organic matter and for macro and meiobenthos from all the stations. A total of 48 grab samples (23 from post-monsoon season and 25 from pre-monsoon season cruises) were collected for the present work. Modified Smith Mc Intyre Grab was used for collecting sediment samples (Plate 3). It traps a substantial volume of sample, as its open mouth covers a surface area of $0.1m^2$. During the sampling, the vessel was maintained stationary and the wire was kept as vertical as possible to ensure vertical set down and lift-up of the grab at right angles to the bottom. As recommended (ICES, 1994), the final 5 m of descent was maintained at a rate < 0.5 $m.s^{-1}$ to minimize the shock bow wave disturbances. The sample showed a distinguishable undisturbed surface layer, often including loose flocculent deposits and no sign of sediment leakage, such as from incompletely closed buckets. Approximately 150 gm of wet sediment sample from each station was taken and dried onboard the ship at 70° C in an oven and stored in the polythene bags for the study of sediment characteristics. The dried samples were taken to the laboratory for further analysis.

2. 2. 2. 1. Macrobenthos

After sub sampling, all the samples remaining in the grab were sieved through 0.5mm (500 μ) sieve to separate specimens from the substrate. For unloading the sediment from the grab and then sieving, a wooden platform was fabricated (Plate 4). The sediment was unloaded in the conical aluminum portion of the platform, which was attached to the upper frame. The lower frame was modified in such a way so as to slide in and out the sieve in the form of a drawer, where the sediment unloaded as directly collected in the sieve. For the present study, 0.5 mm sieve was selected for separating macro benthos.

In order to avoid sample degradation, the sieving was accomplished onboard soon after the sample collection. It was done by washing the sample with seawater in a bucket and then sieving using 500μ sieve. Since immediate processing for taxonomic study is not possible, sieved specimens and residual sediments were transferred to plastic bottles and fixed in 5% neutral formaldehyde with "Rose Bengal" for staining the live organisms. Samples were properly labeled with details like cruise number, date, time, station position and depth.

2.2.2.1. Meiobenthos

At each station, with the help of a glass corer (2.5 cm diameter), sediment samples of 10 cm long cores were drawn and length of the core measured. Replicate (in some cases only one) sub samples were collected from each haul. The samples in Toto were transferred to polythene containers, labeled and material preserved in 70% alcohol-Rose Bengal solution for further examination.

On arrival at the shore laboratory, the sediment samples were processed through a set of two sieves, the upper one of 500μ and the lower with 63μ. Residue retained over 63μ sieve was back washed into a glass container and the same preserved in 70% alcohol or 4% neutral formalin. In some cases, Rose Bengal was used as stain prior to sorting and enumeration. The general methodology was that the residue over 63μ sieves was taken into a 1000 ml beaker and filled with filtered seawater. The diluted sample was elutriated. The supernatant was passed through a 63μ sieve. The meiobenthods retained on this sieve was washed into a 250 ml glass beaker. Meiobenthos in the aliquot sample was then enumerated group wise using a binocular microscope. The total number of organisms in the sample represented by different groups was calculated and expressed as number/10cm^2. Biomass of meiobenthos (mg/10 cm^2) was determined by using a high precision electronic balance (eg. Sartorius).

2.3. Analytical methods

2.3.1. Sediment texture

In the laboratory, for the analysis of sand, silt and clay, oven dried sediment samples were subjected to pipette analysis according to a standard method (Krumbein and Petti John, 1938). The percentage of each grade (sand, silt, clay) was calculated and plotted as triangular graph based on the nomenclature suggested by Shepard (1954)

2.3.2 Organic carbon

Organic carbon in the sediment was estimated by wet oxidation method (El-Wakeel and Riley, 1957), which was then converted into organic matter (Trask, 1939). For this, salt was removed by repeated washing. It was done by thoroughly mixing the sediment sample with fresh water in a 500 ml beaker and keeping the sample for one day for settling and decanted the supernatant. Repeated the process till all the content was removed prior to the estimation.

2.3.3 Benthic samples

In the shore laboratory the sediments were washed again under tap water and the organisms were preserved in 5% neutral formaldehyde and treated with Rose Bengal stain and kept overnight in order to enhance the colour contrast of the organisms. The preserved samples were sieved through 0.5 mm sieve; all the macrobenthic specimens were picked out from the sediment and sorted out. Prior to identification, wet weight of each sample was determined using mono-pan electronic balance. For qualitative enumeration, each sample was examined under a binocular microscope. The organisms were separated into different taxonomic groups for further identification. All taxa were identified to their specific, generic or other higher levels to the extent possible with the help of standard taxonomic references (eg. for polychaetes: Fauval, 1953; Day, 1967; for crustaceans and miscellaneous groups: Gosner, 1971); for molluscs: Satyamurti, 1952) and with the help of available experts. In some cases, specimens could not be identified upto species level due to damage or unresolved taxonomic identity. In the case of doubtful identification, the lowest reliable taxonomic level was given.

Density of organism was given by counting the actual number and then converted it to number/m^2. The determination of the biomass was done on a fresh/wet weight basis and expressed in g/m^2. For meiobenthos, the biomass and density was expressed in mg/10 cm^2 and number/10 cm^2. Fishery potential was calculated from the average biomass of macro and meiobenthos as suggested in earlier reports (Slobodkin, 1962; Parulekar, *et al.*, 1980).

2.3.4 Statistical analysis

Statistical analysis aids to simplify massive data for reliable interpretation. The data were subjected to statistical analyses such as community structure, similarity indices, multiple regression and 3-way ANOVA.

2.3.4.1 Community structure

PRIMER (Plymouth Routines In Multivariate Ecological Research) V 5 software package developed at Plymouth Marine Laboratory (Clarke and Warwick, 1994; Clarke and Gorley, 2001) for windows (version 5.2.8) was used for the estimation of community structure. Diversity indices such as Margalef's index for species richness (Margalef, 1968), Shannon index for species diversity (Shannon and Weaver, 1963), Heip's index for evenness (Heip, 1974) and Pielou's index for dominance (Pielou, 1966) were computed separately for polychaetes and for all the groups together including polychaetes. Indices used for the community structure analysis are given below.

Species richness, $d = (s-1)/Log_{10}(N)$

Shannon $H(s) = -\sum_{i=1}^{i=s}(Pi\ Log_2\ Pi)$

Heip's evenness $J' = e^{H(s)-1}/s-1$

Pielou's dominance = H(s)/Max H(s)

2.3.4.2. Similarity index

Similarity between stations with respect to polychaete species and all groups combined together were calculated using PRIMER V 5 for windows (version 5.2.8). For this Bray-Curtis similarity index (Bray and Curtis, 1957) with fourth root transformation was adopted. Dendrogram was plotted using the group average cluster mode for grouping stations with respect to polychaete species and also with respect to all groups including polychaetes.

2.3.4.3. Predictive multiple regression models

Abundance can be related to the environmental parameters by means of linear regression. But this relation gives only the prediction efficiency of a single factor at a time. A number of factors are jointly controlling the bioactivities at a point of time or space. Therefore, it is very essential that, the quantification parameters be considered simultaneously to have the best predictive model. Pedersen *et al.*, (1995) have given a method for choosing the minimal set of environmental variables that explain the variation in the plankton data. Here, an attempt has been made to choose the best predictive model (Jayalakshmi, 1998) from a set of 2^k predictive models containing individual factor effects and first order interaction effects where 'k' is the number of parameters used as the independent variables. Using explained variability as the criterion for selecting the best model (Snedecor and Cochran, 1967), the factors influencing the benthic productivity in terms of biomass and density has been determined.

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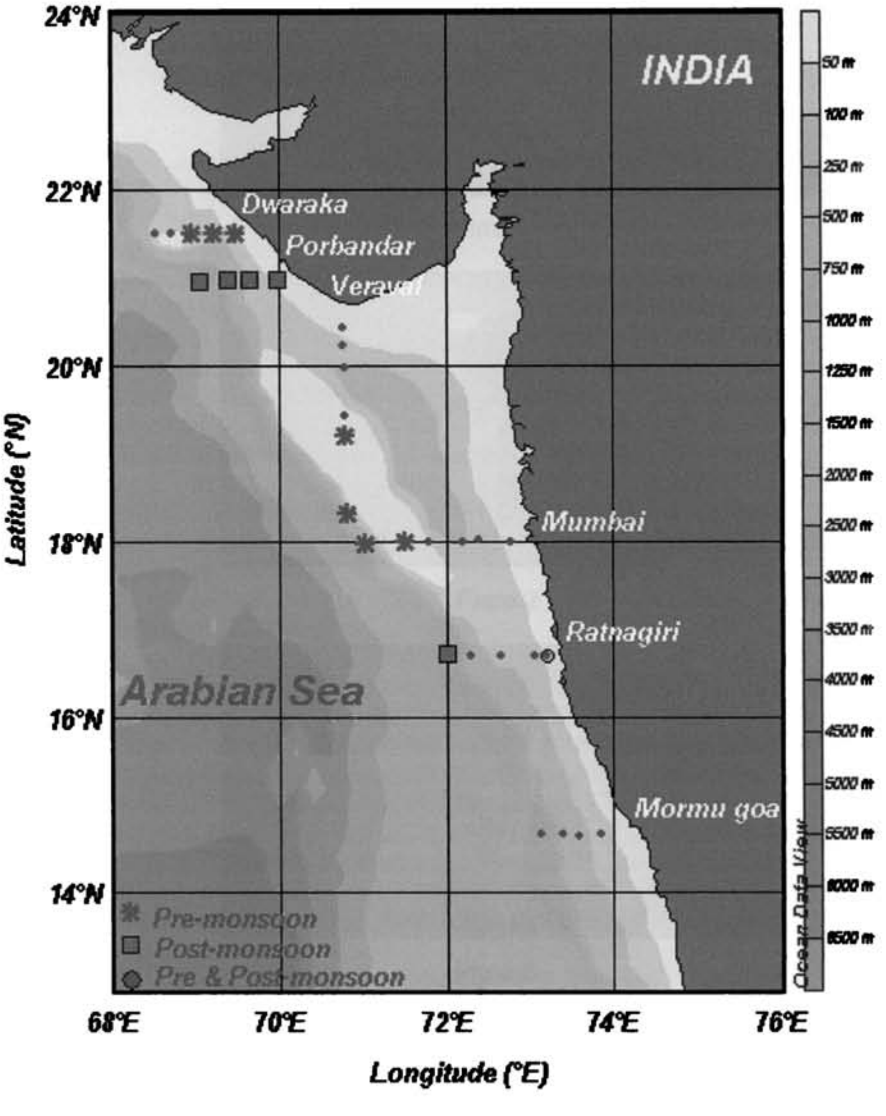

Fig. 1 - Station locations

Plate1

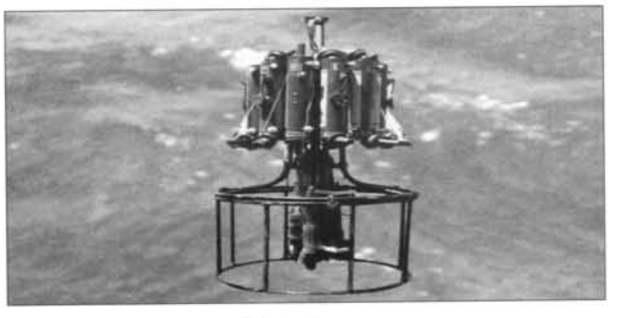

Plate 2

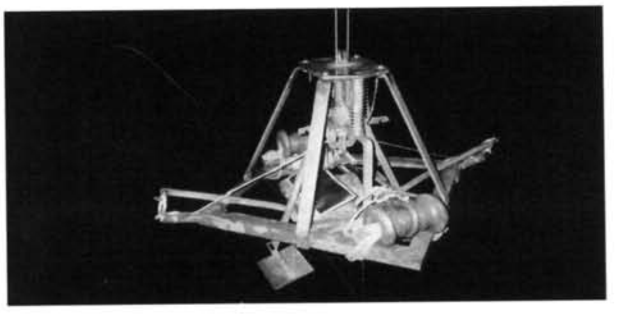

Plate 3

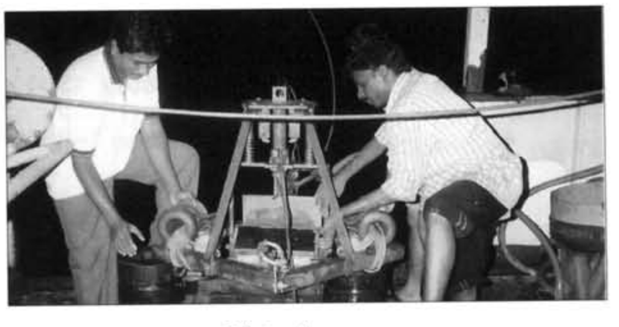

Plate 4

Chapter 3.

Hydrography

3.1. Introduction

Environmental parameters like temperature, salinity and dissolved oxygen have a direct relation to the distribution and abundance of benthic organisms. Various water quality parameters have a glaring influence in a variety of activities of benthos like active colonization, feeding, reproduction, growth etc. The latitudinal thermal gradient is accompanied by major biogeographic changes in pelagic and bottom assemblages of organisms. Seawater has a narrower range of temperature than air, which ranges between −1.9 to 40°C. In the open ocean it ranges from −1.9 to 30°C. Most of the solar energy intercepted by the ocean is absorbed in very shallow water. So temperature in the deeper areas is only about 2 to 4°C, even in the tropics. Temperature is probably the most pervasively important environmental factor affecting marine organisms. At the lower extreme, freezing of seawater results in the formation of ice crystals that disrupt cells and terminate metabolic activity (Levinton, 1982). At lethally high temperature, physiological integration is impaired and enzymes are inactivated, cytoplasm properties are altered and behavior is severely affected at high temperature. Most marine organisms do not regulate their body temperature (Poikulotherms). Temperature effects within lethal extremes thus have great effect on biochemical reactions and metabolism.

Temperature affects the rate of metabolic processes and apparently affects morphology of organisms. Warmer temperature, within limits, generally enhances metabolic and behavioral activity. The relationship of temperature to metabolic rate causes conspicuous physiological problems for marine species that live in thermally varying seasonal environments. Cold winter temperature can depress activity of poikulotherms with no capacity for acclimation. In tropical fishes, cold depression of respiratory system can lead to anoxic condition and death. Many invertebrate species spawn only when an optimum temperature is reached. Seasonal changes in gamete synthesis and liberation are highly correlated with temperature. The lower solubility of oxygen at higher water temperature might limit the individual's capacity for efficient respiration and may also limit the distribution of organism. The cause of heat death in some cases may be due to protein denaturation or thermal inactivation of enzymes. Tolerance of temperature is an important factor regulating the distribution of marine organisms. Thus temperature is a major factor regulating the distribution and abundance of marine organisms.

Salinity ranges from 33 to 38 psu in the open ocean. In the open ocean, salinity is increased by evaporation and sea ice formation and decreased by dilution processes, such as rainfall and river run off. In the coastal waters more drastic variation in salinity is observed because of influence of river input. Salinity change can present problems to marine organisms because of the physical processes of diffusion and osmosis (Levinton, 1982). When salinity changes, marine organisms face the danger of water loss or gain, with concomitant changes in body volume. Effect of salinity is more in the nearshore waters and estuaries where severe fluctuation in salinity is observed due to fresh water influx.

The distribution of oxygen in the ocean is controlled through the exchange with the atmosphere and the biological processes of photosynthesis and respiration. Oxygen from the atmosphere dissolves in seawater at the sea surface. The amount that can be dissolved decreases gradually with increasing temperature and to a lesser extent, with increasing salinity. Amount of organic matter present in the system also influences the availability of oxygen. Particulate organic matter sinks down and accumulates on the density gradient generated by the thermocline. Bacteria breakdown this debris and consume oxygen in the process, thereby producing oxygen minimum layers (Levinton, 1982). Almost all eukaryotic organisms require oxygen for metabolism. The continued absence or even depletion of dissolved oxygen (DO) results in lowering of metabolic activity. Active species consume more oxygen than inactive species. Sponges, ascidians and most bivalves consume much less oxygen than decapods, cephalopods and teleosts. Species actively feeding during day require more oxygen. Oxygen dissolved in water plays a significant physical as well as biochemical role in the life of aquatic organisms. The oxygen - hydrogen sulphide system is responsible for the development of oxidation-reduction potential. This system begins to operate when the oxygen is depleted, mostly due to the presence of large amount of organic matter associated with effective vertical separation of the water masses. Under anaerobic condition, bacteria, which use the oxygen bound in sulphide for oxidation of their organic nutrients, develop, with concomitant formation of gaseous H_2S, which dissolves in the seawater. As H_2S is a powerful biological poison, normal plant and animal life can no longer be sustained in such regions. In certain fine sediments, anaerobic conditions may develop and effectively exclude many species requiring a good supply of oxygen (Fincham, 1984). However, many of the meiobenthic forms thrive in this deoxygenated condition.

Arabian Sea (AS) is unique among the low latitude seas because it is land locked in the north by Asian landmass and has marked continental influence. It experiences seasonal reversal of atmospheric forcing, and consequently the upper layers exhibit different oceanographic characteristics during different seasons. The ecosystem is very much influenced by seasonal winds, thermohaline circulation and remote forcing. Enhanced evaporation is a peculiarity of the AS. The coastline is surrounded by the large landmasses, which enhance the differential heating. The land has a lower capacity to maintain heat that of water. Therefore, a strong land-ocean thermal gradient develops in this region, causing monsoon. As has an extensive bund of oxygen minimum layer which often surfaces in coastal areas during the period of upwelling.

Hydrographical studies along the western continental shelf were limited till the International Indian Ocean Expedition during 1960 to 1965. During the northeast monsoon (Nov-Feb), the winds in the coastal regions of the western India are northerly but currents flow pole ward (Darbyshire, 1967). Coastal current along the east coast of India (East India Costal Current, EICC) flows equator wards, which carries low saline Bay of Bengal (BOB) waters, turn round Sri Lanka and continue to flow towards north as West India Coastal current (WICC) along the west coast of India and supllies low salinity water in the southern AS. In the northern AS, cool and dry continental air brought by prevailing northeast trade winds intensifies the evaporation leading to surface cooling. This combined with reduced incoming solar radiation and high amount of salinity drives convective mixing in the northern AS, that leads to the injection nutrients into the surface layers from thermocline (Bhattathiri *et al.*, 1996). The evaporative cooling and convection leads to the formation of Arabia Sea High Saline Water Masses (ASHSW) in the northern AS. During intermosoon fall under warm and light wind condition, the surface layer becomes more stable which inhibits vertical mixing leading to the thinning of mixed layer. Under these conditions, entrainment of nutrients to the surface is not possible and as a result nutrient depleted layer deepens and eventually leads to poor production.

The continental shelf along the west coast of India comes under the monsoon regime and hence undergoes seasonal reversal with its hydrography and circulation. During southwest (summer) monsoon, the coastal current, WICC along the western shelf is towards south while in NE monsoon (winter monsoon) it is towards north. This type of reversing pattern of circulation is unique to the northern Indian Ocean. Upwelling which brings nutrients to the surface layers in the western shelf during SW monsoon supports high biological productivity is also a peculiar feature observed in the AS.

3.2. Results

Variations of environmental characteristics in the bottom water of the northwest continental shelf of India are examined in this chapter. Temperature, salinity and dissolved oxygen in various depth zones along different transects have been analyzed in this section in three parts. The first part deals with results of hydrographic features of the post-monsoon season, second part describes the same during pre-monsoon season, the third part deals with the seasonal comparison.

3. 2.1. Post-monsoon

Depth wise and transect wise variations of environmental factors during post-monsoon season are presented here.

3.2.1.1. Temperature

Depth wise distribution bottom water temperature in the study area is presented in Fig. 2a-f. During post-monsoon, temperature generally decreased to deeper depths from 30 m onwards at all transects. Off Mormugao there was a gradual decrease in temperature towards deeper depths, but the variation at different depths was low. Off Ratnagiri, Mumbai, Veraval and Porbandar also a decrease in temperature was observed from shallow to deeper depths. Off Dwaraka, only two stations were sampled and high value was observed at shallow station.

Transect wise variation in temperature distribution along different depth zones is presented in Fig. 3a-f. A gradual increase towards northern latitude was noticed at 30 m zone. At 50 m zone temperature fluctuated between transects with lower values in the southern transect and higher values in the northern transect. From 75-150 m zone also temperature fluctuated along different transects. At 75 m zone, highest value was observed off Veraval and lowest value off Mumbai. At 100 m zone, comparatively high values were noticed off Veraval and Dwaraka and low values in the southern transects especially off Mumbai. At 150 m zone, low temperature was observed off Ratnagiri and slightly high temperature off Porbandar and then it decreased towards off Dwaraka. In general, the observations indicated lower temperature in the southern latitude stations and higher values in the northern latitude stations.

3.2.1.2. Salinity

Depth wise distribution of bottom water salinity along different transects is shown in Figurs 4a-f. Off Mormugao a slight increase was noticed upto 75 m followed by a slight decrease to deeper station. Off Ratnagiri also salinity increased slightly to deeper depth up to 75 m and after that a decrease was noticed. Off Mumbai, a general decrease was noticed to deeper areas. Off Veraval and Porbandar also a gradual decrease was noticed towards deeper stations. Off Dwaraka, only 2 observations were made and high salinity was observed in both stations with comparatively high value in deeper station. Generally, in southern transects off Mormugao and Ratnagiri, salinity increased to offshore and rest of transects had high salinity in shallow stations which decreased to deeper zone. Transect wise variation in various depth zones showed a gradual increase towards northern latitude at all depth zones (Figurs 5a-e).

3.2.1.3. Dissolved oxygen (DO)

Depth wise distribution of bottom water dissolved oxygen (hereafter referred to as DO) in the study area is presented in Figurs 6a-f. Off Mormugao, generally a decreasing trend was observed towards deeper areas except an increase at 100 m depth. Off Ratnagiri there was a gradual decrease in DO concentration towards deeper depths. Off Mumbai a general trend of decrease towards deeper stations was observed though the pattern was not consistent. Off Veraval also a decreasing trend was observed with exceptionally low value at 50 m. Off Porbandar, DO increased to 75 m depth and then showed a decrease to deeper station. Off Dwaraka only two observations were made and DO decreased drastically to the deeper station.

Transect wise variation in distribution of DO at various depth zones is given in Fig. 7a-f. At 30 m depth zone variation was not significant among different transects except off Veraval where highest value (0.46ml/l) was observed. At 50 m depth zone, generally southern latitude stations recorded low DO values and northern latitude stations recorded comparatively high values. At 75 m zone, a gradual increase was noticed towards north. At 100 m zone, a fluctuating trend was observed with highest value off Veraval and lowest off Mumbai. At 150 m zone, DO was more or less similar off Ratnagiri and Porbandar but drastically decreased to northernmost transect (off Dwaraka). In general lower latitude stations experienced low DO and higher latitude stations recorded comparatively high values.

3.2.2. Pre-monsoon

Depth wise and transect wise variations of various environmental factors during pre-monsoon are presented here.

3.2.2.1. Temperature

Bottom water temperature distribution in the study area is presented in Fig. 8a-e. Generally temperature first increased then decreased to deeper depth stations at all transects. Transects off Mormugao, Ratnagiri and Mumbai recorded an increase in temperature from 30 m to 75 m depth and then deceased to deeper stations. Off Veraval and Dwaraka increase in temperature was upto 50 m depth zone and then gradually decreased to deeper stations. Off Veraval the decrease was well pronounced from 100 to 200 m depth zone. Off Dwaraka an increase in temperature was observed upto 75 m and then decreased to deeper depth zone (150 m). The decrease was more at 75 m to 100 m depth zone.

Transect wise variation in temperature distribution (Fig. 3a-f) showed that southern transects (off Mormugao and Ratnagiri) recorded high values and northern transects (Off Veraval and Off Dwaraka) recorded low values. Generally temperature decreased towards north. The temperature difference between southern most and northern most stations in each depth zone showed that it was maximum at 75 m zone (3.87 °C) and minimum at 150 m zone (0.83°C). In 30 m, 75 m and 150 m zones, the decrease was gradual but at 50 m and 100 m depth zones decrease was not so gradual with slight increase off Dwaraka. At 200 m depth, only 2 observations were made and the temperature decreased from off Mumbai to Veraval.

3.2.2.2. Salinity

Bottom water salinity distribution in the study area is presented in Fig. 8f-j. In general, salinity was high in the study area with low values in the shallow stations of the southern transects (off Mormugao, Ratnagiri and Mumbai). An increase was observed to greater depths off Mormugao, off Ratnagiri and off Mumbai while no marked variation was observed off Veraval. High values with fluctuating trend was noticed off Dwaraka.

Transect wise variation of salinity in different depth zones (Fig. 5a-f) showed that at the 30 m zone there was a gradual increase of salinity towards north with minimum values off Mormugao (35.09 psu) and maximum off Dwaraka (36.12 psu). At 50 m zone also a gradual increase was observed towards northern transects. At 75 m zone, salinity showed a gradual increase from off Mormugao towards north with exceptionally high value off Ratnagiri. At 100 m zone, fluctuating trend was observed with low value off Veraval (35.74 psu) and high value off off Dwaraka (36.36 psu). At 150 m zone, salinity did not vary much and low value was observed off Veraval (35.72 psu) and high value off Dwaraka (35.89 psu). At 200 m depth, 2 observations were made, salinity decreased from off Mumbai to Veraval.

3.2.2.3. Dissolved oxygen (DO)

Distribution of bottom water DO in the study area is presented in Figurs 8k-o. Generally DO showed a sharp decrease towards deeper depths in the study area. Along Mormugao transect DO showed a decrease to deeper stations. Off Ratnagiri, high DO values were observed at all stations and the pattern of distribution was same as that observed off Mormugao. Off Mumbai, a general trend of decrease was observed except at 75 m depth where a slight increase was noticed. Off Veraval and Dwaraka also, the decreasing trend was observed towards deeper depths. Generally higher values were observed up to 75 m and the gradient increased from shallow to deeper depths.

Transect wise variation of DO distribution in various depth zones (Fig. 7a-f) showed that at 30 m, 50 m and 75 m zones, a gradual increase was observed from south to north. At 100 m zone, a fluctuating trend was noticed with low value off Veraval and high value off Dwaraka. At 150 m zone generally low values were observed and as an exception from the previous depth zones here DO showed a decreasing trend towards north. Beyond 150 m, 2 observations were made and off Mumbai recorded high DO (0.6ml/l) and off veraval recorded low value (0.16ml/l). Generally in the shallow depth zones of 30 to 75 m there was a northward increase in DO values while at 150 m zone, a reverse trend was observed.

3.2.3. Seasonal comparison

Seasonal variations were very conspicuous in the study area. Temperature during post-monsoon decreased to deeper depth stations in all transects while during pre-monsoon it increased initially and then decreased to deeper depths. During post-monsoon, temperature increased to north while during pre-monsoon a northward decrease was noticed and the average temperature in the whole study area was high during pre-monsoon compared to post-monsoon. Salinity distribution, during post-monsoon period showed an increasing trend towards deeper depths only off

Mormugao and Ratnagiri and along other transects it decreased towards deeper depths. During pre-monsoon season salinity increased to deeper areas in the southern transects off Mormugao, Ratnagiri and Mumbai and no such trend in the northern latitude stations was observed. Both seasons exhibited northward increasing trend in salinity distribution. DO generally decreased to deeper areas in both seasons with some exceptions. Latitudinal northward increase of DO was only at 50 m and 75 m zones during post-monsoon season while during pre-monsoon in almost all depth zones northward enhancement in the level of DO was observed. But in the 150 m depth zone DO was low in the northern latitude station. Average DO in the study area was high during pre-monsoon season (2.69ml/l) compared to post-monsoon (0.22ml/l).

Student's *t* statistical analysis showed that temperature and DO showed significant seasonal variations (Table 1). At 30 m depth, temperature and DO have high significant difference between the two seasons ($t=2.3916$, $p<0.05$) indicating ecological differences between post-monsoon and pre-monsoon season. Significant difference ($p<0.05$) was also observed at 50 m zone for both temperature and DO. At 75 m depth also the temperature ($t=7.0475$) and DO ($t=10.9873$) showed significant differences between seasons. At 100 m the significance difference was observed for temperature and DO, and the significance in difference of temperature increased but for DO the difference decreased from 75 m zone. At 150 m depth also the significant difference observed for temperature and DO. For salinity there was no significant seasonal difference between the two seasons.

3.3. Discussion

In the present study, variations in bottom temperature with latitude and depth were observed. Temperature during post-monsoon increased towards north but during pre-monsoon a reverse trend was observed at all depth zones. During post-monsoon temperature decreased from shallow to greater depths whereas during pre-monsoon temperature initially increased then decreased to deeper depths. Qasim (1982) has also noticed a decrease of temperature from south to north during pre-monsoon season in the northern Arabian Sea. The winter is more pronounced in the northern region of the Arabian Sea (AS) than southern region as it is away from the equator (Darbyshire, 1967). This must be the reason for the decrease in temperature from south to north during pre-monsoon season. In general, cooling from south to north and low temperature in the coastal waters (up to 75 m) may be because of the cooling of the land mass in the northern region and a general flow of cold air from the land causing more cooling of the sea close to the land (Sankaranarayanan, 1978). This may be the reason for the low temperature in the shallowest region. Joydas (2002) also noticed a decrease in bottom temperature with depth and latitude. The high values in shallow regions and low values in deeper stations during post-monsoon season may be due to the secondary heating during this period. In this season, no cooling of landmasses is taking places as that of pre-monsoon season.

Salinity showed a general trend of increase towards north at all depth zones during post-monsoon but during pre-monsoon, northward increase was obvious only in shallow depth zones (30 m and 50 m). In other depth zones, salinity values fluctuated with relatively low values in southern transects and high in northern transects. The high rate of evaporation results in the formation of several high saline water masses. The general northward increase during post-monsoon season may be attributed to the presence of Arabian Sea High Saline Water (ASHSW) (Qasim, 1982). The Arabian Sea high saline water, formed in the northeastern AS, can be traced as a tongue of high saline water towards south (Qasim, 1982). Low surface salinity of the west coast of India south of 20° N might be due to the inflow of low saline water from the south and not due to either rainfall or land run off as no major rivers enter this area and the rainfall in the region is quite low (Qasim, 1982). The southern low saline water indicates the presence of north equatorial current (NEC) which carries the low saline waters along with it from the Bay of Bengal (BOB) and the eastern Indian Ocean into the western AS during this season. During the northeast monsoon (pre-monsoon season of the present study), low saline water from the BOB joins the northward flowing equatorial Indian Ocean water and flows as a northward surface current along the west coast of India (Pankajashan and Ramaraju, 1987). The reduced salinity in the shallow depth zones also shows the presence of BOB waters, which is coming from BOB to AS through the coastal current (Darbyshire, 1967, Wyrtki, 1971). Kumar and Mathew (1997) noticed that the maximum northward extension of this low saline water is upto 12° N in January but could be traced upto 17° N in February- March. It starts retreating from March onwards and coincides with the reversal in the upper layer circulation. Kumar and Prasad (1996) reported a weakly stratified layer of high salinity in the north, thinning towards south in the northern AS. They also added that very low saline water towards the south indicates the influence of BOB waters, being carried along the shelf by the northward flowing coastal current. Joydas (2002) pointed out that the low saline condition in the nearshore region could be attributed to the river discharge. In the present study, deeper waters of southern transects (off Ratnagiri and Mumbai) showed an increase in salinity during both seasons. This increase may be due to the presence of ASHSW. The core of ASHSW seen below the surface in the north deepens while spreading towards south, which may cause the increased salinity in the south.

DO was found to increase from south to north in shallow depth zones (30 m and 50 m) and the trend got reversed in deeper zone (150 m) during pre-monsoon season. DO showed fluctuating trends in between these zones (75 m and 100 m). Generally low values were observed during post-monsoon as compared to pre-monsoon. During both seasons DO decreased to deep in all transects. Qasim (1982) reported a distinct decrease from inshore to off shore. Moreover it decreased towards north in the deeper areas of 150 m zone as observed by Joydas (2002). This depletion of oxygen in the shelf edge of northern latitudes may be associated with the oxygen minimum layer described by Gupta *et al.*, (1976b, 1980) and Qasim (1982). They opined that limited mixing, high organic production, sinking and decomposition of large amount of organic matter were the reasons for this oxygen depletion in higher latitudes. Ivanenko and Rozanov (1961) have reported the presence of H_2S in the oxygen deficient zones of AS and BOB. Nejman (1961) observed sinking of high saline, high temperature, oxygen poor water in the Persian Gulf and Gulf of Aden and spread into the subsurface layers which may have its influence on the low oxygen and high saline water observed in the northern transects. Rao and Jayaraman (1970) suggested that the oxygen minimum is because of near stagnant conditions in the north and central parts of the AS. According to Wyrtki (1973) the oxygen minimum layer is due to the isolation and stagnation of the intermediate water, limited horizontal advection and high primary productivity.

The distribution of DO in the northern Indian Ocean is different from most of the other open ocean areas in that the surface layer is well mixed down to the thermocline and oxygen maximum could occasionally be observed within this layer, especially during pre-monsoon season. The intensity of the incident solar radiation is very high during this period, which causes maximum primary production to occur a few meters below the sea surface (Qasim, 1977). This together with high vertical stability may result in the observed oxygen maximum in the shallow depths. The strong density gradient prevent any significant exchange of DO from the euphotic zone to layers below the thermocline, and the horizontal advection is poor due to the semi enclosed nature of the region. These features in conjunction with a high rate of supply of organic matter from the surface result in a severe depletion of DO below the thermocline throughout the northern Indian Ocean, a feature recognized by several workers (Nejman, 1961, Wyrtki, 1971, 1973, Gupta *et al.*, 1976a, 1976b, Naqwi *et al.*, 1982).

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Depths	Temperature	**Salinity**	**Dissolved oxygen**
30 m	2.3079 (8)	0.7482 (8)	25.5504 (8)
50 m	7.0498 (7)	0	18.0304 (7)
75 m	7.0475 (8)	1.1142 (8)	10.9873 (8)
100 m	9.6623 (8)	1.8541 (8)	4.82820 (8)
150 m	4.8320 (6)	0.3487 (6)	3.09490 (6)

Table 1 - Seasonal comparison of environmental parameters based on Student's *t* test (Degree of freedom is given in bracket).

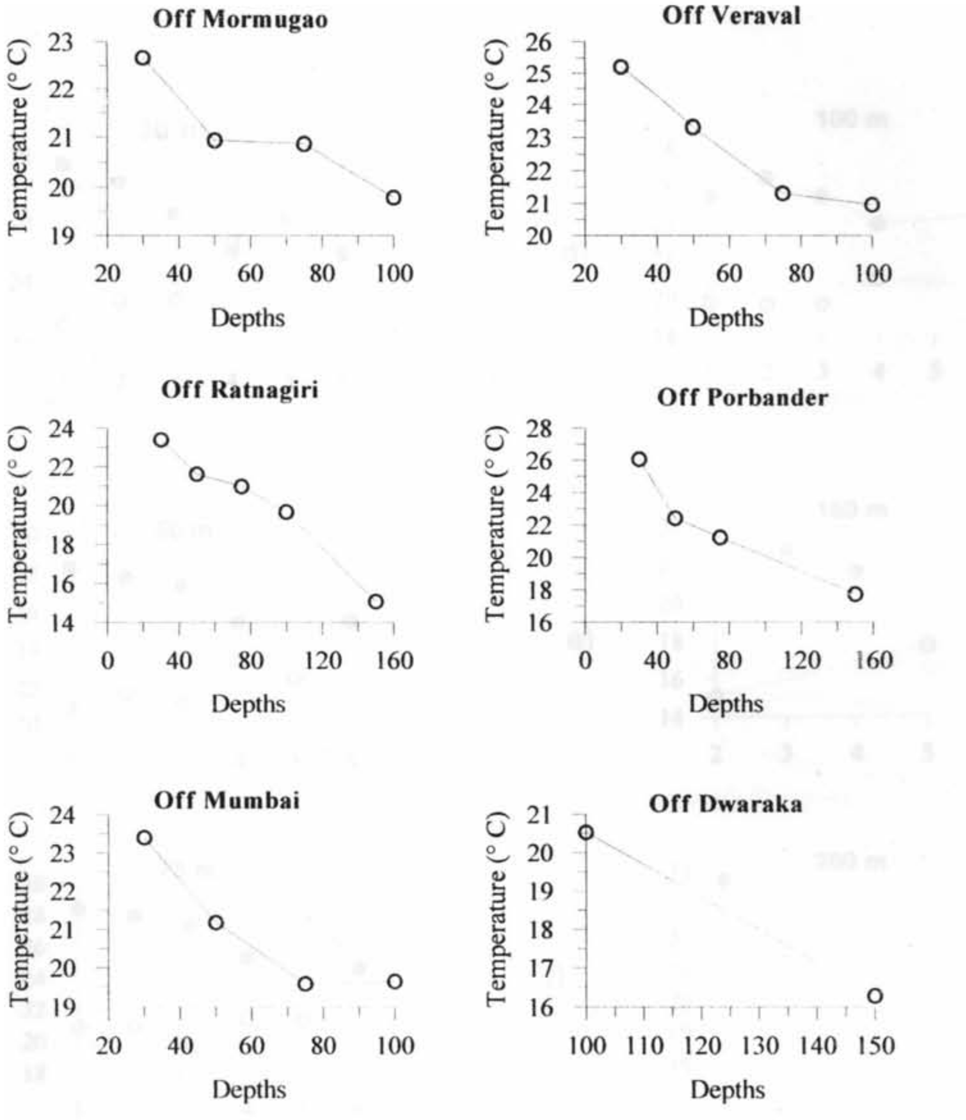

Fig. 2 - Depth wise distribution of temperature (°C) during post monsoon

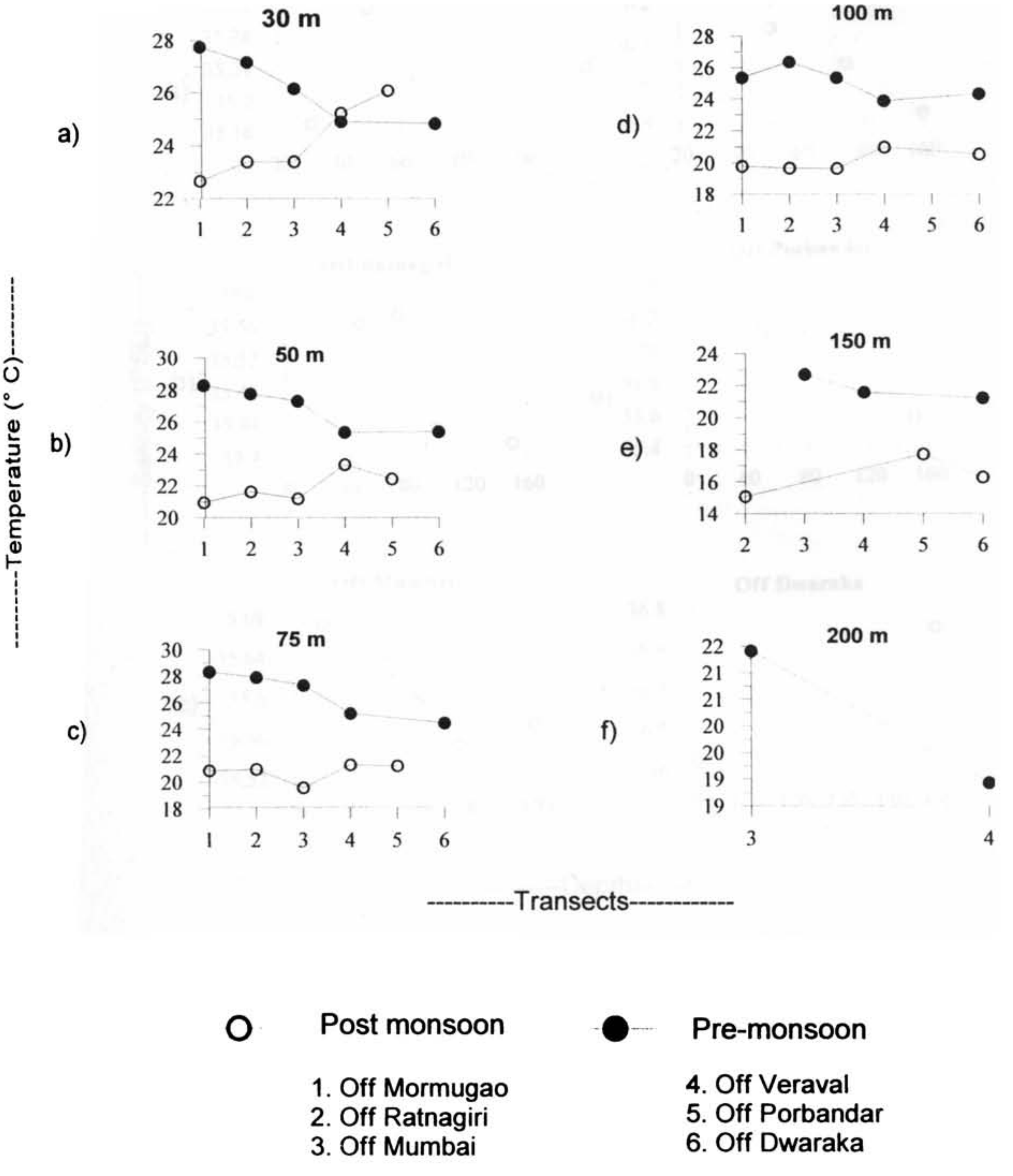

Fig. 3 - Transect wise distribution of temperature (°C) in various depths

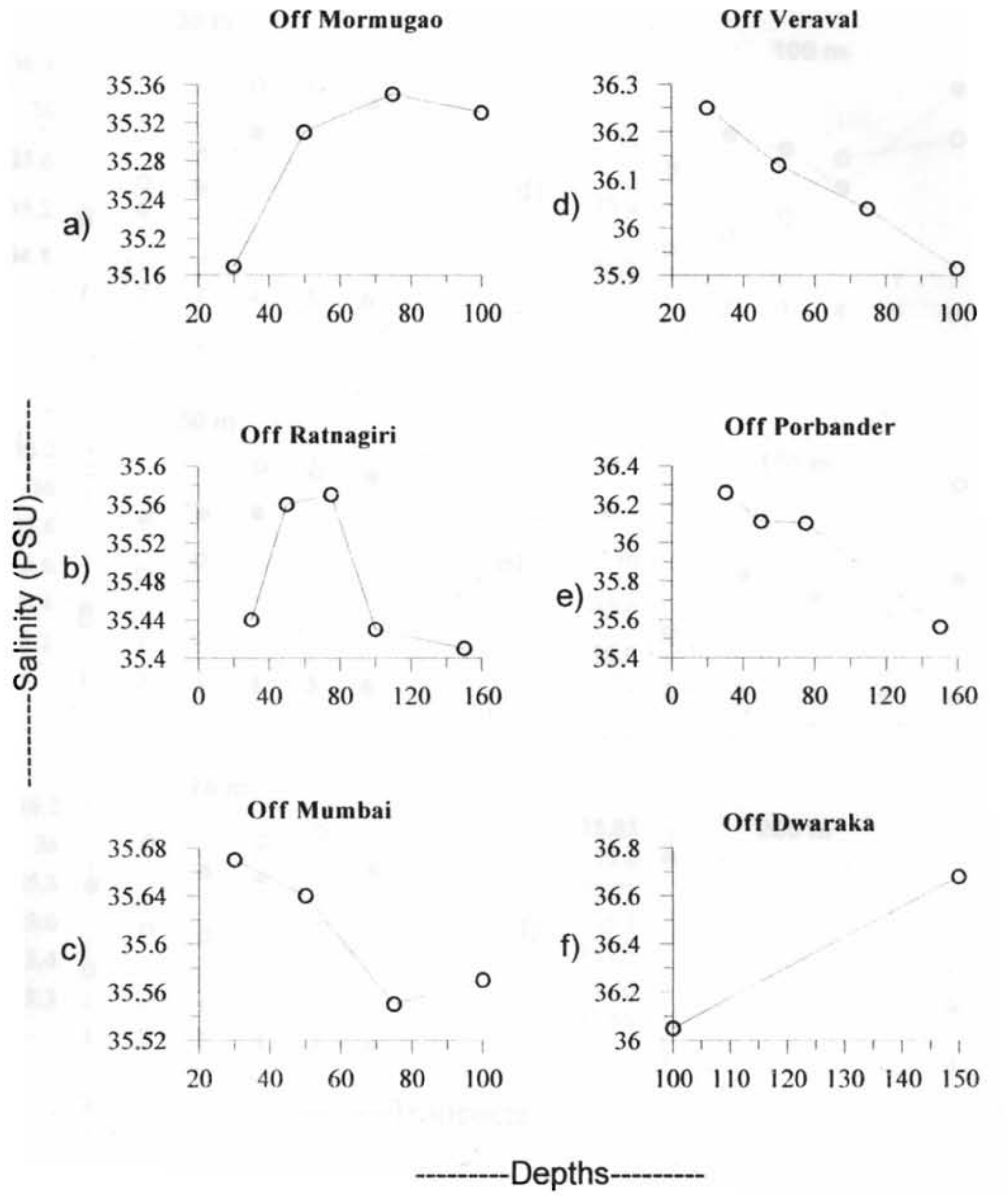

Fig. 4 - Depth wise distribution of salinity (*psu*) during post monsoon

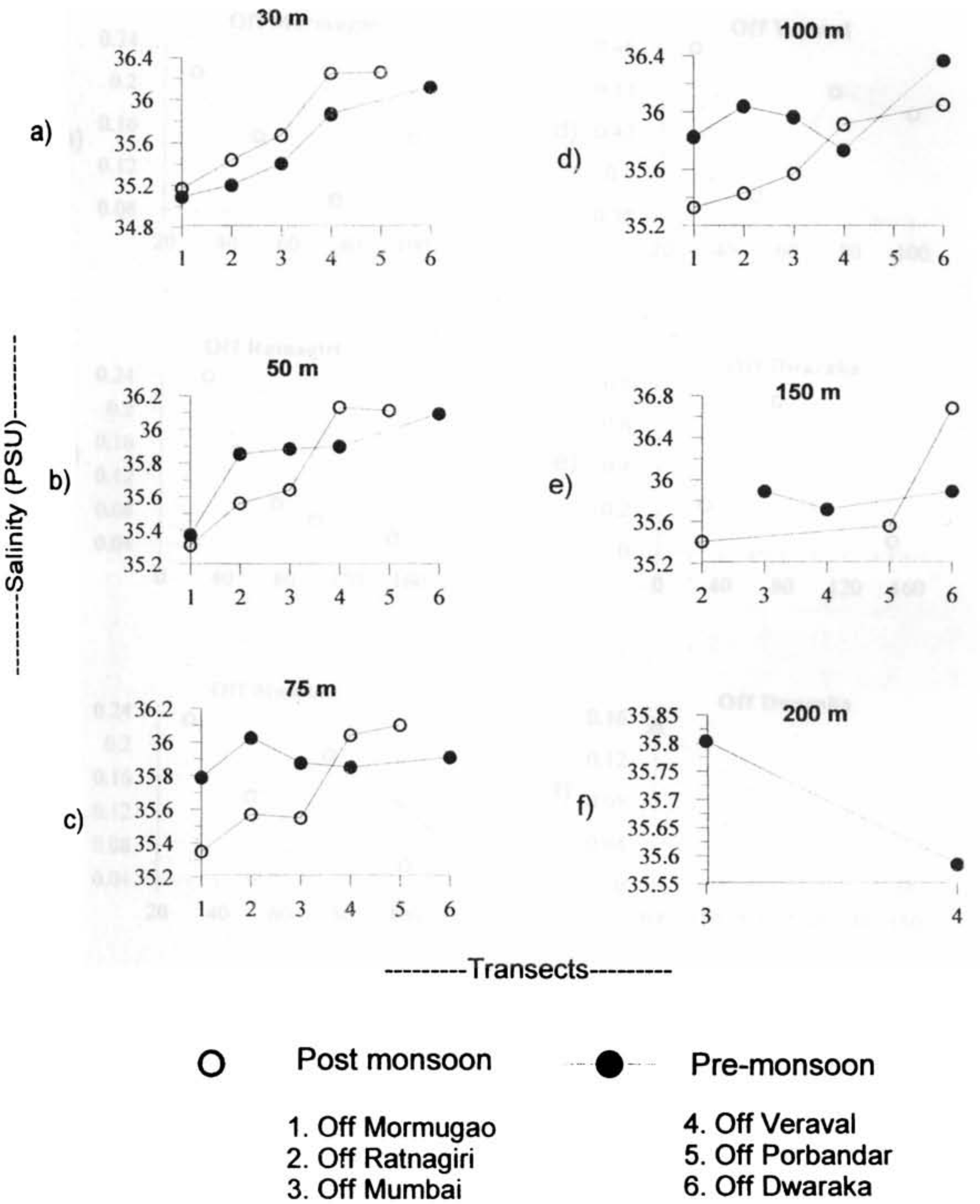

Fig. 5 - Transect wise distribution of salinity (*psu*) in various depths

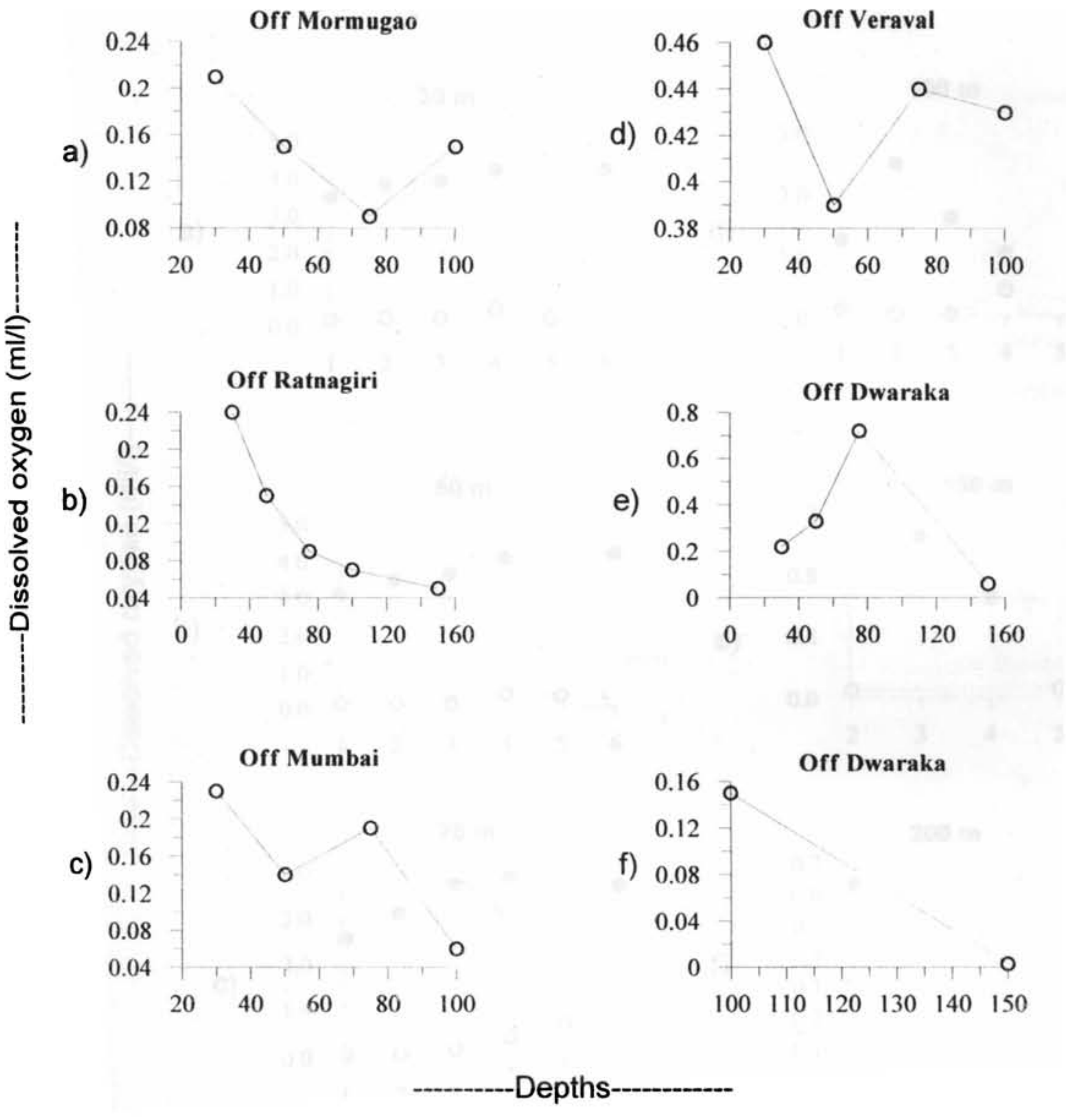

Fig. 6 - Depth wise distribution of dissolved oxygen (ml/l) during post monsoon

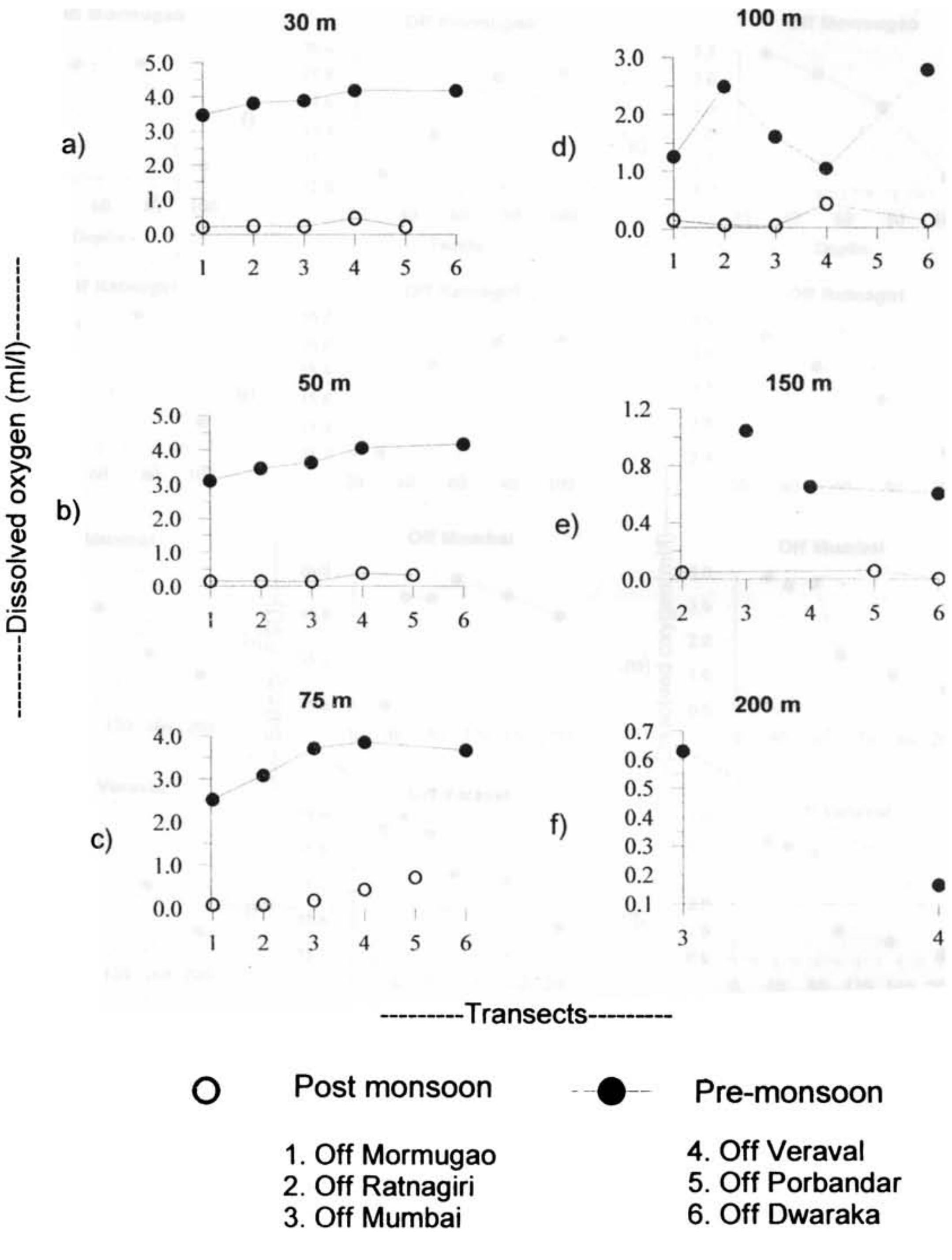

Fig. 7 - Transect wise distribution of dissolved oxygen (ml/l) in various depths

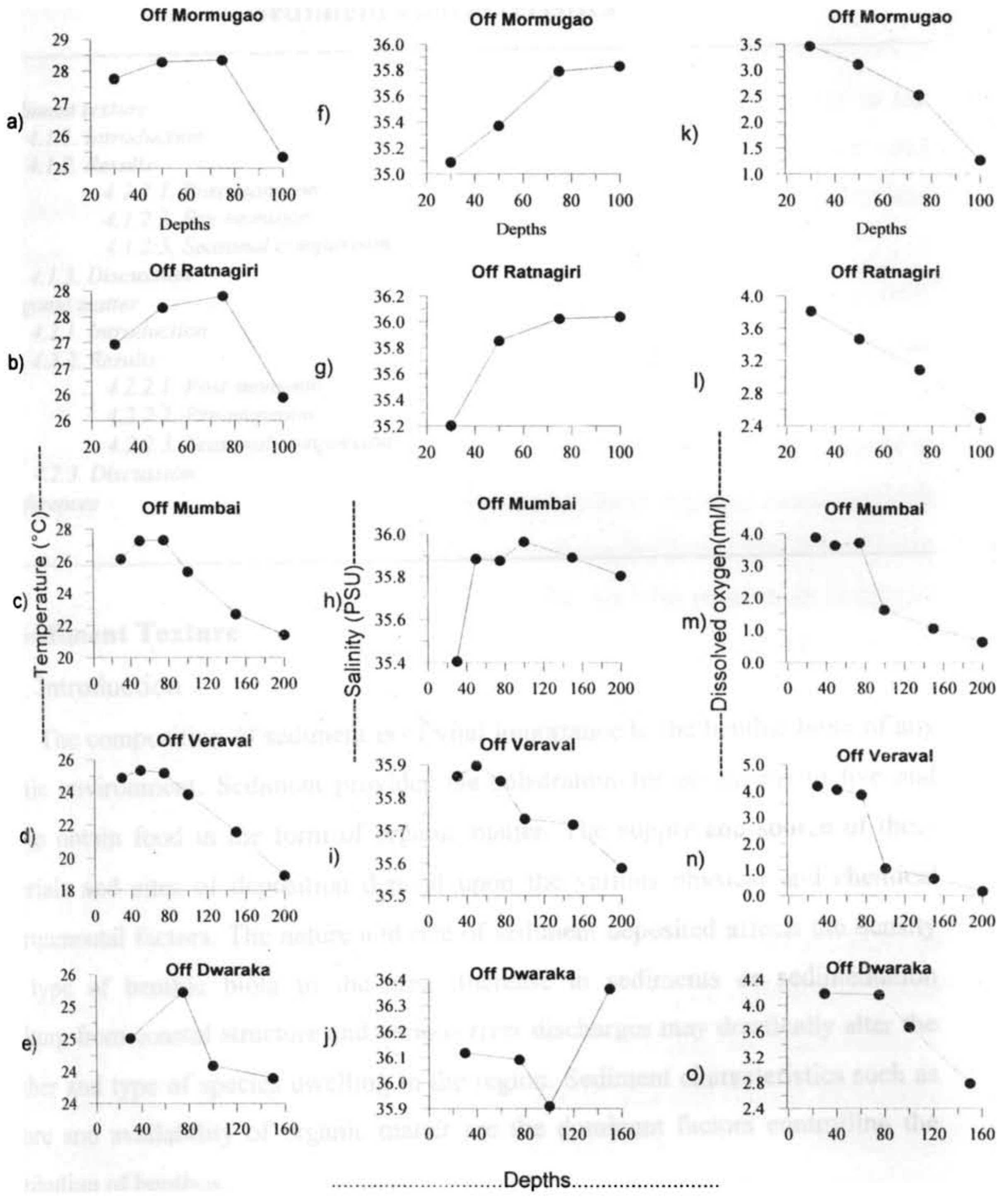

Fig. 8 - Depth wise distribution of hydrographic parameters during pre-monsoon

Chapter 4.

Sediment characteristics

4.1. Sediment Texture

4.1.1. Introduction

The composition of sediment is of vital importance to the benthic biota of any aquatic environment. Sediment provides the substratum for organisms to live and aslo to obtain food in the form of organic matter. The supply and source of these materials and sites of deposition depend upon the various physical and chemical environmental factors. The nature and rate of sediment deposited affects the density and type of benthic biota in the area. Increase in sediments or sedimentation resulting from coastal structure and various river discharges may drastically alter the number and type of species dwelling in the region. Sediment characteristics such as texture and availability of organic matter are the dominant factors controlling the distribution of benthos.

The continental shelf and its adjoining land of the study area is bordered by Western Ghats and is influenced by monsoon. The climate is tropical with maximum precipitation during monsoon and the shelf is floored with different types of sediments. According to Stewert and Pilkey (1965) the continental shelf in the study area can be divided into inner shelf and outer shelf marked by the difference in the topography and sediment type. Studies by Nair (1971) and Siddiquie and Rajamanickam (1974) have shown that the inner shelf has smooth featureless topography whereas the outer shelf is formed by rugged topography.

Width of the continental shelf varies from about 100 km off Suarashtra (Off Dwaraka) coast (Gupta, 1979) to 280 –300 km wide off Mumbai (Kidwai and Nair, 1972) and this narrows down to about 100 km off Ratnagiri to a progressive narrowing of 60 km wide shelf off Mormugao (Nair,1975). The shelf off Mumbai is composed of various features like pinnacles with and without adjacent troughs, which are usually 1-2 m deep (Nair,1975). In addition to these features a number of large mound shaped protuberances with a relief of 6 to 8m are also present. In Ratnagiri the pinnacles and troughs are poorly developed as compared to off Mumbai and when it reaches Mormugao pinnacles with relatively gentle depression occur on a slopping shelf. A notable feature is that pinnacles and troughs are most prominent off Mumbai where the shelf is flat and widest and become relatively subdued in profile towards south where the shelf is generally half or less than half of width. Wider shelf Off Mumbai narrows in Ratnagiri and further narrows southwards.

Many workers have studied the substrata of northwestern region and most of them pertain to the regional studies including estuaries and gulf regions and a few studies were carried out in the shelf region to assess the textural characteristics. Kidwai and Nair (1972) studied the sediment texture and distribution of organic matter in the NW coast of India (18-22° N) and later, Nair (1975) described the nature and origin of small-scale topographic prominences on the western continental shelf of India. Parulekar *et al.*, (1976) studied the sediment texture and organic matter distribution off Mumbai region upto 60 m depths. Ansari *et al.*, (1977) Ansari (1978), Hashimi *et al.*, (1978) and Nair *et al.*, (1978) reported the textural characteristics of central west coast (13-16° N) of India. Benthos and sediment characteristics of entire west coast of India were studied by was that of Harkantra *et al.*, (1980) describing the texture and organic matter up to 70 m depth. The other reports were that of Ansari *et al.*, (1980) for Mormugao coast (20-840m) and Setty and Nigam (1982) for west coast (14-22° N). Vizakat *et al.*, (1991) while studying the population ecology and community structure of benthos described the texture and organic matter in the 5-15 m contour off Konkan, west coast of India and Rao (1991) studied the clay mineral distribution in the continental shelf and slope of Saurashtra coast. The other works in the west coast included that of Narayana and Prabhu (1993) who studied the texture and geochemistry of sediments of Honavar shelf, Harkantra and Parulekar (1994) who studied the benthos and sediment characteristics in the 5-10 m depths of Rajapur Bay, west coast of India (16° 34' N) and Ingole *et al.*, (2002) worked in the coastal waters of Dabhol, west coast of India. Joydas (2002) gave an account on the sediment texture and macrobenthos of west coast of India.

4.1.2. Results

Spatial variations in the sediment characteristics of the northwest continental shelf of India are examined in this chapter. Results are described in 3 parts-first part deals with sediment texture and its spatial variations during post-monsoon and second part deals with the same during pre-monsoon seasons, and seasonal changes are described in the third part.

4.1.2.1. Post-monsoon

Six types of texture were observed which include sandy, silty sand, clayey sand, silty clay, clayey and mixed type (where sand, silt and clay in almost equal proportion) (Fig. 9 a & b). Of these silty clay dominated in the study area. Clayey sediment, the second dominant texture, was present at 5 stations followed by sandy sediments (4 stations). Silty sand was present in 2 stations and clayey sand and mixed type texture were present only in one station each. Spatial distribution showed that, generally northern transects (off Porbandar and off Dwaraka) showed predominance of fine sediment. Shallow depths (30 m and 50 m) of southern transects (off Mormugao, Ratnagiri and Mumbai) and northern transect (off Veraval) showed more fine sediment texture while beyond 50 m of these transects sand fraction increased.

Distribution of sediment texture in different depth zones is given in Fig. 10. Sand percentage increased as depth increased except at >150 m zone where sand and clay were more or less same. Silt was in a medium concentration at all depth zones while clay was more in the shallow depth zones (30 and 50 m) and decreased towards deeper zone except at >150 m zone.

Transect wise variation of sediment texture at each depth zone is given in Figs. 11-15. At 30 m zone there was no significant transect wise variation in the sediment texture. Sand was low in this zone. Silt fluctuated with highest value off Mormugao and lowest off Porbandar. Clay was high and no significant variation among different stations was observed. At 50 m zone also, sand was generally low with slightly higher value recorded off Mumbai region. Silt fluctuated with highest value off Mormugao and lowest off Mumbai. Clay was generally high at all stations with minimum value off Mormugao and maximum off Porbandar. At 75 m zone, sand dominated over clay and increased towards Mumbai and decreased towards north and the lowest value observed off Porbandar. Silt percentage was low at all transects and fluctuated with maximum value off Ratnagiri and minimum off Veraval. Clay percentage was highly fluctuating with highest value off Porbandar and lowest off Mumbai region. At 100 m zone, sand percentage increased towards north except off Dwaraka, with highest value observed off Veraval and lowest off Dwaraka. Silt showed the reverse trend and decreased up to off Veraval, but the highest percentage was observed off Dwaraka. Clay was generally low at all transects except off Dwaraka. At 150 m depth zone, the southern transect station (off Ratnagiri) recorded high sand content and decreased significantly to the northern transects (off Porbandar and Dwaraka) and a reverse trend was found in clay percentage. Silt slightly increased towards north. In general, shallow depth zones (30 and 50m) were dominated by clay and beyond 75 m depth, clay percentage reduced and taken over by sand, but still in the deeper depths of northern latitude stations retained high clay content.

4.1.2.2. Pre- monsoon

During pre-monsoon also 6 types of sediment texture were observed, which includes sandy, clayey sand, sandy clay, clayey silt, silty clay and mixed type (where sand, silt and clay in equal proportion) (Fig. 16 a & b). Of these, silty clay, clayey sand and sandy sediment were predominant. Mixed type sediment was observed only at 2 stations, silty clay was present at 7 stations, clayey sand and sandy sediment at 5 stations each, clayey silt was present at 4 stations and sandy clay was seen only at one station. Spatial distribution showed that southern latitude stations were sand dominated while in the northern latitude stations sand fraction reduced.

Distribution of sediment texture in different depth zones is given in Fig. 17. There was a gradual increase in sand content from 30 m zone towards deeper zone (>150 m). Silt and clay was high in the shallow depth zones (30 and 50 m) and decreased towards deeper zones.

Transect wise variation of sediment texture at each depth zone is given in Figs. 18-22. At 30 m zone, sand was generally low at all transects. Silt showed fluctuating values with lowest value off Mumbai and highest value off Veraval. Clay was generally high with fluctuating trend and comparatively high value off Mumbai region and low value off Veraval. At 50 m zone also sand was low, but slightly high value was observed off Marmagao transect. Silt content fluctuated with maximum off Veraval and minimum off Mormugao. Clay was generally high, but showed fluctuation. Highest clay content was observed off Mumbai and lowest off

Veraval similar to 30 m zone. At 75 m depth zone, southern latitude stations showed high sand content and northern latitude stations had low sand content. High sand percentage was observed off Mumbai and low values off Veraval and Dwaraka. Percentage of silt showed a reverse trend. Clay was low along southern transects and comparatively high in northern transect stations with lowest value observed off Mumbai and the highest off Dwaraka. At 100 m depth zone, the pattern was reversed as compared to the previous depth zone, where an increase in sand content was observed towards north except off Dwaraka. Silt was generally low with high values off Mormugao and Dwaraka and low off Ratnagiri and Veraval. Silt content was absent off Mumbai. Clay decreased towards north with exceptionally high value off Dwaraka. At 150 m zone, the highest sand percentage was noticed off Mumbai and comparatively low values off Veraval and Dwaraka. Silt was generally low and clay showed an increase to northern stations with lowest value off Mumbai and highest off Dwaraka. In general, at 30 and 50 m depth zones, sand was low and fine fraction was high and beyond 75 m, sand was more compared to clay. At 75 m and 150 m zones sand decreased towards north and fine fraction increased, but at 100 m zone, a reverse pattern was noticed towards north except off Dwaraka.

4.1.2.3. Seasonal comparison

There were significant changes in the composition of texture during both the seasons. More than 80% of stations differed in its texture between two seasons. Out of the 17 stations, 15 stations showed variations in the sediment composition during pre-monsoon season. At 50 m depth of Mormugao transect, the silty clay fraction observed during post-monsoon has changed to sandy clay during pre-monsoon and at 100 m station, silty sand was changed to mixed type. Off Ratnagiri, clayey sediment has changed to clayey silt at 30m and to silty clay at 50 m. Silty sand at 75 m was replaced by clayey sand and sandy texture changed to clayey sand. Off Mumbai region, clay and silty clay sediment at 30 and 50 m has changed to silty clay whereas in deeper depths no change has taken place. Off Veraval region silty clay at 30 and 50 m was replaced by clayey silt and clayey sand at 75 m also changed to clayey silt. Sand in the deeper station showed no change as that of previous transect. Off Dwaraka, shallow depth recorded no change in the texture, but in deeper station silty clay has changed to sandy clay. In general shallow stations have high clay percentage and deeper stations sustained more of sand during both the seasons. Sand percentage decreased to north during both seasons however, during post-monsoon season the decrease was not as gradual as pre-monsoon.

Statistical analysis based on Student's *t* test showed that significant difference between two seasons observed in the shallow depths of 30 m and 50 m only (Table 2). Silt and clay showed significant difference in the 30 m while only clay showed considerable difference between two seasons at 50 m zone.

4.1.3. Discussion

The results of the study revealed transect wise and depth wise variations in the texture during the two seasons. Southern part sustained coarser fraction whereas northern part showed fine texture. Depth wise, shallow areas sustained more clay content and deeper stations had more sand content. Six types of sediment textures were obtained during both the seasons, in which silty clay dominated during post-monsoon while silty clay, clayey sand and sandy sediment were predominant during pre-monsoon.

Occurence of fine sediment texture in the shallow areas and coarser sediment in the deeper depths is comparable to that of earlier reports. Nair and Pylee (1968) showed that inner shelf (40m) of west coast of India are floored with poorly sorted silty clay and further southwards a zone of fine to medium sand exist. Kidwai and Nair (1972) pointed out that outer shelf of Mumbai is generally coarser and inner shelf is finer with silt and clay. Nair (1975) while elucidating the textural characteristics of western continental shelf (off Mumbai to Karwar) of India, reported fine sediments with comparatively high organic matter (1.9-3.9%) in the inner shelf (<50m) and sand in the outer shelf (55-90m). Parulekar *et al.*, (1976) reported almost a uniform pattern in sediment distribution off Mumbai region upto 60m depths. Mud constituted the major component with varying fractions of silt and clay. Beyond 60 m depth zone texture showed variations in composition. Hashimi *et al.*, (1978) studied the grain size off Vengurla and Mangalore and reported fine sediment (clayey silt and silty clay) in the inner shelf and coarser fractions (silty, clayey sand to sand) in the outer shelf. Nair *et al.*, (1978) in the same area reported three most abundant sediment types which are clayey silt, silty sand and sand. Clayey silt was confined to the shallow areas of <50m and shelf edges (shelf break) and sand in between. Ansari *et al.*, (1980) studied the sub-littoral meiobenthos of Goa coast (20-840m) and noticed that the substrates were predominantly of fine sand except at a few stations where mud dominated deposits (clayey silt and sandy silt) were found. Rao (1991) stated that textural pattern of inner continental shelf and slope of Saurashtra are silty clay or clayey silt while the outer shelf sediments are relict carbonate sands. Narayana and Prabhu (1993) studied the texture and geochemistry of sediments of Honavar shelf, west coast of India and reported a variety of sediments from silty clay to sand-silt-clay to sand. Sediments of 30-50 m depths off Saravathi river mouth and 100-200 m depth zone exhibit sand-silt-clay texture and in between these depths, the sediment was sandy. Prabhu *et al.*, (1997) who studied the textural characteristics of near shore sediments of Honnavar, south west coast of India and found that percentage of sand was more near the river mouth of Saravathi whereas the content of clay showed an increasing trend with depth. This showed the trapping of sediment by the estuary.

Many rivers empty into the study area, which include Indus, Tapti, Sabarmathi,Mahi, Saravathi, Vashishti, Zuari, Mandovi etc. These rivers carry large amount of fresh water and sediment to the Arabian Sea. The high percentage of fine sediment in the near shore region may be of riverine origin. Transportation and deposition of sediments from different sources have worked out by several authors. Nair *et al.*, (1978) opined that during the coarse of their transportation from coast, some of the fine sediments were deposited on the inner shelf and balance bypassed the outer shelf and got deposited. When salinity reduced during monsoon season, low saline sediment laden water is discharged into the relatively higher saline waters of the inner shelf and thus sediments got flocculated and deposited. Drake (1976) studied the marine sediment transport of southern California and reported that 80% of the sediment discharged during flood was in shallow waters of <50m depth. He attributed the deposition largely to the physico–chemical flocculation. Hashimi *et al.*, (1978) pointed out that the accumulation of fine sediment in the inner shelf might be due to the prevalence of low energy conditions in that region. It implied the absence of physical processes capable of removing fine fraction. The experimental studies of Krone (1962), Kuenen (1965) and Postma (1967) have shown that velocities required to erode the mud, which has once been deposited, were greater than the velocity, which transport them. This was due to the cohesive nature of the fine-grained sediments. Therefore fine sediments deposited during monsoon were unlikely to be eroded during pre-monsoon or post-monsoon season. Nayak (1996) suggested that grain size parameters were being used as indicators of depositional environment. He pointed out that when grain size decreases sorting improves. Coarser grain size and poor sorting indicated high-energy environment. McCave (1972) suggested that the balance between supply and marine transport ability controls location and rate of mud accumulation. The waves, both shelf waves and near-inertial internal waves, winnow the silt and clay, making the outer shelf sediments relatively sand rich (Narayana and Prabhu, 1993). Ingole *et al.*, (2002) opined that sand fraction carried by rivers was deposited at the mouth of the river and silty clay was transported further seaward and got deposited. In the present study sandy deposits was seen in deeper depth during both seasons, but the percentage varied between the seasons, which may be due to the variation in the transportation of currents (Pandarinath and

Narayana, 1991). Limited input of coarser material in the north may be due to trapping of coarser material by rivers. During the filtering processes rivers/estuaries trap coarse size particle and allow only fine particle to escape into the inner shelf. The sandy nature in the outer shelf may be due to the relict nature of sediments and the absence of conditions favorable for deposition (Hashimi and Nair, 1981).

The increased percentage of clay in the northern regions in both seasons may be due to the influence of the river Indus in the north. However, clay content in the shallow areas of Mormugao area due to the discharge brought by Mandovi and Zuari Rivers. Harkantra *et al.*, (1980) described 7 major types of substrata with two differentiated areas as north and south of Mormugao (15° N). Sediment was fine and dominated by silt and clay in the region north of Mormugao and sandy with little percentage of silt and clay in the region south of Mormugao. In the present study also study area could be divided into two parts as fine sediment dominated in the north and sand dominated in south. Setty and Nigam (1982) found that the inner part of Gulf of Kutch area hold very fine-grained clayey silt whereas Mumbai region (16-17° N) was sandy in nature below which sediment was mostly clayey with patches of sand and silty clay. In Mormugao sector, sandy sediment predominated followed by clay. The present data agrees well with the above findings.

Seasonal variations in the sediment texture could be due to the monsoonal flow and also due to the intensity, direction and current speed that makes the difference in sedimentation.

4.2. Organic matter (OM)

4.2.1. Introduction

Organic content of bottom sediment may be more causal factor than the sediment grain size in determining infaunal distribution because it is a dominant source of food for deposit feeders and indirectly for suspension feeders. Organic matter (hereafter reffered to as OM) may influence benthos through availability of food supply and the consumption of OM-bound sediment and subsequent generation of faecal pellets, which will alter the mechanical composition of sediments. Bader (1954) suggested that size of the sediment particle influence the OM content. Extremely small size sediment had large amount of OM and vice versa. In addition to the influence through food, OM also influences benthos by regulating the oxygen availability in the bottom water and the interstitial space. Bacteria utilize the oxygen for decomposition of OM, which in turn reduces the available oxygen to organisms. In the decomposition of OM, Bader (1954) opined that in areas where high degree of decomposition in a low organic content sediment, the relative amount of decomposition per unit volume of sediment will be low when compared with an area where the degree of decomposition is same but OM is greater. So, in other words coefficient of the degree of decomposition is dependent only upon the actual decomposition while the coefficient for the amount of decomposition is dependent also upon the amount of organic carbon. Waksman and Starkey (1931) have shown that natural decomposition of OM can produce aldehydes, H_2S, methane and many other toxic products. Reuszer (1933) and Waksman *et al.*, (1933) have shown that degree of decomposition is correlated with the abundance of bacteria. Liagina and Kuznetzow (1937), ZoBell and Stadler (1940), ZoBell and Feltham (1942) have shown that abundant bacterial activity causes a serious drain on the available oxygen supply. So decomposition of OM by bacteria is an ecological factor resulting from the production of toxic products and depletion of available oxygen. The factors that favour a high organic carbon content in the bottom sediments are: 1) abundant supply of OM in the overlying waters 2) relatively rapid accumulation of fine-grained sediments and 3) low oxygen content of the bottom. According to Parulekar *et al.*, (1982,1992) varied but rich benthic fauna and high biomass values are dependent on high organic production in the overlying water column. They added that food availability is the major factor controlling the distribution pattern of deep-sea benthos. Detritus and bacteria form the main food for deep-sea benthos (Tietjen, 1971). Detritus is produced mainly in the euphotic zone and reaches the bottom after passing through the bentho-pelagic zone. The absolute amount of OM reaching the sea floor therefore depends on the level of production in the surface water. A clear indication of the effects of surface productivity on benthic biomass has reported by Mann (1982) and Parulekar *et al.*, (1982).

4.2.2. Results

Spatial variations in the OM during post-monsoon and pre-monsoon seasons were examined in this section inthree parts- first part deals with OM and its spatial variations during post-monsoon and second part deals with the same during pre-monsoon seasons, and seasonal changes are described in the third part.OM distribution was related with substrata. In general, clay and silt retained more OM than sand..

4.2.2.1. Post-monsoon

Average of OM in different depth zones is given in Fig. 23. OM was high at 30 and 50 m zones, which reduced at 75 and 100 m zones and again increased at 150 m zone. Transect wise variation at each depth zone is given Table 2. At 30 m depth zone there was a gradual decrease of OM from 1.96 % (off Mormugao) to 0.42% (off Porbandar). At the 50 m zone also, a decrease was noticed from lower to higher latitude with highest value off Ratnagiri (3.33%) and lowest off Porbandar (0.54%). At 75 m zone a fluctuating trend was observed where the lowest OM was recorded off Veraval (0.36%) and the highest off Porbandar (1.36%). At 100 m zone, generally low values were observed with an exceptionally high value off Dwaraka (1.84%). Here also no regular transect wise pattern was noticed in OM distribution. At 150 m zone, 3 stations were sampled, southern latitude station, off Ratnagiri recorded minimum value whereas northern latitude station off Porbandar recorded maximum value.

In general, two different patterns were observed in the latitudinal distribution of OM. In the shallow zones of 30 m and 50 m, OM decreased to north where as in the deeper depth zone (beyond 75 m) no regular pattern was observed; however northern latitude stations recorded relatively high OM.

4.2.2.2. Pre-monsoon

Average of OM in different depth zones is given in Fig. 24. OM was more in the shallow depths (30 and 50 m) decreased to deeper depths (100 m), but again increased beyond 150 m zone. Transect wise variation at each depth zone is given in Table 3. At 30 m depth zone, minimum value was observed off Dwaraka (1.07%) and maximum off Ratnagiri (3.63%). At 50 m zone, OM was highly variable and the highest value was observed off Ratnagiri and lowest values were noticed off Mormugao and Veraval. At 75 m zone also OM fluctuated between stations and maximum value was observed off Ratnagiri (1.67%) and minimum off Mormugao (0.36%). At 100 m zone high values were found off Mormugao and Ratnagiri and low values off Mumbai and Veraval and again an increase was observed off Dwaraka. At 150 m depth zone, only 3 observations were made and the OM was low off Mumbai and high off Veraval. At >150 m depth only one station was sampled and high OM (3.33%) was noticed.

In general, different depth zones recorded different pattern of distribution and no particular trend was observed in OM distribution. However, high values were found in the southern transect especially off Ratnagiri.

4.2.2.3. Seasonal comparison

Distribution of OM during the two seasons showed that 65% of the stations were influenced by seasonal changes. In the study area most of the stations showed significant variation (>60% variation). Majority of the stations showed an increase in OM % from post-monsoon to pre-monsoon. Maximum variation was found at 100 m depth off Mormugao (0.48% of OM during post-monsoon changed to 1.78%

during pre-monsoon) followed by 75 m depth off Porbandar (0.36% of OM changed to 1.31%). The lowest variation was found at 120m off Mumbai. Likewise in other transects significant variations were observed which could be attributed to the seasonal changes. Student's *t* test showed that significant difference was observed only in the 30 m depth and eventhough variations in deeper depths notivced but were not at a significant level.

4.2.3. Discussion

OM showed considerable variation with respect to depth and latitude. In general more OM was retained in the fine sediments in the shallow zones (30 and 50 m). The minimum average values were found at 75 and 100 m depths (<1%) and maximum average values were found at 30 and 50 m depths (1.5-2%) during both seasons.

In general, OM in the sediment was related to the texture of the sediment. In the present study OM ranged from 0.36 to 3.33% during post-monsoon and from 0.18 to 4.52 % during pre-monsoon season. Low values were found in sandy or sand dominating sediment and high values were found in the finer sediments during both seasons. Affinity of OM towards fine sediment fraction has observed by several workers. Murthy *et al.*, (1969) reported OM off Mumbai ranging from 0.24 to 3.15% (av. 1.93%) in the silt-clay fractions. Kidwai and Nair (1972) reported an OM in the clay and silt ranging between 4 and 8 % in the NW coast of India. Parulekar *et al.*, (1976) studied the OM off Mumbai region and suggested that clay and silty clay retained higher OM than the sand and clayey sand substratum. Hashimi *et al.*, (1978) reported the OM up to 5% in the fine grained sediment of the inner shelf and <1% in the coarser sediment of the outer shelf along the west coast of India (13-16°N). Paropkari (1979) studied the OM of northwestern continental shelf of India and reported OM in the range of 0.42 to 3.86% with an average of 1.64%. He also stressed the existence of a definite relationship of OM with texture and depth. Ansari *et al.*, (1980) reported values in the range of 0.62 to 2.05% off Goa region with highest value in the outer most station, which was muddy in nature while Harkantra *et al.*, (1980) reported OM varying from 0.47 to 6.18% (av. 3.15%) in the west coast of India. Higher organic carbon in the fine substrata of clay and silt and low values in the sandy substratum also suggested a relationship with the textural characteristics of the sediment. Narayana and Prabhu (1993) recorded the OM ranging between 0.1 and 2.87% with uneven distribution in the Honavar shelf, west coast of India. Joydas (2002) reported a value ranging from 0.24-6.23% with an average of 2.81 which is slightly higher than the present study.

One factor favouring the accumulation and preservation of OM in mud was the sediment size. The fine-grained sediments have larger surface area and tend to adsorb more OM than coarse sediments. This may be the reason for high OM in the fine-grained sediment. Once associated with mud, OM remains preserved due to high rate of sedimentation in the near shore region and the reduced condition associated with such rapidly deposited mud. This preservation together with new discharge from rivers increases the OM in the inner shelf region.

Present study showed high OM in shallow and deeper regions and a low OM in between. During pre-monsoon and post-monsoon seasons, OM was high in the shallow zones (30 and 50 m). The high OM in the shallow regions may be due to river discharge and high biological productivity in the overlying water (Degens and Ittekott, 1984) and may also be due to the impact of low energy conditions prevailing in the area that accumulate fine sediments which can hold more OM (Hashim *et al.*, 1978). During the coarse of their transportation from the coast, some of the fine sediment gets deposited on the inner shelf and balance bypasses to the outer shelf and gets deposited (Nair *et al.*, 1978). The reason for high OM at 50 m depth especially during post-monsoon, in the present study may also be due to the bypassing of the fine sediment in the shallowest region and getting deposited a little away from the coast.

Present study also showed high OM in stations beyond 100 m depth during both seasons. Increased OM in the outer regions of Mormugao and off Veraval may be due to the low oxygen content (Carruthers *et al.*, 1959) in these areas preventing degradation, especially off Veraval where the DO was low (<0.5ml/l). Nair (1975) also reported inner shelf with high OM (1.9-3.9%) against the outer region (0.88-0.95%) from the western continental shelf (14-18° N) of India and also attributed this high OM to the reducing environment in the sediment. Joydas (2002) also reported similar results of high OM in the shallow and deeper depths and low values in the 76-100 m zone. It was suggested that high concentration of organic carbon in the deep sediment layer could be due to the presence of refractory fraction of OM left after the carbon mineralisation (Anon, 1997). High OM in deeper depths may also be a result of the preservation under a reducing environment and in part by the rapid deposition (Kidwai and Nair, 1972). The high OM in the shallow and deeper areas may be attributed to the fine-grained nature of the sediments and to the variation in the benthic productivity (Paropkari *et al.*, 1978). They also have attributed that the grain size and biological productivity are the major contributing factors for the variation in OM content in the area. Kolla *et al.*, (1978) opined that the factors such as biological productivity, water depth, pressure, turbulance and water chemistry influence the OM distribution.

An additional feature relevant to the distribution of OM in marine sediments is the difference in composition of OM. If the OM is proteinaceous in nature it is hydrolyzed during diagenesis (cementation and re-crystallization) and if it contains humic acid and lignitic OM, it survives compaction and diagenesis (Degens *et al.*, (1969). Kidwai and Nair, (1972) suggested that the distribution of OM in a depositional environment might be explained in terms of its production, destruction and dilution in the environment. A marine depositional environment contains usually allochthonous OM transported to the site of deposition by river discharge and autochthonous OM, which originates at the site of deposition by the degradation of organisms living in the water and the bottom. Rate of production of OM are usually higher in areas of upwelling.

Latitudinally, OM decreased to north below 75 m and beyond 75 m, fluctuating values were observed with exceptional high values in the north during post-monsoon. During pre-monsoon, no regular trend was observed, but relatively high values were found in southern transects especially off Ratnagiri. But Joydas (2002) could not observe any latitudinal trend in OM distribution in the west coast.

The seasonal difference in the distribution of OM can be attributed to the changes in the texture of the sediment. The amount of riverine input, filtration activities of the rivers and estuaries, strength of the waves and currents, amount of DO in the bottom water together with degradation by microorganisms may be playing a role in the variations in the OM distribution.

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Depths	Transects	Organic matter (%)	Texture Nomenclature
30 m	Off Mormugao	1.96	Silty clay
	Off Ratnagiri	1.54	Clayey
	Off Mumbai	1.13	Clayey
	Off Veraval	0.59	Silty clay
	Off Porbandar	0.42	Clayey
50 m	Off Mormugao	2.40	Silty clay
	Off Ratnagiri	3.33	Clayey
	Off Mumbai	1.78	Silty clay
	Off Veraval	0.71	Silty clay
	Off Porbandar	0.54	Clayey
75 m	Off Mormugao	0.82	Clayey sand
	Off Ratnagiri	0.71	Silty sand
	Off Mumbai	0.83	Sandy
	Off Veraval	0.36	Clayey sand
	Off Porbandar	1.36	Silty clay
100 m	Off Mormugao	0.48	Silty sand
	Off Ratnagiri	0.77	Sandy
	Off Mumbai	0.59	Sandy
	Off Veraval	0.29	Sandy
	Off Dwaraka	1.84	Silty clay
150 m	Off Ratnagiri	0.50	Silty clay
	Off Porbandar	2.44	Mixed
	Off Dwaraka	1.54	Silty clay

Table 2 - Organic matter distribution during post-monsoon season

Depth zones	Transects	Organic matter (%)	Texture nomenclature
30 m	Mormugao	2.22	Sandy clay
	Ratnagiri	3.63	Clayey silt
	Off Mumbai	2.14	Silty clay
	Off Veraval	2.08	Clayey silt
	Off Dwaraka	1.07	Silty clay
50 m	Mormugao	0.83	Sandy clay
	Ratnagiri	4.52	Silty clay
	Off Mumbai	2.62	Silty clay
	Off Veraval	0.89	Clayey silt
	Off Dwaraka	1.81	Silty clay
75 m	Mormugao	0.36	Clayey sand
	Ratnagiri	1.67	Clayey sand
	Off Mumbai	0.68	Sandy
	Off Veraval	1.31	Clayey silt
	Off Dwaraka	0.95	Silty clay
100 m	Mormugao	1.78	Mixed
	Ratnagiri	1.61	Clayey sand
	Off Mumbai	0.18	Sandy
	Off Veraval	0.18	Sandy
	Off Dwaraka	0.94	Silty clay
150 m	Off Mumbai	0.60	Sandy
	Off Veraval	3.27	Mixed
	Off Dwaraka	1.07	Sandy clay
>150 m	Off Veraval	3.33	Clayey sand

Table 3 - Organic matter distribution during pre-monsoon season

Depths	Sand	Silt	Clay	Organic matter
30 m	0.1835 8)	4.0213 (8)	4.0450 (8)	2.2024 (8)
50 m	0.5039 (7)	1.3402 (7)	3.0123 (7)	0.4776 (7)
75 m	0.6190 (8)	0.0718 (8)	0.8414 (8)	0.6344 (8)
100 m	0.7095 (8)	0.0323 (8)	1.0083 (8)	0.2217 (8)
150 m	1.1455 (6)	2.2272 (6)	0.5924 (6)	0.3007 (6)

Table 4 - Seasonal comparison of sediment characteristics based on Student's *t* test (Degree of freedom is given in bracket)

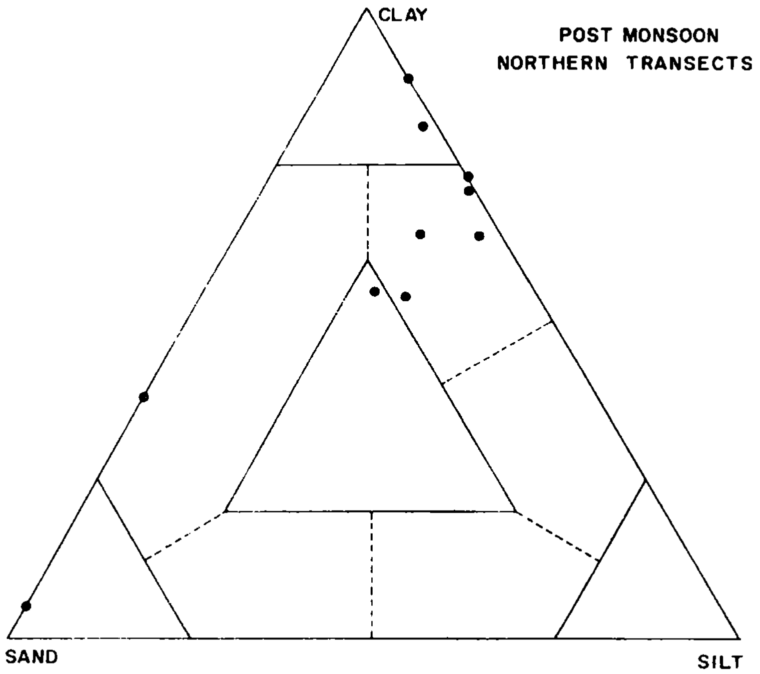


Fig. 9a - Triangular diagram showing sediment distribution in southern transects during post-monsoon season

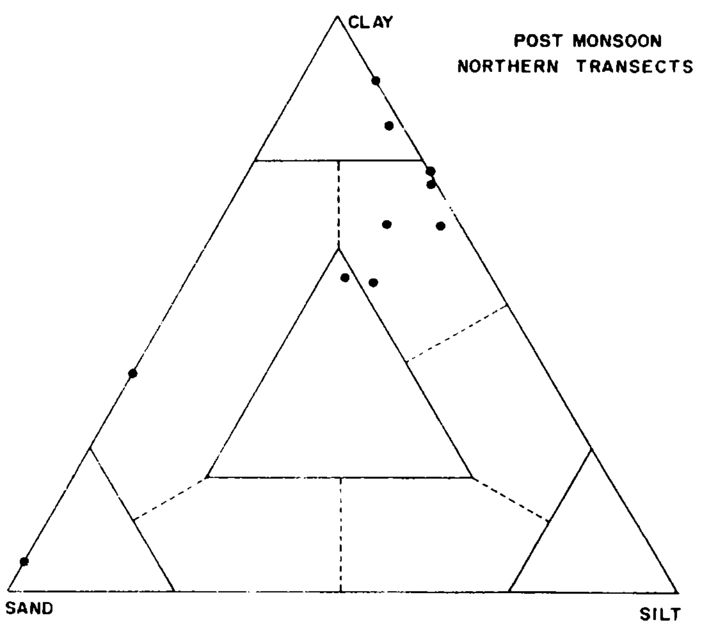


Fig. 9b - Triangular diagram showing sediment distribution in northern transects during post-monsoon season

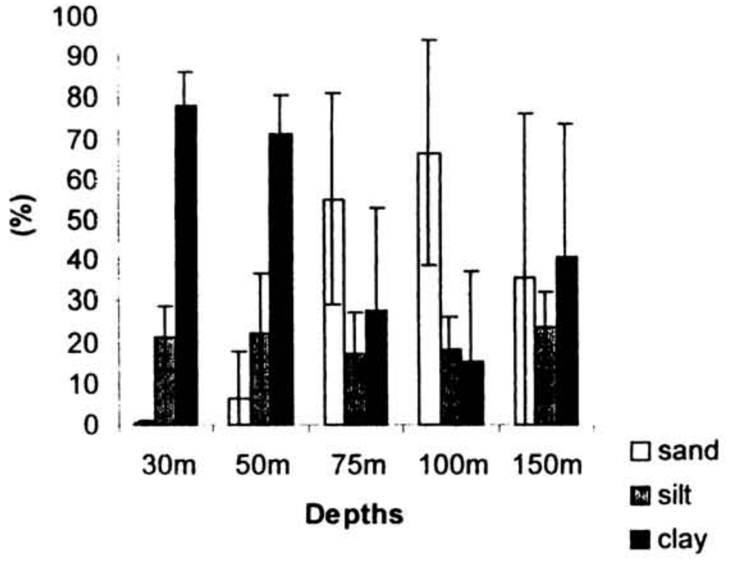
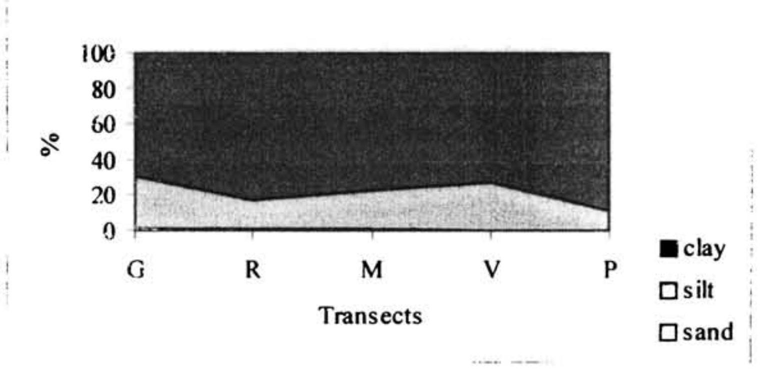
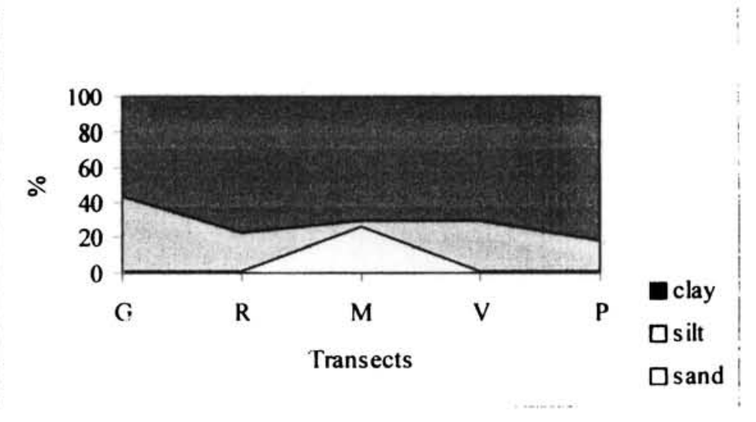


Fig. 10 - Depth wise distribution of sediment texture



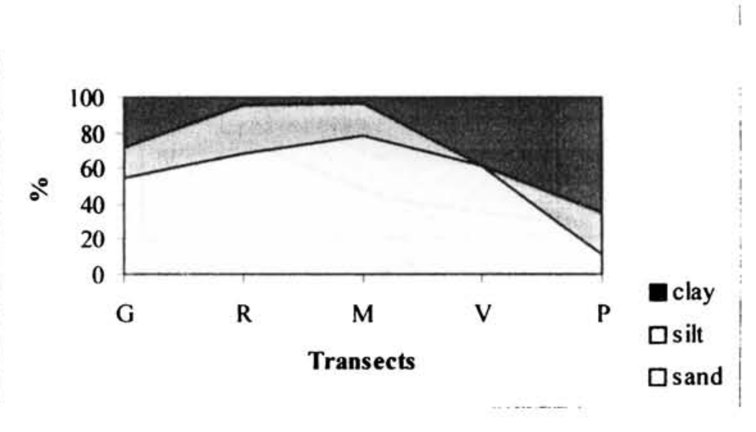
G - Off Mormugao, R- Off Ratnagiri, M- Off Mumbai,
V- Off Veraval, P- Off Porbandar

Fig. 11- Transect wise distribution of sediment texture at 30 m



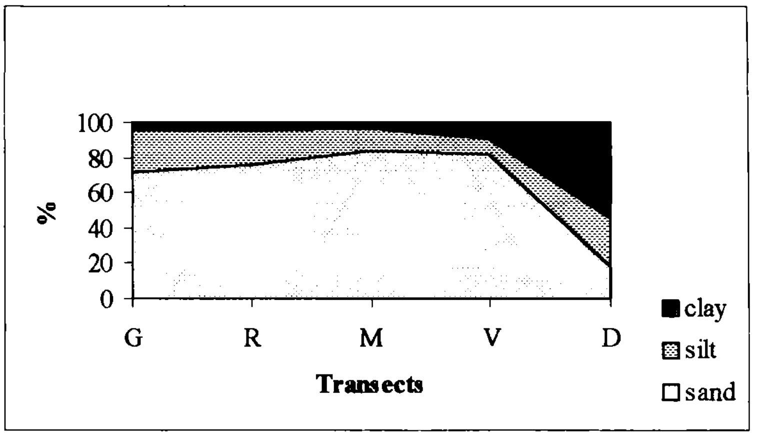
G- Off Mormugao, R- Off Ratnagiri, M- Off Mumbai,
V- Off Veraval, P- Off Porbandar

Fig. 12 - Transect wise distribution of sediment texture at 50 m



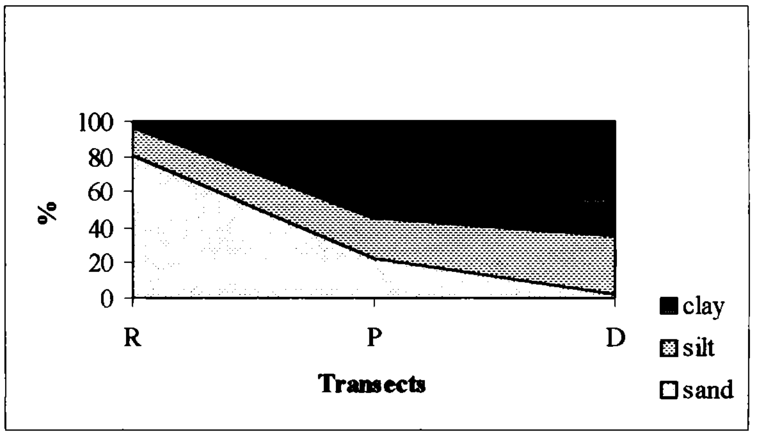
G-Off Mormugao, R- Off Ratnagiri, M- Off Mumbai,
V- Off Veraval, P- Off Porbandar

Fig. 13 - Transect wise distribution of sediment texture at 75 m



G-Off Mormugao, R- Off Ratnagiri, M- Off Mumbai,
V- Off Veraval, D- Off Dwaraka

Fig. 14 Transect wise distribution of sediment texture at 100 m



R- Off Ratnagiri P- Off Porbandar D - Dwaraka

Fig. 15 - Transect wise distribution of sediment texture at 150 m

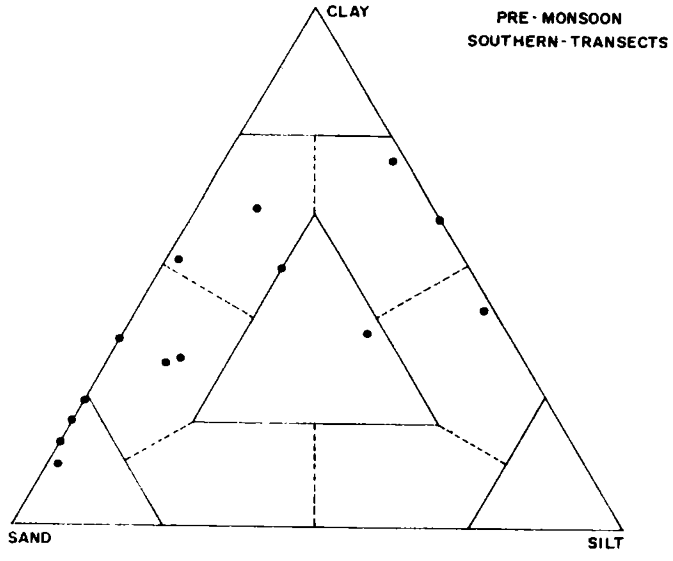


Fig. 16a. Triangular diagram showing sediment distribution in southern transects during pre-monsoon season

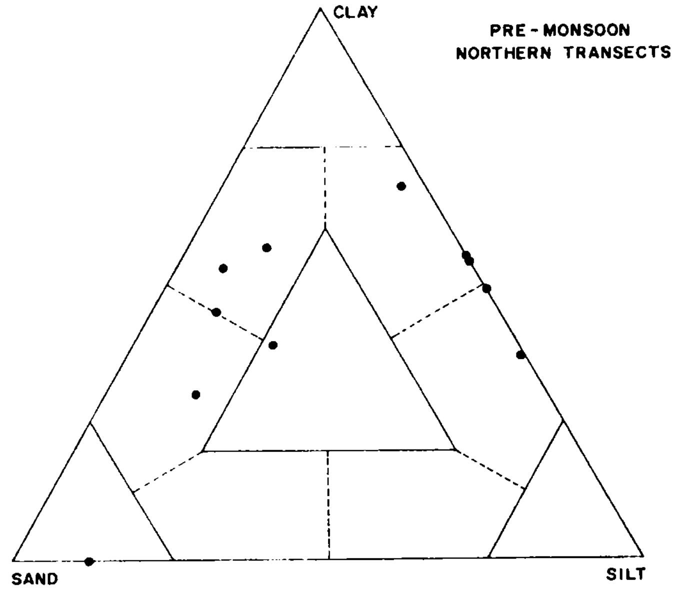


Fig. 16 b Triangular diagram showing sediment distribution in northern transects during pre-monsoon season

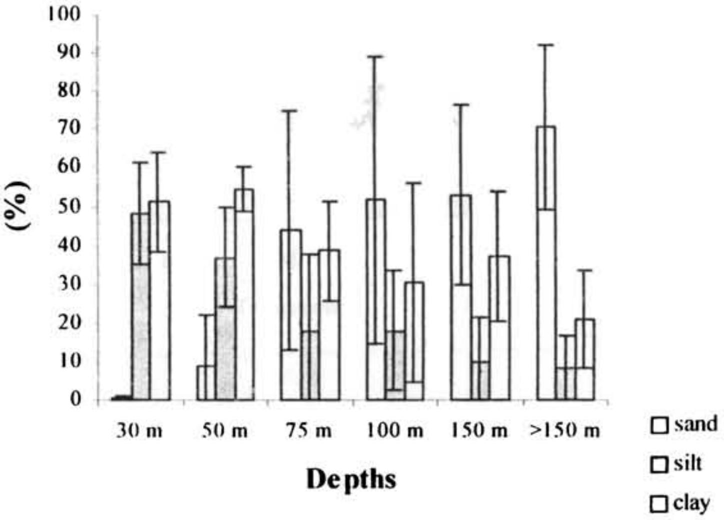
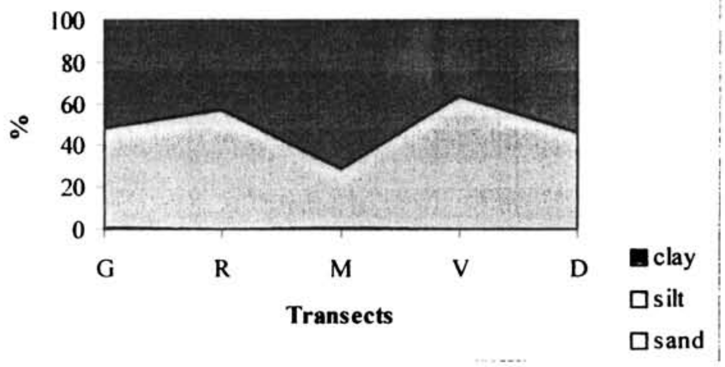
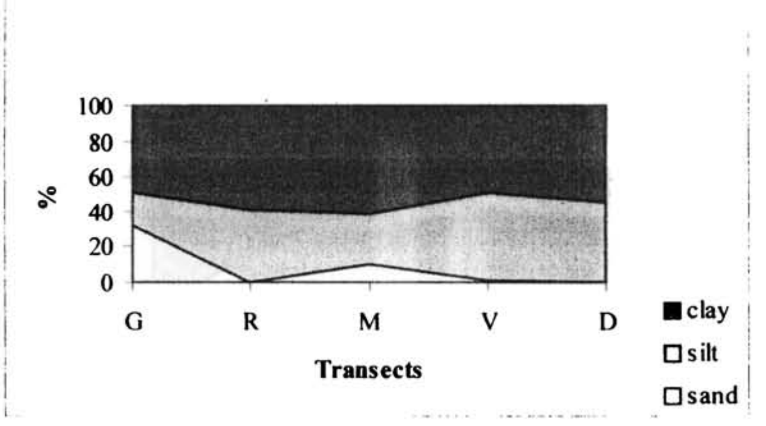


Fig. 17 - Depth wise distribution of sediment texture



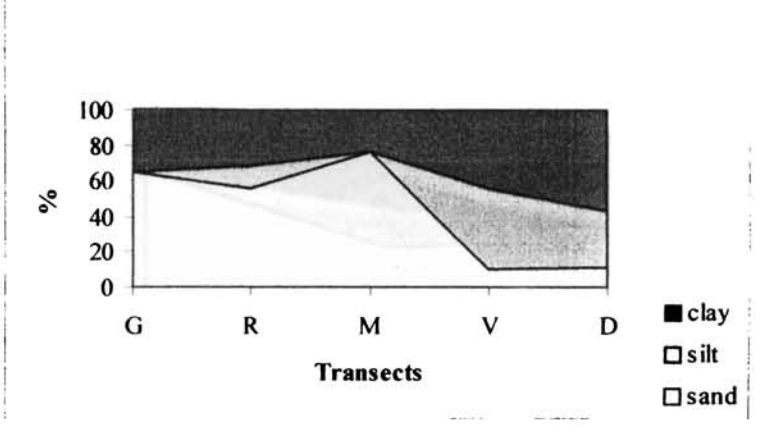
G- Off Mormugao, R-Off Ratnagiri, M- Off Mumbai,
V- Off Veraval, D - Off Dwaraka

Fig. 18 - Transect wise distribution of sediment texture at 30 m



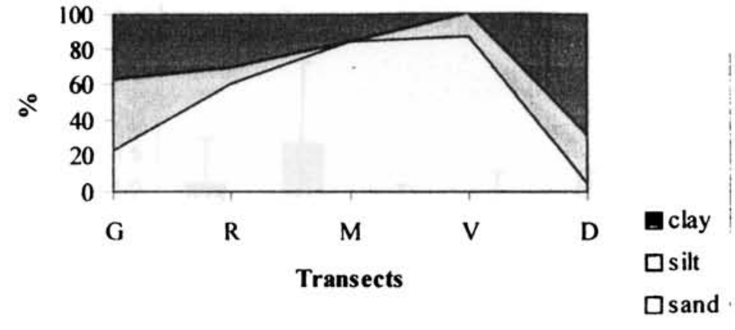
G- Off Mormugao, R-Off Ratnagiri, M- Off Mumbai,
V- Off Veraval, D- Off Dwaraka

Fig. 19 - Transect wise distribution of sediment texture at 50 m



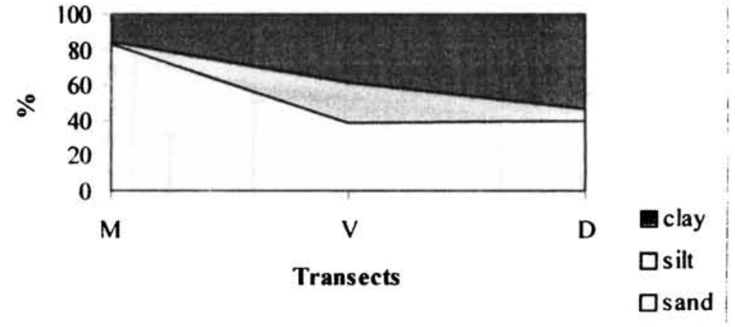
G- Off Mormugao, R- Off Ratnagiri, M- Off Mumbai,
V- Off Veraval, D- Off Dwaraka

Fig. 20 - Transect wise distribution of sediment texture at 75 m



G- Off Mormugao, R-Off Ratnagiri, M- Off Mumbai,
V- Off Veraval, D- Off Dwaraka

Fig. 21 - Transect wise distribution of sediment texture at 100 m



G- Off Mormugao, R-Off Ratnagiri , M- Off Mumbai,
V- Off Veraval, D- Off Dwaraka

Fig. 22 - Transect wise distribution of sediment texture at 150 m

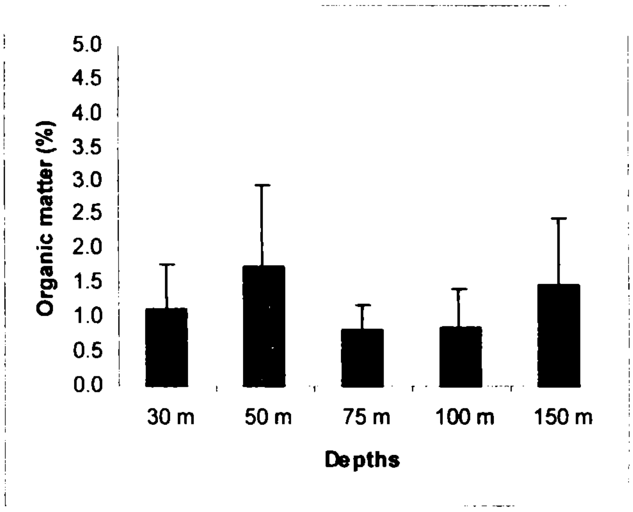


Fig. 23 - Distribution of organic matter (average) in different depths during post monsoon

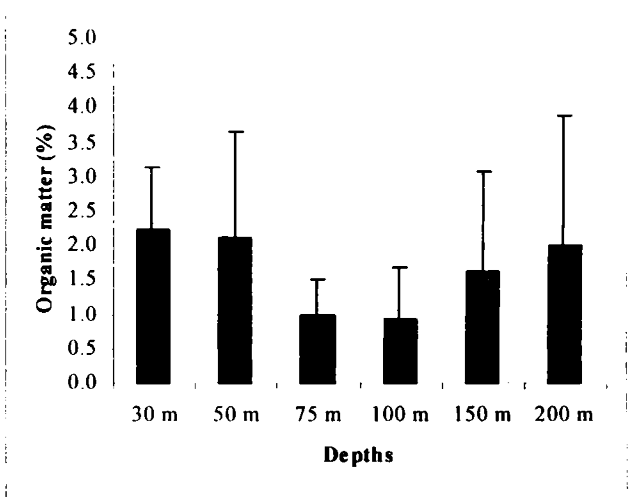


Fig. 24 - Distribution of organic matter (average) in different depths during pre-monsoon

Chapter 5.
Standing Stock

5.1. Introduction

It is well recognized that benthic production is a tool for measuring the biological productivity of an area. Estimation of standing stock of benthos is important for the assessment of demersal fishery resources, as they form an important source of food for demersal fishes and shellfishes. Benthic organisms have an important role in the food chain, either at secondary level as feeding detritus and plant material or at tertiary level as food for predators. Hence, the availability of benthos at any region can be an indicator of demersal fishery potential of that area. The standing crop of macrobenthos is not only important to the demersal fishes which directly feed on them, but also to many pelagic species that restrict to shallow waters during some period of their life. Also, benthic organisms have been regarded as the best indicators of the environmental changes caused by pollution, because of their constant presence, relatively long life span, sluggish or sedentary habits and tolerance to differing stress.

Quantitative study of benthos attained importance after the work of Peterson (1911, 1913) in Danish waters. Belegvad (1930,1932), Jones (1956) and Sanders (1956) after carrying out intensive studies on the bottom fauna have revealed the importance of study of benthic biomass in the evaluation in utilization of benthos as food for higher carnivores and fishes. Sanders (1969) and Sanders *et al.*, (1965) also studied faunal distribution and salinity and ecology of deep-sea benthos.

In the Indian basin, the bottom fauna was first studied by Annandale (1907) and Annandale and Kemp (1915). Neyman (1969) reported the benthos of the shelves in the northern part of Indian Ocean and Desai (1973) studied the benthic productivity of the Indian Ocean. After that Parulekar (1981), Parulekar *et al.*, (1982 b) worked on the benthos of the Indian Ocean and other investigations on the benthos of the entire Indian basin includes Parulekar *et al.*, (1982a), Parulekar (1985), Parulekar *et al.*, (1992) and Ansari *et al.*, (1996). Harkantra *et al.*, (1980) studied the benthos of the entire west cost up to 70 m depth, Joydas and Damodaran (2001) studied the polychaetes along the west coast of India and Joydas (2002) reported the macrobenths along the west coast of India. Most of the studies in the west coast were concentrated on the central west coast, which includes the works of Parulekar (1973), Ansari *et al.*, (1977b), Harkantra and Parulekar (1981), Devassy *et al.*, (1987), Varshney *et al.*, (1988), Vizakat *et al.*, (1991), Prabhu *et al.*, (1993) and Gopalakrishnan and Nair (1998). In the southwest coast, the earlier reports on the benthos from the coastal and estuarine waters were mainly from the investigations of Seshappa (1953), Kurian (1953,1967), Damodaran (1973) and Pillai (1977). The works pertaining to NW coast of India were a few, of which Savich (1972) and Prabhu & Davan (1974) have demonstrated a direct relation between demersal fish catch and abundance of bottom fauna of the Pakistan shelf and Mormugao coast respectively. Parulekar and Wagh (1975) and Qasim (1982) also studied the benthos of shelf region of NW coast of India. Other works on benthos along the northwest coast of India were that of Parulekar *et al.*, (1976) off Mumbai, Harkantra and Parulekar (1994) off Rajapur Bay, and Ingole *et al.*, (2002) of Dabhol.

5.2. Results

Spatial variations in the benthic biomass and density of the northwest continental shelf of India are examined and discussed in this chapte in 5 parts. First and second part deals with biomass and density of macrobenthoc during post-monsoon and pre-monsoon seasons, third and fourth part deals with biomass and density of macrobenthos and fifth part deals with the seasonal comparison.

5.2.1. Biomass of macrobenthos

5.2.1.1. Post-monsoon

Averages of total biomass were given in Fig. 25. Maximum biomass was observed at 30 m zone (8.01 g/m^2) and minimum at 150 m zone (0.79g/m^2). Average values showed a decrease towards deeper depths. Transect wise biomass of various groups in different depth zones is given in Table 5. At 30 m depth zone, total biomass varied from 3.72 g/m^2 (off Mumbai) to 16.07g/m^2 (off Veraval) with an average of 8.01g/m^2. In most of the stations polychaetes contributed more to the total biomass except off Ratnagiri and off Porbandar stations where miscellaneous groups collectively contributed more to the total biomass than polychaetes. Contribution of miscellaneous group was mainly from sipunculids. At 50 m zone total biomass varied from 1.71 g/m^2 (off Mormugao) to 18.88 g/m^2 (off Veraval) with an average of 6.75 g/m^2. In most of the stations polychaetes contributed more to the total biomass except off Ratnagiri and Mumbai where molluscs contributed more to the total biomass than polychaetes. At 75 m zone total biomass varied from 0.44 g/m^2 (off Mormugao) to 1.7g/m^2 (off Veraval) with an average of 0.88 g/m^2. In this depth zone, at all stations polychaetes contributed more to the total biomass except off Mumbai where molluscs contributed more than polychaetes. At 100 m zone total biomass varied between 0.06 g/m^2 (off Veraval) and 3.32 g/m^2 (off Mormugao) with an average of 1.41g/ m^2. In this depth zone, even though average biomass was more for crustaceans, in various stations different taxa contributed more to the total biomass. Off Mormugao, crustaceans contributed more to the total biomass and off Ratnagiri polychaetes contributed more. Off Mumbai and off Dwaraka molluscs have major contribution to the total biomass. Off Veraval, polychaetes and molluscs contributed more and both have equal share to the total biomass. At 150 m zone, biomass ranged from 0.53 g/m^2 (off Dwaraka) to 1.17 g/m^2 (off Porbandar) with an average of 0.79g/ m^2. At this depth zone, average biomass of different taxa showed that total biomass was constituted mainly by molluscs followed by polychaetes. Eventhough average biomass of molluscs was high, off Ratnagiri station, crustaceans were the major contributor to the total biomass. At this depth zone, at all stations polychaetes were the second contributor to the total biomass.

Transect wise variation of total biomass in each depth zone (Table 5) showed that, at 30 m depth zone, values fluctuated in different transects. Stations off Mormugao, Off Mumbai and Off Porbandar showed low biomass while off Ratnagiri and off Veraval recorded high biomass. At 50 m zone also no regular trend in biomass distribution was observed. In the next depth zone (75 m) there was an increase in total biomass from south to north except off Porbandar. At 100 m zone a decreasing trend towards north was observed for total biomass with a high value off Dwaraka. At 150 m zone total biomass increased from off Ratnagiri to off Porbandar and then decreased off Dwaraka. At this depth on an average, molluscs contributed more to the total biomass. In general, no regular latitudinal trend was observed during post-monsoon except a general increase at 75 m zone towards north and a decrease to north at 100 m. However southern and northern transect average values showed that northern transects have higher values (4.34 g/m^2) than southern transects (2.75 g/m^2) (Fig. 26).

5.2.1.2. Pre-monsoon

Average values for total biomass in different depth zones is given in Fig. 25. Average of total biomass was maximum at 50 m depth zone (7.46 g/m^2) and minimum at >150 m depth zone (0.32 g/m^2). Generally high biomass was observed in the shallow depths (upto 75 m)and low biomass beyond 75 m depth. Transect wise biomass distribution at different depth zones is given in Table 6. At 30 m depth zone, total biomass varied from 0.86 g/m^2 (off Ratnagiri) to 14.25 g/m^2 (off Dwaraka) with an average of 4.69 g/m^2. Qualitative composition at this depth zone showed that miscellaneous groups collectively contributed more followed by polychaetes to the total biomass. Contribution of miscellaneous groups was mainly from stations off Dwaraka, Veraval and Mormugao. Off Mormugao sipunculids contributed more and off Veraval and Dwaraka, juvenile fish, sipunculids and nemertene worms collectively exceeds the polychaete biomass. At 50 m depth zone, total biomass varied from 1.56 g/m^2 (off Ratnagiri) to 15.87 g/m^2 (off Mumbai) with an average of 7.46 g/m^2. At this zone average value showed that polychaete had a discrete dominance over all other groups in contributing more to the total biomass. At 75 m zone total biomass varied from 2.6 g/m^2 (off Mormugao) to 17.51 g/m^2 (off Ratnagiri) with an average of 6.85 g/m^2. Even though average biomass of polychaetes was high, contribution of polychaetes were low at stations off Mormugao and Veraval. Off Mormugao, contribution of molluscs was more to total biomass than Polychaetes while off Veraval, crustaceans and miscellaneous group contributed more. Molluscs comprising of bivalves and gastropods and miscellaneous group constituted mainly by juvenile fishes and nemertene worms. Crustaceans comprised mainly of amphipods. At 100 m zone total biomass varied from 0.87g/m^2 (off Mormugao) to 3.95 g/m^2 (off Dwaraka) with an average of 2.07 g/m^2. Even though average biomass of polychaerte was high, its contribution to the total biomass was more only at stations off Ratnagiri and Dwaraka. Off Mormugao, Mumbai and Veraval stations contribution of molluscs was more especially off Veraval. At 150 m zone, only three observations were made and total biomass varied from 1.76 g/m^2 (off Veraval) to 5.86 g/m^2 (off Mumbai) with an average of 3.43 g/m^2. Even though average biomass was maximum for crustaceans, at each station different groups contributed more to the total biomass, i.e., polychaetes have higher contribution to the total biomass at station off Dwaraka, crustaceans contributed more to the total biomass off Mumbai and molluscs showed better contribution to the total biomass off Veraval. At >150 m depth zone, only two observations were made and total biomass varied between 0.02 g/m^2 (off Veraval) to 0.61 g/m^2 (off Mumbai) with an average of 0.32 g/m^2. Off Mumbai, crustaceans and miscellaneous groups exceeded polychaetes whereas off Veraval polychaetes alone were present.

Transect wise variation of total biomass in each depth zone showed a general increase to north (Table 6). At 30 m depth zone total biomass exhibited wide variation with a general increase towards north. At 50 m zone, total biomass was fluctuating transect wise while at 75 m depth zone a general increase to north was observed with exceptionally high value off Ratnagiri. At 100 m zone also an increasing trend was observed in biomass distribution towards north except off Mumbai transect. At 150 m zone, 3 observations were done, total biomass decreased from off Mumbai to off Veraval and then increased to Off Dwaraka. In general there was a northward increase in biomass. Few exceptional values in the southern stations noticed were off Ratnagiri and Mumbai. Southern and northern average values showed comparatively high biomass in north (Fig. 27)

5.2.2. Density of macrobenthos

5.2.2.1. Post-monsoon

Averages of total density were given in Fig. 28. Highest total average density was recorded at 30 m zone (2654 / m^2) and lowest at 150 m zone (257 / m^2) and decreased from shallow to deeper depths. Transect wise density distribution in different depth zones during post-monsoon is given in Table 7. At 30 m zone total density ranged from 360 (off Porbandar) to 4820/ m^2 (off Mormugao) with an average of 2654/ m^2. Polychaetes dominated at all the stations followed by crustaceans. At 50 m zone, total density ranged from 210 / m^2 (off Ratnagiri) to 4100/ m^2 (off Veraval) with an average of 1388/ m^2. In this zone also polychaetes showed an obvious dominance over other groups. Crustaceans were the second dominant group in most of the stations. At 75 m zone, total density varied from 110 / m^2 (off Porbandar) to 942/ m^2 (off Ratnagiri) with an average of 464/ m^2 and polychaetes had a distinct dominance over other groups. Crustaceans were the second dominant group in most of the stations. At 100 m zone, total density ranged from 25 / m^2 (off Veraval) to 770/m^2 (off Mormugao) with an average of 327 / m^2. At all the stations polychaetes dominated except off Dwaraka where molluscs dominated. At 150 m zone three stations were sampled and density ranged between 90 /m^2 (off Ratnagiri) and 560 /m^2 (off Dwaraka) with an average of 257 /m^2. Polychaetes dominated off Ratnagiri and Porbandar while molluscs dominated off Dwaraka.

Transect wise density distribution in different depth zones during post-monsoon is given in Table 7. Transect wise variation of total density showed that at 30 m zone there was a gradual decrease in total density towards north except off Veraval. At 50 m zone, total density fluctuated with low value off Ratnagiri and high value off Veraval while at 75 m zone, high values were seen in southern transect stations with a decreasing trend towards north. At 100 m zone also decreasing trend was noticed in total density towards north with an exceptionally high value off Dwaraka mainly because of the presence of molluscs and polychaetes. In 150 m zone as an exception from the other depth zones, an increase was observed for total density towards north with exceptional high value off Dwaraka. In general comparatively high density was observed in southern transect stations in most of the depth zones. Average values of southern and northern transects also showed relaatively higher average density in the southern transect (1200/m^2) and lower in the northern transect (800/m^2)(Fig. 29).

5.2.2.2. Pre-monsoon

Average of total density in different depth zones is given in Fig. 28. Average density was highest at 75 m (3578/m^2) and lowest at >150m (620/m^2). Density first increased from 30 m to 75 m zone then decreased to deeper depths. Transect wise density distribution in different depth zones during pre-monsoon is given in Table 8. At 30 m zone total density varied from 570/m^2 (off Ratnagiri) to 1740/m^2 (off Dwaraka) with an average of 1220/m^2. At all stations polychaetes dominated in the population counts except off Ratnagiri where density of molluscs was more than that of polychaetes. At 50 m zone total density varied from 710/m^2 (off Ratnagiri) to 5250/m^2 (off Mormugao) with an average of 2623/m^2. At all the stations polychaetes had an obvious dominance over all other groups. In the next depth zone, 75 m, total density varied from 530/m^2 (off Veraval) to 10090/m^2 (off Ratnagiri) with an average of 3578/m^2. As that of previous depth zone, here also polychaete had a well-defined dominance at all stations followed by miscellaneous group and crustaceans. At 100 m depth zone total density varied from 1760/m^2 (off Dwaraka) to 2400/m^2 (off Veraval) with an average of 2060/m^2 and polychaetes dominated at all stations. At 150 m zone, total density varied from 140/m^2 (off Veraval) and 1885/m^2 (off Mumbai) with an average of 1493 /m^2. At this zone, off Veraval station, molluscs dominated and polychaete density reduced considerably than rest of the groups. At >150 m zone only two stations were sampled and total density ranged between 10 /m^2 (off Veraval) and 1230 /m^2 (off Mumbai) with an average of 620 /m^2. Off Mumbai, polychaete dominated followed by miscellaneous group and crustaceans while off Veraval only polychaete was present and lowest density in the study area was observed at this station.

Transect wise density distribution in different depth zones during pre-monsoon is given in Table 8. Transect wise variation of density distribution in different depth zones showed that at 30 m zone, total density was fluctuating with high average values in north. At 50 m also total density fluctuated with low value off Ratnagiri and high value off Mormugao station. At 75 m depth zone, fluctuating trend was observed and variation of total density between transects was more in this zone. Highest value was observed off Ratnagiri and lowest off Veraval. At 100 m zone, the variation among transect was low and no regular trend was observed along transects. At 150 m zone, fluctuating trend was observed. Off Mumbai and Off Dwaraka total density was more or less similar and off Veraval, total density reduced significantly. It was comparatively high in southern latitude station (off Mumbai) and then decreased to off Veraval then showed an increase to off Dwaraka, thus showing an irregular pattern. At > 150 m zone, only two stations were sampled and high total density was observed off Mumbai and low off Veraval. In general no regular transect wise trend was observed in total density, however, average values showed relatively high values in the southern transect (Fig. 30).

5.2.3. Biomass of meiobenthos

5.2.3.1. Post-monsoon

Biomass distribution of meiobenthos during post-monsoon season is given in Table 9. Average biomass showed a general decrease towards deeper depths with highest value at 30 m (1.91 mg/10 cm^2) and lowest at 150 m (0.08 mg/10 cm^2). At 30 m zone, total biomass varied from 0.66mg/10 cm^2 (Off Mormugao) to 4.09 mg/10 cm^2 (off Veraval) with an average of 1.91 mg/10 cm^2. Contribution of individual groups to the total biomass at different depth zones showed that nematodes contributed more to the total biomass followed by copepods. Relatively higher values were observed in the northern transect stations. At 50 m zone, total biomass varied from 0.55 mg/10 cm^2 (off Porbandar) to 1.39 mg/10 cm^2 (off Ratnagiri) with an average of 0.98 mg/10 cm^2. Here also nematodes contributed more to the total biomass. Off mormugao, low biomass was noticed and off Ratnagiri recorded highest biomass after that it decrased towards north. At 75 m zone, total biomass varied from 0.34 mg/10 cm^2 (off Mumbai) to 1.55 mg/10 cm^2 (off Mormugao) with an average of 0.75 mg/10 cm^2. Here all the component groups have more or less similar share to the total biomass. Bioomass generally decreased from south to north. At 100 m zone, total biomass varied from 0.49 mg/10 cm^2 (off Ratnagiri) to 1.6 mg/10 cm^2 (off Veraval) with an average of 0.85 mg/10 cm^2. Here the contribution of nematodes to the total biomass was low. No regular transect wise pattern was observed. At 150 m zone, only three observations were made and total biomass varied from 0.03 mg/10 cm^2 (off Porbandar) to 0.15 mg/10 cm^2 (off Dwaraka) with an average of 0.08 mg/10 cm^2. Here nematodes and all the miscellaneous groups together contributed to total biomass and copepods were absent. Here also no regular transect wise trend was observed. Overall faunal composition showed that nematodes were contributed more to the total biomass (53%) (Fig. 31) and average value was more in northern transect (1.28 mg/10 cm^2) than southern transect (0.92 mg/10 cm^2).

Percentage contribution of various taxa in different depth zones showed that (Table. 10) contribution of nematodes to the total biomass generally decreased as depth increased. Highest percentage was observed at 30 m (72%) and lowest at 100 m (18.4%). Percentage contribution of copepods and miscellaneous groups were relatively high in deeper depths. Copepods contributed minimum at 50 m (8.9%) and maximum at 100 m (42.3%). Miscellaneous groups have lowest share at 30 m (12.3%) and highest at 150 m (54.2%).

5.2.3.2. Pre-monsoon

Sufficient data for the pre-monsoon period is not available, and interpretation is based on the data obtyained from stations at 30 m, 75 m and 100 m (Table 11). Biomass at 30 m depths was low off Mormugao and Mumbai while it was high off Ratnagiri, Veraval and Dwaraka. Overall percentage contribution (Table 11) showed that nematodes contributed 27.3 % to the total biomass, copepods contributed 4.8% and rest of the groups collectively contributed 67.8% to the total biomass.

5.2.4. Density of meiobenthos

5.2.4.1. Post-monsoon

Density distribution of meiobenthos during post-monsoon season is given in Table 12. Average of total density showed that density decreased towards deeper depths. Highest average density was observed at 30 m (427/10 cm^2) followed by 50 m (187/10 cm^2) and lowest at 150 m (13/10cm^2). Nematodes were the dominant group contributing 91% to the total population (Fig. 32). Of the remaining groups, copepods were relatively more (4%) followed by foraminifers and miscellaneous groups.

At 30 m depth zone, density varied from 144/10 cm^2 (off Ratnagiri) to 770/10 cm^2 (off Veraval) with an average of 427/10 cm^2 (Table 12). Nematodes were the dominant group followed by copepods and foraminifers. Relatively high density was observed in north. At 50 m zone, total density varied from 95/10 cm^2 (off Porbandar) to 285/10 cm^2 (off Ratnagiri) with an average of 187/10 cm^2. Here also nematodes were the dominant group followed by foraminifers, and copepods contributed least to the total density. At this depth, comparatively high density in the southern transects. At 75 m zone, total density varied from 41 /10 cm^2 (off Veraval) to 177 /10 cm^2 (off Mormugao) with an average of 90/10 cm^2. Nematodes dominated the zone, followed by copepods, and foraminifers. Here also southern transects recorded more density. At 100 m zone, total density varied from 38/10 cm^2 (off Ratnagiri) to 128/10 cm^2 (off Mormugao) with an average of 66/10 cm^2. More or less similar density was obserced at all stations except off Mormugao. Similar to the previous depth zone, here also nematodes were the dominant taxa, copepods were the second dominant group and foraminifers were the least abundant group. At 150 m zone, total density varied from 9/10 cm^2 (off Dwaraka) to 19/10 cm^2 (off Ratnagiri) with an average of 13/10

cm^2 with a dominance of nematodes. In general no distinct transect wise trend was observed.

Percentage contribution within individual group at different depth (Table 13) showed that contribution of nematodes decreased with increasing depth while, rest of the groups showed an opposite trend. Highest contribution of nematodes was at 30 m (56.7%) and lowest at 150 m (1.5 %). Copepods contributed maximum at 150 m zone (37.4%) and minimum at 50 m zone (9%). Miscellaneous groups also have relatively lower percentage contribution at 30 m (19.7%) and higher contribution at deeper depths of 100 m (28.5%), but exceptionally low value at 150 m (3.6%).

5.2.4.2. Pre-monsoon

Density followed the similar trend as that of biomass with relatively low density at the 30 m depth off Mormugao and Mumbai while, high density was observed at 30 m depth off Ratnagiri, Veraval and Dwaraka (Table 14). Overall percentage contribution by various groups to the total density (Table 14) showed that nematodes contributed more to the total density (65.3%) followed by foraminifers (25%) and miscellaneous groups (8%). Copepods were the least abundant group (1.3%).

5.2.5. Seasonal comparison

In general, average biomass and density of macrobenthos in the whole study area were high during pre-monsoon season than post-monsoon period (Fig. 33&34). In both seasons shallow depth stations registered high biomass and density, while it reduced considerably in deeper stations with some exceptions. During post-monsoon, even though no regular trend was observed, average biomass showed comparatively high value in the northern transect than its southern counterpart (Fig. 26). Biomass showed a northward increase during pre-monsoon. Average value of this season also showed comparatively high value in the northern transect than southern transect (Fig. 27), however, exceptionally high biomass was observed at 75 m depth off

Ratnagiri. Density was comparatively high in the southern transects in both seasons (Fig. 29&30). All depth zones of pre-monsoon season recorded high biomass except at 30 m depth zone, and at few depth zones the seasonal variation was more.

During post-monsoon, generally all the groups have high biomass in shallow areas (30 m and 50 m) and low at deeper zones (beyond 50 m). in addition to the high biomass of crustaceans in the shallow depths, it was also more in the middle or deeper depths off Mormugao (100 m) Ratnagiri (150 m) and Mumbai (75 m). During pre-monsoon season polychaetes and miscellaneous groups showed high biomass up to 75 m depth and low values beyond 75 m while crustaceans showed low biomass in shallow areas (up to 50 m depth) in all transects and high in middle (75 m) or deeper depths (beyond 75 m). Molluscs were high in deeper stations (from 75 m to 150 m). In other words, season wise comparison showed that during post-monsoon most of the groups have more biomass in shallow areas while during pre-monsoon only polychaetes and other groups have more biomass in shallow areas (30 m and 50 m).

Students t statistical analysis (Table 15) showed no significant difference in biomass and density between two seasons except for the polychaete density and total density at 100 m depth zone. Observed difference may be due to the uneven distribution of organisms in various stations. Seasonal comparison for meiobenthos was not possible due to lack of sufficient data, however, average biomass and density of meiobenthos showed relatively higher values during pre-monsoon than post-monsoon.

5.3. Discussion

In the present study biomass in the whole study area varied from 0.05 to 18.88g/ m^2 (av. 3.81g/ m^2) during post-monsoon and 0.02 to 15.87g/m^2 (av. 4.53g/ m^2) during pre-monsoon season. Density in the whole study area varied from 10 to 4820/ m^2 (av. 1040/ m^2) during post-monsoon and 10 to 10090/m^2 (av. 2104/m^2) during pre-monsoon season. At 30 m to 50 m zones an average biomass of 7.38 g/m^2

and 6.08 g/m^2 were recorded during post-monsoon and pre-monsoon seasons respectively, which is comparable with the result of Joydas (2002) who reported a biomass of 8.3 g/m^2 in the 30-50 m depth zone for the continental shelf of entire west coast of India.

Average density at the 30 m depth zone was 2654/m^2 and 1220/m^2 during post-monsoon and pre-monsoon seasons respectively. Average density reported by Prabhu *et al.*, (1993) in the 30 m depth zone off Gangolli, west coast of India was 1725 and 1775 /m^2 in the two consecutive years is comparable to the density reported during the present study. In the present study, average density observed at the 30 m and 50 m zone during pre-monsoon was 1922/m^2, and was comparable with density (1969/m^2) reported by Joydas (2002) in the 30-50 m zone of NW coast of India during same period.

Since no similar works were available, present study was compared with data from other earliedr works. Neyman (1969) reported a biomass of 20 g/m^2 in the NW coast of India. Parulekar *et al.*, (1982 a) reported an average biomass of 14.06 g/m^2 for both macro and meio benthos together from the 20-40 m depth range. Parulekar *et al.*, (1976) studied the quantitative aspects of benthos off Mumbai from 12 to 77 m depth and reported a low biomass values from nil to 4.63g/m^2 with no uniformity in the macrobenthic production. They reported an average of 1.1g/m^2 in the study area off Mumbai. Harkantra *et al.*, (1980) reported an average biomass of 7.77 g/m^2 in the west coast from 30-70 m zone. Parulekar and Wagh (1975) recorded an average total biomass of 46.9 g/m^2 from 40-140 m depths stations in the NW coast of India. Parulekar *et al.*, (1982a) observed an average biomass for both macro and meiobenthos was 12.39 g/m^2 from 20-200 m. Qasim (1982) recorded a mean biomass of 6.74g/ m^2 in the NW coast of India and biomass reported by Ansari *et al.*, (1996) ranged from 10 to 100g/ m^2 with a mean of 20 g/ m^2 in the NW Indian shelf from 20 to 350m depth.

Difference in biomass and density noticed by earlier workers may be due to the use of different types of gears (Neyman, 1969; Parulekar and Wagh, 1975; Parulekar *et al.*, 1976; Harkantra *et al.*, 1980; Parulekar *et al.*, 1982a; Qasim, 1982) or due to sampling in different seasons from diverse ecosystems (Ansari *et al.*, 1996). In addition to the above reasons, biomass reported by Parulekar *et al.*, (1982a) was a total of both macro and meiobenthos. The average biomass value ($4.53g/m^2$) for the study area as a whole during pre-monsoon season in the NW coast is well comparable to that of Joydas (2002) who reported an average value of $5.3g/m^2$ in the northwest coast of India during pre-monsoon.

During post-monsoon biomass was generally high in shallow depths (30 m and 50 m) and during pre-monsoon season it was high from 30 to 75 m and low in the deeper stations beyond 75 m. Density also followed more or less the same trend with high values in shallow stations and low in deeper depths in both seasons. This was in agreement with earlier reports (Kurian, 1953, 1967,1971; Neyman, 1969; Parulekar, 1973; Parulekar and Dwivedi, 1974; Parulekar and Wagh, 1975; Parulekar *et al.*, 1976; Ansari *et al.*, 1977b; Harkantra *et al.*, 1980 & 1982; Parulekar *et al.*, 1982 b; Qasim, 1982; Devassy *et al.*, 1987; Prabhu *et al.*, 1993; Ansari *et al.*, 1996; Joydas and Damodaran, 2001). Enrichment of coastal waters due to riverine flow and land run off seems to be one of the factors contributing to richness of fauna in the nearshore regions (Parulekar, 1973). Devassy *et al.*, (1987) reported high biomass in the near shore region and attributed it to the influx of nutrient rich river water. Influence of nutrient rich water is reported by other workes also (Kurian, 1971; Harkantra *et al.*, 1980; Harkantra and parulekar, 1981). But the work of Gopalkrishnan and Nair (1998) recorded low benthic population in the nearshore areas (5m) and rich fauna in 20 m contour of Mangalore. Ansari *et al.*, (1996) also reported a decreasing standing crop with increasing depth and distance from the shore. They reported that neritic coastal waters of continental shelf (up to 200m depth) were often highly productive and many of the world's commercial fisheries were located in the nearshore waters. However they noticed an increase in the diversity of benthos in deeper waters as observed by Parulekar *et al.*, (1992). High production reported by Devassy *et al.*, (1987) in the near shore areas (5m depth) was also attributed to the variation in sediment texture. High biomass and numerical abundance in shallow depth zones can be due to high primary productivity (Radhakrishna *et al.*, 1978). Parulekar and Wagh (1975) stated that Arabian Sea is charecterised by rich bottom fauna which is attributed to the inflow of equatorial waters of low salinity causing stratification in the water column. Low benthic biomass at higher depths is probably because of an inflow of subsurface water with low oxygen content.

In the present study there was no obvious latitudinal variation in benthic biomass but comparatively high biomass values were observed in north in both seasons. This is in agreement with earlier reports of Neyman (1969), Humphrey (1972), Parulekar and wagh (1975), Parulekar *et al.*, (1982a) and Ansari *et al.*, (1996). As per the differential production in the south and north latitudes, Parulekar and Wagh (1975) demarcated the Arabian Sea shelf into two zones, one north of 20° N upto 23° and south of 20° N upto 17° N and biomass in the Arabian Sea decreases gradually southward. Humphrey (1972) has attributed high phosphate content and higher primary production to the difference in biomass production in the northern region as compared to the southern region. The rich bottom life in the Arabian Sea is attributed to rich plankton in the region enhanced by upwelling and intrusion of subsurface water during monsoon (Qasim, 1977). Neyman (1969) suggested that 15° N is the boundary between high and low productive zones. During pre-monsoon, off Ratnagiri showed an exceptional high biomass and density at 75 m depth. This variation observed may be due to the impact of localized biotic or abiotic factors or both. But Elizarov (1968) reported abundance of bottom life in the southern part of Arabian Sea and correlated the abundance to an inflow of equatorial waters of low salinity causing a strongly expressed stratification of water masses. Harkantra *et al.*,

(1980) also reported high values in shallow region with more diverse fauna in southern region of west coast and the difference may probably due to the influence of equatorial waters and upwelling. In the areas where ridges and sills develop low oxygen and high H_2S condition, the benthic biomass is either very impoverished or absent (Parulekar, 1986). However study of Joydas (2002) could not found any north–south variation in biomass in the west coast of India.

Distribution of benthos showed a different pattern with higher population density in the southern latitude for both seasons as compared to the northern latitude. The change in trend could be due to variations in the size of the organisms. Usually population density and biomass are directly related but if the size variation among individuals is too large, the direct relation is lost. Parulekar and Ansari (1981) studied the macrobenthos of Andaman Sea and reported an inverse relationship between biomass and population density. Ansari *et al.*, (1994) also reported that biomass did not follow the same trend as that of density due to the presence or absence of large sized organisms whilst Harkantra *et al.*, (1980) observed a direct relation between benthic density and biomass except at few stations having large sized organisms in the west coast of India.

The decrease of fauna towards deeper depths was influenced by environmental parameters like temperature, salinity and DO (Ingole *et al.*, 2002; Parulekar and Ansari, 1981). Variation in temperature during pre-monsoon may influence the benthic population. Ingole *et al.*, (2002) reported temperature and salinity were regarded as regulators of the reproductive cycle of the marine invertebrates. Marine species inhabiting the tropical region generally have a narrow range of temperature tolerance since they normally live in a temperature regime that is close to their upper tolerance limit. The important variables controlling the distribution and abundance of benthic organisms in the tropical regime are salinity (Alongi, 1990; Parulekar and Dwivedi, 1974), and sediment stability (Wildish and Kristmanson, 1979; Warwick and Uncle, 1980). Seasonal variations observed in benthic production could be due to changes in the hydrographical and textural features. Harkantra and Parulekar (1981) also reported distinct seasonal changes in the benthos in the shallow depths off Goa.

Present study showed an average meiobenthic biomass of 0.99 mg/10 cm2 during post-monsoon and 4.77 mg/10cm2 during pre-monsoon which is within the range of the earlier reports from the coastal waters of India (Damodaran, 1973; Parulekar *et al.*, 1976; Rodrigues *et al.*, 1982). Sajan (2003) studied the meiobenthos of west coast of India and reported a biomass of 1.27 mg/10cm^2 in the northwest coast, which is more or less similar to the post-monsoon biomass value obtained in the present study. Average meiobenthic density in the present study was 169/10cm^2 during post-monsoon and 886/10cm^2 during pre-monsoon. Ansari *et al.*, (1980) reported a density of 250-2925/10cm^2, which is higher than the present report. Sajan (2003) reported a density of 225/10cm^2 in the northwest coast of India which is closely similar to density of the post-monsoon season.

Present study revealed high meiobenthic biomass and density in the shallow depths of all transects during post monsson season and at a few transects (off Mormugao and Mumbai) during pre-monsoon season. High occurrence of meiofauna in the shallow depths was in agreement with earlier reports (Parulekar *et al.*, 1976; Ansari *et al.*, 1980;Rodrigues *et al.*, 1982; Ansari and Parulekar, 1998; Sajan, 2003). Rodrigues *et al.*, (1982) attributed the high meiobenthic biomass in the near shore region to the enrichment of coastal waters due to riverine flow and land runoff. Fluctuations in the meiofaunal density and biomass at some stations may probably be as a result of graizing by macrofauna, or presumably because of the predator-prey relationship existing among meiobenthos itself (Mare, 1942).

Present study showed that among meiobenthos, nematodes contributed more to the total biomass and population density. Mc Intyre (1969) suggested that nematodes were generally the dominant taxon in marine meiofauna. Parulekar *et al.*, (1976) found that biomass was mainly represented by nematodes and density by foraminifers and nematodes. Ansari *et al.*, (1980) reported dominance of nematodes followed by foraminifers while Rodrigues *et al.*, (1982) reported dominance of nematodes followed by polychaetes. Ansari and Ingole (1983) and Sajan (2003) also noticed the dominance of nematodes followed by harpacticoides. The increased biomass and density in the shallow stations during pre-monsoon may be due to high surface productivity.

Trend in meiobenthic distribution between transects was not discernible, but average values showed relatively high biomass and density along the northern transects. Neyman (1969) showed that benthos were sparse in the northern shelf of western India at depths of 75-200m, attributing this to the low oxygen content in the water along the north. Present study reported dominance of nematodes among the other groups in shallow (95%) as well as deeper depths of 150 m depth (79%) even though density of total meiofaunal and nematodes decreased with depth. This can be explained by the tolerance capacity of nematodes in low oxygen conditions as observed by Damodaran (1973), Gooday *et al.*, (2000) and Bernhard *et al.*, (2000). Sajan (2003) reported 87% of the total meiofauna represented by nematodes beyond 150 m.

Present study showed that during post-monsoon macrobenthos and meiobenthos were more in the shallow depths than deeper depths reveals their positive relationships among themselves but Desai and Krishnankutty (1967) noticed an inverse relationship between macro and meiofauna. Average macrobenthic density was $1372/m^2$ and $2104/m^2$ during post-monsoon and pre-monsoon seasons respectively. Average density irrespective of seasons was $1738/m^2$. Average meiobenthic density during post-monsoon was $169/10\ cm^2$ ($16900/m^2$) and during pre-monsoon it was $886/10\ cm^2$ ($88600/m^2$). Average meiobenthic density irrespective of seasons was $52750/m^2$. The relation between macro and meiobenthos in the present study was in the ratio of 1:30. Parulekar *et al.*, (1976) reported an average ratio of macro to meiofauna was in the order of 1:16,000 and opined that contribution of nematodes and foraminifers in the meiofauna seems to be the main factor for such a large difference in the faunal distribution. Rodrigues *et al.*, (1982) reported a population ratio of macro:meio fauna was 1:91. Comparison of macro-meiofauna ratios can indicate genuine differences in the utilization of particular habitats by the fauna. He also reported that ratio varies with the change in the sediment texture. Ansari *et al.*, (1982) reported that meiofauna was numerically 94-2193 times more than macrofauna with an overall contribution of 50 % to the total standing crop. Parulekar *et al.*, (1992) reported a ratio of 1:467 between macro and meiofauna. Ansari *et al.*, (1977a) stated that relative proportion of macro to meiofauna was of the order of 1:3500, which indicates the important role of meiofauna in the benthic community. High meiobenthic density in the present study reveals that meiobenthos is not limiting the macrobenthic production as that of surface primary production.

5.4. References

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Transects	Polychaetes	Crustaceans	Molluscs	Miscellaneous group	Total
30 m					
Off Mormugao	3.80	0.15	0.07	0.00	4.02
Off Ratnagiri	4.11	1.52	0.16	5.85	11.64
Off Mumbai	2.00	0.00	1.72	0.00	3.72
Off Veraval	14.26	0.71	1.10	0.00	16.07
Off Porbandar	0.08	0.02	0.00	4.50	4.60
Average	**4.85**	**0.48**	**0.61**	**2.07**	**8.01**
50 m					
Off Mormugao	1.20	0.49	0.02	0.00	1.71
Off Ratnagiri	0.15	0.99	3.89	0.00	5.03
Off Mumbai	0.86	0.00	1.03	0.00	1.89
Off Veraval	15.32	0.10	2.86	0.60	18.88
Off Porbandar	6.20	0.04	0.00	0.00	6.24
Average	**4.75**	**0.32**	**1.56**	**0.12**	**6.75**
75 m					
Off Mormugao	0.40	0.00	0.04	0.00	0.44
Off Ratnagiri	0.30	0.09	0.11	0.00	0.50
Off Mumbai	0.22	0.23	0.40	0.00	0.85
Off Veraval	0.95	0.26	0.49	0.00	1.70
Off Porbandar	0.53	0.00	0.36	0.00	0.89
Average	**0.48**	**0.12**	**0.28**	**0.00**	**0.88**
100 m					
Off Mormugao	1.00	2.32	0.00	0.00	3.32
Off Ratnagiri	0.71	0.43	0.00	0.00	1.14
Off Mumbai	0.16	0.00	0.62	0.00	0.78
Off Veraval	0.03	0.01	0.03	0.00	0.06
Off Dwaraka	0.38	0.00	1.40	0.00	1.78
Average	**0.45**	**0.55**	**0.41**	**0.00**	**1.41**
150m					
Off Ratnagiri	0.07	0.61	0.00	0.00	0.68
Off Porbandar	0.56	0.00	0.61	0.00	1.17
Off Dwaraka	0.14	0.00	0.39	0.00	0.53
Average	**0.26**	**0.20**	**0.33**	**0.00**	**0.79**

Table 5 – Macrobenthic biomass (g/m^2) during post-monsoon season

Transects	Polychaetes	Crustaceans	Molluscs	Miscellaneous group	Total
30 m					
Off Mormugao	0.26	0.01	0.12	0.65	1.04
Off Ratnagiri	0.41	0.02	0.42	0.01	0.86
Off Mumbai	1.61	0.01	0.69	0.04	2.35
Off Veraval	1.29	0.01	0.00	3.62	4.92
Off Dwaraka	5.18	0.05	0.15	8.87	14.25
Average	**1.75**	**0.02**	**0.28**	**2.64**	**4.69**
50 m					
Off Mormugao	8.80	0.00	0.00	0.17	8.98
Off Ratnagiri	0.96	0.08	0.49	0.03	1.56
Off Mumbai	14.00	0.10	0.09	1.68	15.87
Off Veraval	2.68	0.01	0.00	0.76	3.45
Off Dwaraka	6.61	0.05	0.15	0.66	7.46
Average	**6.61**	**0.05**	**0.15**	**0.66**	**7.46**
75 m					
Off Mormugao	0.83	0.02	1.58	0.17	2.60
Off Ratnagiri	14.73	0.54	0.39	1.85	17.51
Off Mumbai	2.83	0.08	0.46	0.03	3.40
Off Veraval	0.77	1.00	0.00	2.25	4.02
Off Dwaraka	5.03	0.26	0.14	1.29	6.72
Average	**4.84**	**0.38**	**0.51**	**1.12**	**6.85**
100 m					
Off Mormugao	0.20	0.03	0.46	0.17	0.87
Off Ratnagiri	1.77	0.03	0.10	0.14	2.04
Off Mumbai	0.25	0.24	0.38	0.34	1.21
Off Veraval	0.26	0.05	1.88	0.09	2.28
Off Dwaraka	3.58	0.04	0.24	0.09	3.95
Average	**1.21**	**0.08**	**0.61**	**0.17**	**2.07**
150 m					
Off Mumbai	0.82	2.90	0.27	1.87	5.86
Off Veraval	0.00	0.03	1.72	0.01	1.76
Off Dwaraka	1.51	0.67	0.23	0.26	2.67
Average	**0.78**	**1.20**	**0.74**	**0.71**	**3.43**
>150 m					
Off Mumbai	0.06	0.34	0.00	0.21	0.61
Off Veraval	0.02	0.00	0.00	0.00	0.02
Average	**0.04**	**0.17**	**0.00**	**0.11**	**0.32**

Table 6 – Macrobenthic biomass (g/m^2) during pre-monsoon season

Transects	Polychaetes	Crustaceans	Molluscs	Miscellaneous group	Total
30 m					
Off Mormugao	4730	80	10	0	4820
Off Ratnagiri	3810	90	40	80	4020
Off Mumbai	1560	20	0	0	1580
Off Veraval	2080	340	30	40	2490
Off Porbandar	340	10	0	10	360
Average	**2504**	**108**	**16**	**26**	**2654**
50 m					
Off Mormugao	1480	40	10	0	1530
Off Ratnagiri	160	30	20	0	210
Off Mumbai	340	0	60	0	400
Off Veraval	3860	180	10	50	4100
Off Porbandar	680	20	0	0	700
Average	**1304**	**54**	**20**	**10**	**1388**
75 m					
Off Mormugao	740	0	0	0	740
Off Ratnagiri	932	10	0	0	942
Off Mumbai	300	10	20	0	330
Off Veraval	120	70	10	0	200
Off Porbandar	90	10	0	10	110
Average	**436**	**20**	**6**	**2**	**464**
100 m					
Off Mormugao	680	70	20	0	770
Off Ratnagiri	140	20	0	0	160
Off Mumbai	80	0	10	0	90
Off Veraval	20	5	0	0	25
Off Dwaraka	160	0	430	0	590
Average	**216**	**19**	**92**	**0**	**327**
150m					
Off Ratnagiri	80	0	10	0	90
Off Porbandar	100	0	20	0	120
Off Dwaraka	60	0	500	0	560
Average	**80**	**0**	**177**	**0**	**257**

Table 7 – Macrobenthic density (No/m^2) during post-monsoon season

Transects	Polychaetes	Crustaceans	Molluscs	Miscellaneous group	Total
30 m					
Off Mormugao	830	10	30	130	1000
Off Ratnagiri	260	10	290	10	570
Off Mumbai	1400	20	170	10	1600
Off Veraval	970	70	0	150	1190
Off Dwaraka	1380	110	30	220	1740
Average	**968**	**44**	**104**	**104**	**1220**
50 m					
Off Mormugao	5230	0	0	20	5250
Off Ratnagiri	490	70	110	40	710
Off Mumbai	2950	260	60	50	3320
Off Veraval	1070	10	0	130	1210
Off Dwaraka	2435	85	43	60	2623
Average	**2435**	**85**	**43**	**60**	**2623**
75 m					
Off Mormugao	840	30	160	20	1050
Off Ratnagiri	8750	490	450	400	10090
Off Mumbai	3440	130	140	80	3790
Off Veraval	430	50	0	50	530
Off Dwaraka	1160	330	70	870	2430
Average	**2924**	**206**	**164**	**284**	**3578**
100 m					
Off Mormugao	1860	20	180	20	2080
Off Ratnagiri	1450	30	330	120	1930
Off Mumbai	1030	580	160	360	2130
Off Veraval	1610	180	350	260	2400
Off Dwaraka	1220	190	170	180	1760
Average	**1434**	**200**	**238**	**188**	**2060**
150m					
Off Mumbai	1190	365	50	280	1885
Off Veraval	10	30	70	30	140
Off Dwaraka	1550	170	50	30	1800
Average	**1080**	**273**	**73**	**67**	**1493**
>150 m					
Off Mumbai	700	110	0	420	1230
Off Veraval	10	0	0	0	10
Average	**355**	**55**	**0**	**210**	**620**

Table 8 - Macrobenthic density (No/m^2) during pre-monsoon season

Transects	Nematodes	Copepods	Miscellaneous group	Total
30m				
Off Mormugao	0.53	0.00	0.13	0.66
Off Ratnagiri	0.46	0.06	0.33	0.85
Off Mumbai	2.04	0.16	0.00	2.20
Off Veraval	2.42	1.15	0.52	4.09
Off Porbandar	1.43	0.12	0.20	1.75
Average	**1.38**	**0.30**	**0.23**	**1.91**
%	**72.0**	**15.6**	**12.3**	
50m				
Off Mormugao	0.44	0.06	0.13	0.63
Off Ratnagiri	0.94	0.12	0.33	1.39
Off Mumbai	0.84	0.09	0.20	1.13
Off Veraval	0.47	0.09	0.65	1.21
Off Porbandar	0.29	0.06	0.20	0.55
Average	**0.60**	**0.09**	**0.30**	**0.98**
%	**60.9**	**8.9**	**30.5**	
75m				
Off Mormugao	0.52	0.19	0.85	1.55
Off Ratnagiri	0.31	0.34	0.20	0.85
Off Mumbai	0.12	0.09	0.13	0.34
Off Veraval	0.08	0.37	0.20	0.65
Off Porbandar	0.26	0.09	0.00	0.35
Average	**0.26**	**0.22**	**0.27**	**0.75**
%	**34.5**	**28.9**	**36.4**	
100m				
Off Mormugao	0.40	0.16	0.20	0.75
Off Ratnagiri	0.08	0.22	0.20	0.49
Off Mumbai	0.11	0.09	0.65	0.85
Off Veraval	0.03	1.12	0.46	1.60
Off Dwaraka	0.16	0.22	0.20	0.57
Average	**0.16**	**0.36**	**0.34**	**0.85**
%	**18.4**	**42.3**	**39.8**	
150m				
Off Ratnagiri	0.05	0.00	0.00	0.05
Off Porbandar	0.03	0.00	0.00	0.03
Off Dwaraka	0.02	0.00	0.13	0.15
Average	**0.04**	**0.00**	**0.04**	**0.08**
%	**46.8**	**0.0**	**54.2**	

Table 9- Meiobenthic biomass (mg/10cm^2) distribution during pos-monsoon season

Depths	Nematodes	Copepods	Miscellaneous group
30 m	72.0	15.6	12.3
50 m	60.9	8.9	30.5
75 m	34.5	28.9	36.4
100 m	18.4	42.3	39.8
150 m	46.8	0.0	54.2

Table 10 - Percentage contribution of meiobenthic groups in different depths

Transects	Depths	Nematodes	Copepods	M.G. *	Total
Mormugao	30 m	0.16	0.00	2.15	2.30
	75 m	0.46	0.00	4.36	4.82
	100 m	5.92	0.00	1.76	7.67
Ratnagiri	30 m	0.60	0.06	2.21	2.87
	75 m	0.26	0.00	1.24	1.50
Off Mumbai	30 m	0.58	0.00	7.02	7.60
	75 m	5.12	1.55	15.67	22.34
Veraval	30 m	1.15	0.34	0.65	2.14
	75 m	0.31	0.40	1.17	1.88
Dwaraka	30 m	0.42	0.34	1.63	2.38
	75 m	0.35	0.06	0.65	1.06
	100 m	0.30	0.00	0.33	0.63
Average		**1.30**	**0.23**	**3.23**	**4.77**
%		**27.3**	**4.8**	**67.8**	

Table 11- Meiobenthic biomass (mg/10 cm^2) distribution during post-monsoon (M.G.* - Miscellaneous group)

Transects	Nematodes	Copepods	Foraminifers	M.G.*	Total
30m					
Off Mormugao	155	0	4	2	161
Off Ratnagiri	135	2	2	5	144
Off Mumbai	600	5	15	0	620
Off Veraval	713	37	12	8	770
Off Porbandar	420	4	12	3	439
Average	405	10	9	4	427
%	94.8	2.2	2.1	0.8	
50m					
Off Mormugao	130	2	3	2	137
Off Ratnagiri	276	4	0	5	285
Off Mumbai	248	3	11	3	265
Off Veraval	137	3	3	10	153
Off Porbandar	86	2	4	3	95
Average	175	3	4	5	187
%	93.8	1.5	2.2	2.5	
75m					
Off Mormugao	154	6	4	13	177
Off Ratnagiri	92	11	3	3	109
Off Mumbai	35	3	3	2	43
Off Veraval	24	12	2	3	41
Off Porbandar	76	3	0	0	79
Average	76	7	2	4	90
%	84.9	7.8	2.7	4.7	
100m					
Off Mormugao	118	5	2	3	128
Off Ratnagiri	24	7	4	3	38
Off Mumbai	32	3	4	10	49
Off Veraval	9	36	5	7	57
Off Dwaraka	47	7	0	3	57
Average	46	12	3	5	66
%	69.9	17.6	4.6	7.9	
150m					
Off Ratnagiri	16	0	3	0	19
Off Porbandar	10	0	2	0	12
Off Dwaraka	7	0	0	2	9
Average	11	0	2	1	13
%	82.5	0.0	12.5	5.0	

Table 12 - Meiobenthic density (No/10 cm^2) distribution during post-monsoon (M.G.* - Miscellaneous group)

Depths	Nematodes	Copepods	Foraminifers	M.G*	Total
30 m	56.7	31.0	44.4	19.7	54.5
50 m	24.6	9.0	20.7	25.2	23.9
75 m	10.7	22.6	11.8	23.0	11.5
100 m	6.5	37.4	14.8	28.5	8.4
150 m	1.5	0.0	8.2	3.6	1.7

Table 13 - Percentage contribution of meiobenthic groups in different depths
M. G* - Miscellaneous groups

Transects	Depths	Nematodes	Foraminifers	Copepods	M.G*	Total
Off Mormugao	30 m	46	12	0	33	91
	75 m	136	34	0	67	237
	100 m	1740	624	0	27	2391
Off Ratnagiri	30 m	177	0	2	34	213
	75 m	77	7	0	19	103
Off Mumbai	30 m	170	0	0	108	278
	75 m	1506	886	50	241	2683
Off Veraval	30 m	338	14	11	10	373
	75 m	91	90	13	18	212
Off Dwaraka	30 m	123	13	11	25	172
	75 m	102	52	2	10	166
	100 m	89	16	0	5	110
Average		**383**	**146**	**7**	**50**	**586**
%		**65.34**	**24.86**	**1.27**	**8.49**	

Table 14 - Distribution of meiobenthic density (No/10 cm^2) during pre-monsoon
M. G* - Miscellaneous groups

	30 m	50 m	75 m	100 m	150 m
Biomass					
Polychaetes	1.1841 (8)	0.4478 (7)	1.6782 (8)	1.1021 (8)	0.5432 (6)
Crustaceans	1.5840 (8)	1.2902 (7)	1.4058 (8)	1.0498 (8)	0.7928 (6)
Molluscs	0.9181 (8)	1.5868 (7)	0.8002 (8)	0.4768 (8)	0.2453 (6)
Others	0.2671 (8)	1.5153 (7)	2.4222 (8)	0	0
Total	0.9426 (8)	0.1568 (7)	2.1625 (8)	0.8501 (8)	1.0104 (6)
Density					
Polychaetes	1.8842 (8)	0.1847 (7)	1.5981 (8)	6.4973 (8)	1.4782 (6)
Crustaceans	1.0106 (8)	0.4817 (7)	2.0775 (8)	0.7676 (8)	1.2390 (6)
Molluscs	1.58 (8)	0.8589 (7)	2.0532 (8)	1.5429 (8)	1.0968 (6)
Others	1.7746 (8)	2.0786 (7)	1.7438 (8)	0	0
Total	1.7209 (8)	1.2604 (6)	1.7981 (8)	9.4887 (8)	1.3558 (6)

Table 15- Seasonal comparison of macrobenthic biomass and density based on Student's *t* test in different depths (Degree of freedom is given in bracket).

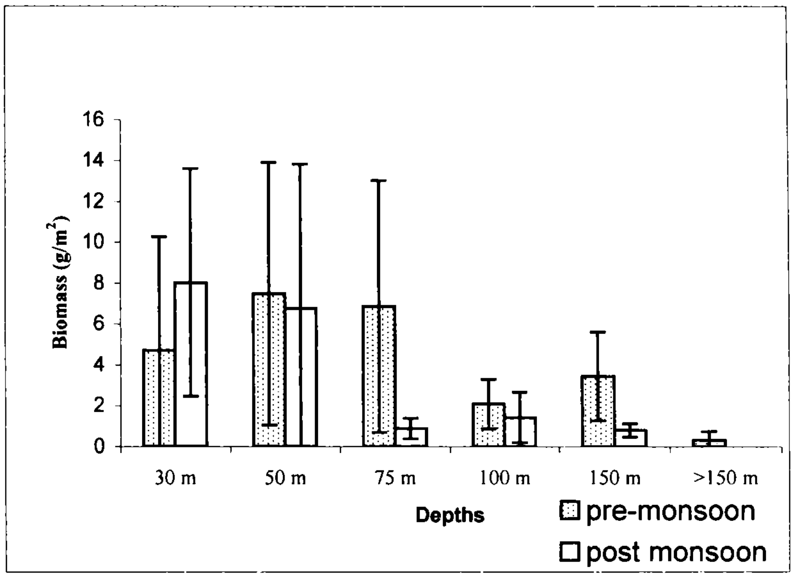

Fig. 25 - Depth wise average biomass of macrobenthos during pre-and post monsoon

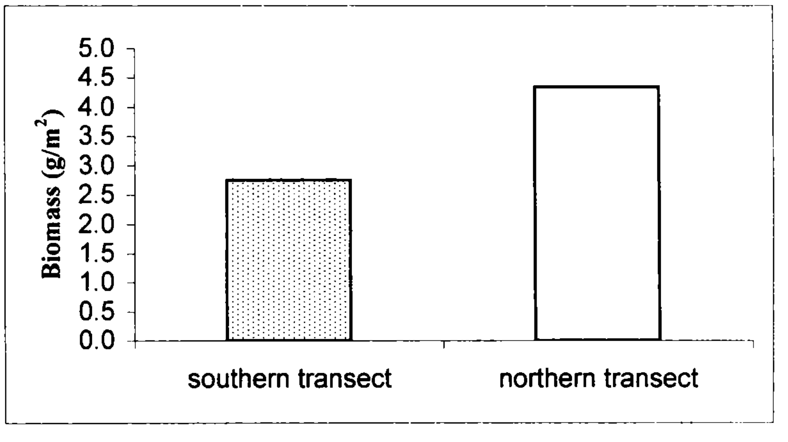

Fig. 26 - North-South transects wise average biomass of macrobenthos during post-monsoon

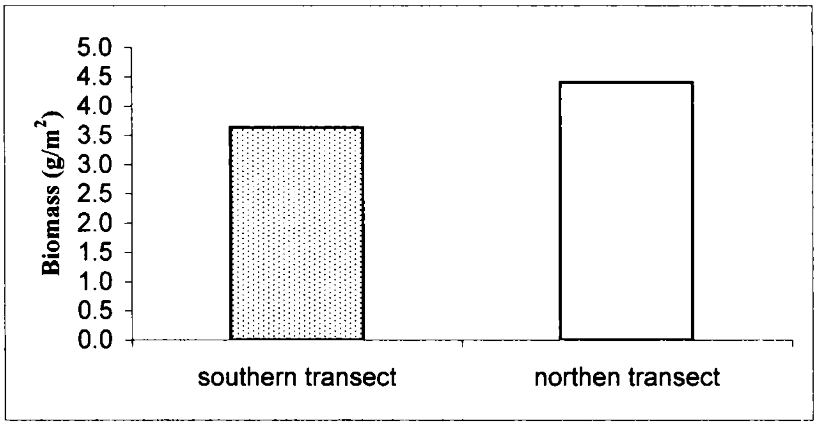

Fig. 27 - North-South transects wise average biomass of macrobenthos during pre-monsoon

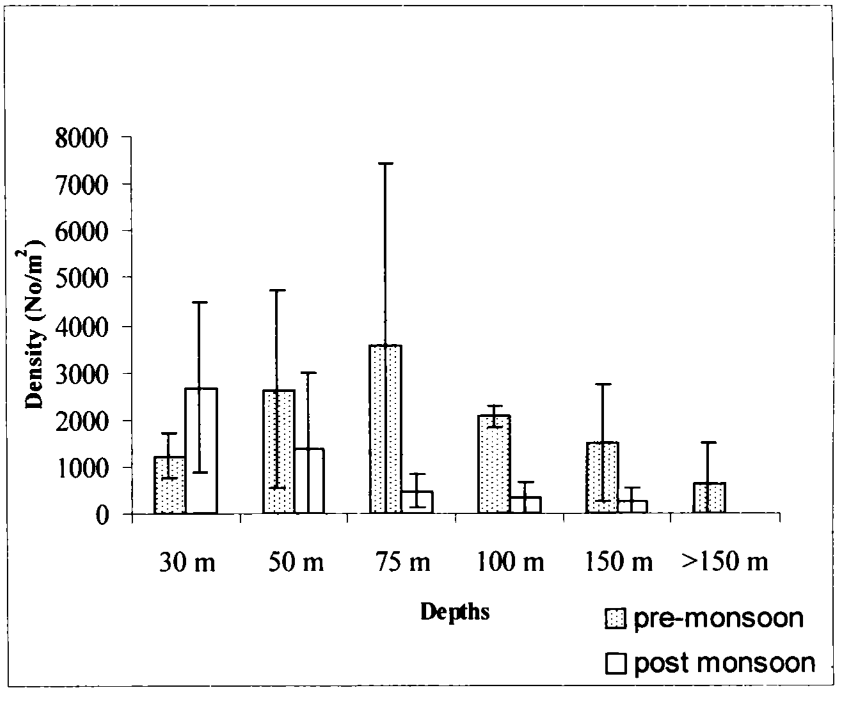

Fig. 28 - Depth wise average density of macrobenthos during pre-and post monsoon

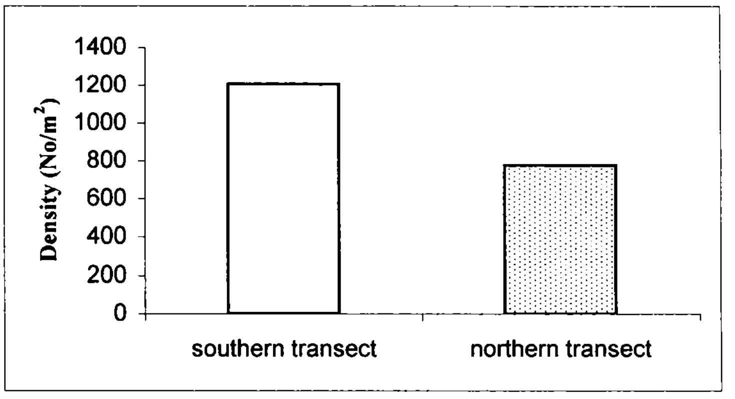

Fig. 29 - North-South transects wise average density of macrobenthos during post-monsoon.

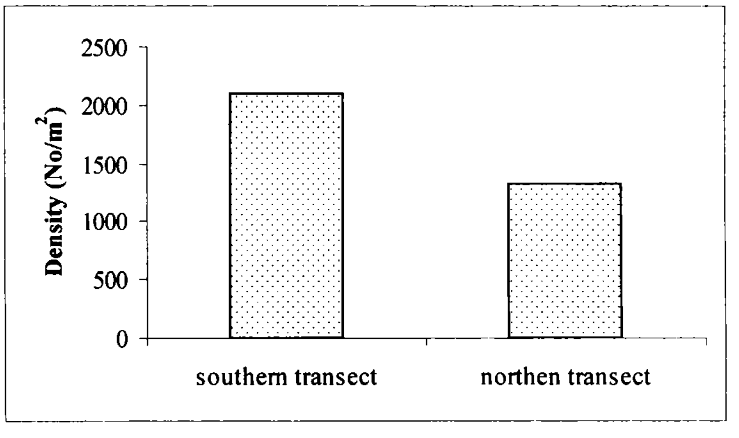

Fig.30 - North-South transect wise average density of macrobenthos during pre-monsoon

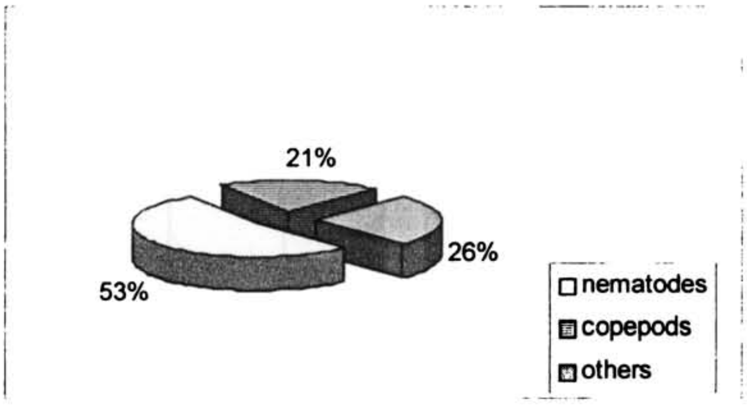

Fig. 31- Percentage contribution of meiobenthic biomass during post monsoon

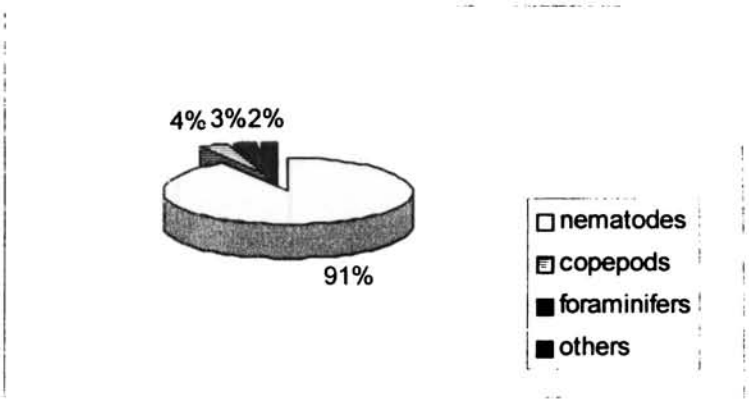

Fig. 32 - Percentage contribution of meiobenthic density during post monsoon

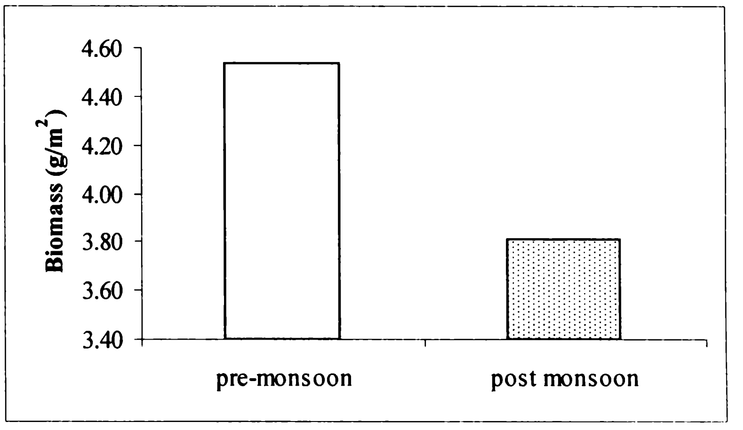

Fig. 33 - Seasonal comparison of macrobenthic biomass

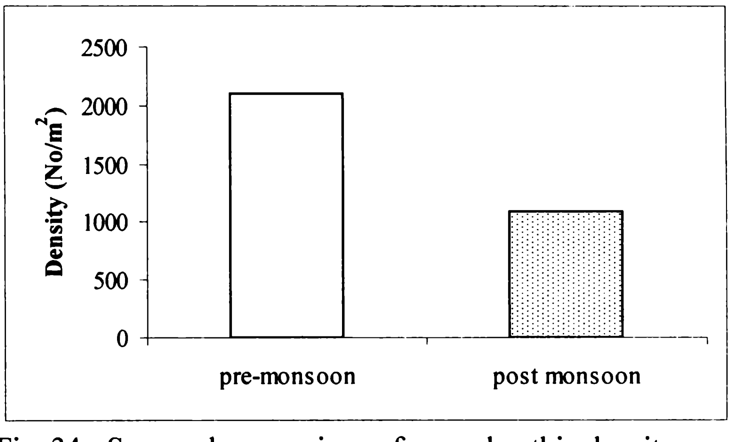

Fig. 34 - Seasonal comparison of macrobenthic density

Chapter 6

Faunal Composition and Community Structure

6.1. Introduction

The ocean is an interesting and least understood dynamic environment with full of bizarre and fascinating biota. This ecosystem is a self-containing world with a complex food chain and many organisms have adapted to the extreme and unusual conditions. About 29 animal phyla are known to inhabit this largest ecosystem of which 14 are exclusively found in marine environment. About 98% of all species are known to exist in coastal and open waters belong to benthos besides to marine microorganisms (Peres, 1982). Benthic ecosystem is the least known ecosystem because of its immensity and inaccessibility.

Along the west coast of India, most of the benthic studies were carried out in the shallow (5-20 m) inshore waters (Kurian, 1971; Damodaran, 1973; Parulekar and

Wagh, 1975; Parulekar *et al*, 1976; Ansari *et al*, 1977; Harkantra and Parulekar, 1981; Devassy *et al*, 1987; Varshney *et al*, 1988; Vizakat *et al*, 1991; Harkantra and Parulekar, 1991&1994; Prabhu *et al*, 1993; Gopalakrishnan and Nair, 1998 and Ingole *et al*, 2002). Parulekar *et al* (1982), Ansari *et al* (1996) have attempted to study the benthos from the deeper depths of Indian EEZ. Later, Joydas (2002) and Sajan (2003) worked on the macro and meiobenthos from the west cost of India respectively.

6.2. Results

Depth wise and transect wise variations in the faunal composition of northwestern continental shelf of India are examined and discussed in this chapter. The description is presented in three parts. The first part deals with results of faunal composition during post-monsoon and pre- monsoon periods. Second part describes the community structure analysis of polychaetes and all groups including polychaetes. Third part of the result deals with the similarity indices for both the seasons.

Based on their occurrence benthic organisms were differentiated into 3 catregories such as 'abundant', 'moderately abundant' and 'rare'. The 'abundant' are those organisms present in more than 75% of the total stations sampled in each depth zone and 'moderately abundant' are those occurred in 25-75% of the stations and the remaining is considered as 'rare'.

6.2.1. Faunal composition

6.2.1.1. Post-monsoon

Fauna composed of polychaetes, crustaceans, molluscs and miscellaneous groups (Plates 5-8). Percentage contribution of each group is given in Fig. 35. Polychaetes constituted 86% followed by molluscs (9%) and crustaceans (4%). Miscellaneous groups formed only 1% to the total population. Other than polychaetes, crustaceans contributed substantially along most transects except off Mumbai and Porbander where molluscs dominated.

Percentage contribution of various polychaete families is presented in Table 16. Polychaetes were composed of errantia (6%) belonging to 10 families and sedentaria (94%) belongigng to 14 families. Eunicidae (2.8%) and Pilagidae (1.2%) were the major families in Errantia. Other important families among errantia were Nephtydae (0.58%), Aphrodite (0.53%), Glyceridae (0.41%) and Pisionidae (0.27%). Among 14 sedentarian families, Spionidae was the dominant one (64.2%) followed by Magelonidae (10.3%), Cirratilidae (5.1%), Cossuridae (5%), Capitellidae (3.6%), Paraonida (2.2%) and Sternaspidae (1.2%). Of the 76 species present during post-monsoon, 25 species belonged to errantia and 51 species to sedentaria.

Depth wise percentage occurrence of polychaete species is presented in Table 17. At 30 m depth zone, 37 species were present of which 8 species were coming under errantia and 29 under sedentaria. Of the 37 species, 6 species were considered as 'abundant' (*Prinospio pinnata, P. polybranchiata, Magelona capensis, Cirratulis cirratus*, *Cossura coasta* and *Capitella capitata)* and 12 were 'moderately abundant' of which *Ancystrosyllis constricta, Lumbrineries aberans, Prinospio cirrifera, Magelona cincta* and *Heteromastus bifidis* were the major ones (i.e., present in more than 50% of the stations). The remaining 19 species were considered as 'rare'. Species contributed more to the total density were *Cossura coasta* (6100/m^2), *Magelona cincta* (5800/m^2), and *Prinospio cirrifera* (5400/m^2).

At 50 m zone altogether 34 species were present, composed of 11 errantia and 23 sedentaria. Among these, 7 were regarded as 'abundant' (*Ancystrosyllis constricta, Prinospio pinnata, P. polybranchiata, P. cirrifera, Cirratulis cirratus, Cossura coasta* and *Capitella capitata*) and 10 species were treated as 'moderately abundant' of which *Lumbrineries aberrans, L. hartmani, Prinospio ehlersi, Magelona capensis, Paraheteromastus tenuis and Sternaspis scutata* were the major ones and 17 were included in the 'rare' catogery. Dominant species were *Magelona cincta* (8000/m^2), *Prinospio sexoculata* (7400/m^2) and *Magelona capensis* (3900/m^2).

At 75 m zone, 59 species were present of which 19 belonged to errantia and 40 to sedentaria. Of the 59 species, 4 were 'abundant' (*Prinospio pinnata, P. polybranchiata, P. cirrifer* and, *Cossura coasta),* and 18 were 'moderately abundant' of which *Ancystrosyllis constricta, Malacoceros indicus, Magelona cincta, Cirratulis cirratus* and *Scolariella dubia* were the important ones and 37 were 'rare'. *Prinospio cirrifera* (1700/m^2), *Malacoceros indicus* (1200/m^2), *Prinospio polybranchiata and Cirratulis cirratus* (1100/m^2each) and *Sthenelais boa* (1000/m^2) were the major contributors to the total density.

At 100 m zone, 27 species were present; of which 8 were from errantia and 19 from sedentaria. Only one species could be considered as 'abundant' in this zone (*Prinospio pinnata*) and 10 species as 'moderately abundant'. Among the moderately abundant species the major ones were *Glycera longipinnis, Lumbrineries hartmani, Prinospio polybranchiata, P. cirrifera, Cirratulis cirratus and Capitella capitata.* Sixteen species were considered as 'rare'. In this zone *Pygospio elegans* (1500/m^2) and *Prinospio polybranchiata* (1300/m^2) were the dominant species.

At 150 m zone, six species were present including one errantia and 5 sedentaria. An exception from the other depth zones, all the 6 species recorded were considered as 'moderately abundant' which includes *Ancystrosyllis constricta, Prinospio pinnata, P. polybranchiata, Cirratulis chrysoderma, Paraonides lyra lyra and Cossura coasta* of which *P. pinnata* and *C. coasta* were the major ones. *C. coasta* (1000/ m^2) is the only species which contributed more to the total density in this zone.

Among the non-polychaete taxa, crustaceans were mainly constituted by decapods and amphipods; molluscs by pelecypods and miscellaneous groups by sipunculoides. Here also occurrence of different groups were categorized to 'abundant', 'moderately abundant' and 'rare'. Percentage occurrence of each group is presented in Table 18.

At 30 m zone, a total of 18 groups/species were found, of which 2 groups were considered as 'abundant' (decapod species and carridian prawns), 6 groups as 'moderately abundant' of which megalopa larvae and sipunculids were major ones and ten groups were considered as 'rare'.

At 50 m depth zone, 14 groups were present, and none could be included in the 'abundant' category, and the only one 'moderately abundant' group/species was bivalve *Tellina sp.* and rest of them were regarded as 'rare'.

At 75 m depth 8 groups were present and 'abundant' group was absent and only one taxa was considered as 'moderately abundant' (caridian prawns) and rest of the 7 groups were included in the 'rare' category.

At 100 m zone 15 groups were present of which 4 were 'moderately abundant' which included cardiun sp., mactra sp., decapod sp. and lobster. Eleven groups were considered as 'rare' and no group occurred as 'abundant'.

At 150 m zone, 4 groups were present of which bivalve *Tellina* sp. was 'abundant' and 3 groups/species (bivalves *Cardium* sp, *Mactra* sp. and *Sunetta scripta*) were 'moderately abundant' and 'rare' species were absent.

6.2.1.2. Pre- monsoon

During pre- monsoon, polychaete contributed 80% followed by miscellaneous groups (7%), crustacean (7%) and molluscs (6%) to the total fauna (Fig. 36). In all transects, molluscs dominated among non-polychaete groups except off Mumbai and Porbander where crustaceans and miscellaneous groups dominated respectively.

Polychaetes were composed of errantia and sedentaria. The former constituted only 28.3% and latter formed 71.7% to the total polychaetes density (Table 19). A total of 33 families were encountered of which errantia comprised of 13 families and sedentaria of 20. Of the 13 errant families Pilargidae (7.8%) and Eunicidae (6.6%) were dominant. Other major families were Syllidae (4.8%), Aphroditidae (4.2%) and

Nephtydae (2%). Among the 20 sedentarians families Cirratulidae contributed maximum (19.7%) to the total density followed by Spionidae (15.2%), Capitellidae (7.2%), Ampharetidae (8.3%), Cossuridae (5%) and Terebellidae (3.6%). Of the total 133 polychaete species encountered, errantia was represented by 43 species and sedentaria by 90 species.

Depth wise occurrence of different polychaetes species is presented in Table 20. At 30 m depth zone, 52 species were present of which 12 species were of errant type and 40 were sedentarian. Of the 52 species, 6 species were considered as 'abundant' (*Ancystrosillis constricta, Lumbrineries hartmani, Prionospio pinnata, P. polybranchiata, Cossura coasta* and *Capitella capitata*) and 21 species were 'moderately abundant' among which *Nephtys dibranchis, Prionospio cirrobranchia, P. cirrifera, Magelona cincta, Ciriformia afer, Heteromastus bifidis, Notomastus fauvelli, Schyphoproctus* sp. and *Sternaspis scutata* were the major ones (present > 50% of the stations). The remaining 25 species can be considered as 'rare'. In this zone, species which contributed more to the total density were *Cossura coasta* (730/m2), *Prionospio pinnata* (600/m2), *P. polybranchiata* (530/m2), and *Sternaspis scutata* (490/m2)

At 50 m zone, 58 species were obtained of which 18 species were errant forms and 40 were sedentarians. Of the 58 species, 8 were 'abundant' (*Ancistrosyllis constricta, Nephtys dibranchis, Lumbrineries aberrans, Prinospio pinnata, P. polybranchiata,, Cossura coasta, Capitella capitata and Sternaspis scutata*) and 50 were 'moderately abundant' of which *Glycera longipinnis, Lumbrineries hartmani, Prinospio cirrobranchiataa, P. cirrifera, Magelona cincta, Cirratulis cirratus, Cirriformia afer, Paraonides lyra lyra , Aricidea fauveli, Notomastus abberans, Paraheteromastus tenuis, Amphictius gunneri,* and *Etione* sp. were the major ones and no species could be considered as 'rare'. In this depth zone *Ancistrosyllis* *constricta* (920/m2), *Prionospio pinnata (820/m2), Cirratulis afer (1810/m2)* were the dominant species.

At 75 m zone a total of 72 species were present, among which errantia constituted 26 species and sedentaria 46 species. Of the 72 species, 10 species were considered as 'abundant' which included *Ancistrosyllis constricta, Prionospio pinnata, P. cirrobranchia, P. cirrifera, Magelona cincta, Cirratulis cirratus, Cirriformia afer, Cossura coasta, Maldane sarsi,* and *Amphicteis gunneri.* In the 'moderately abundant' group, 18 species were noticed of which *Nephtys dibranchis, Gonioda emerita, Lumbrineries hartmani, Prinospio polybranchiata* and *Capitella capitata* were the major ones. The 'rare' ones included 44 species. In this zone *Cirratulis cirratus* (1710/m2) and *C. chrysoderma* (1280/m2) were the dominant species.

At 100 m zone, a total of 66 species were recorded, errantia constituted by 24 species and sedentaria represented by 42 species. Of the total 66 species, 9 species were regarded as 'abundant' which included *Ancistrosyllis constricta, Prionospio pinnata, P. cirrifera, Magelona cincta, Cirratulus cirratus, Tharyx* sp., *Capitella capitata, Notomastus aberans,* and *Amphicteis gunneri.* Nine species were 'moderately abundant' (*Nephtys dibranchis, Prionospio cirrobranchiata, Cirriformia afer, Cossura coasta, Syllis spongicola, Lumbriconeries aberrans, L. hartmani, Heteromastides bifidus* and *Maldane sarsi*), and as many as 48 species were found to be 'rare'. Species such as *Notomastus aberrans (1110/m2), Cirratulus cirratus (800/m2), Prinospio pinnata (560/m2)* and *Ancistrocyllis constricta (660/m2)* contributed more to the total density.

At 150 m depth zone, only two stations could be sampled and 39 species were present of which 12 belonged to errantia and 27 to sedentaria. Of the 39 species encountered in this zone, only one species, *Cossura coasta* was considered as 'abundant' and 38 species were 'moderately abundant' of which *Ancistrocyllis constricta, Syllis spongicola, Prinospio pinnata, Magelona cincta, Cirratulis cirratus, Notomastus fauveli, Amphicteis gunneri* were the major ones and no species could be included in the 'rare' category. Dominant species were *Amphicteis gunneri* (490/m^2) and *Ancistrosyllis constricta* (390/m^2).

In >150 m zone, 15 'moderately abundant' species were present of which 4 were coming under errantia and 11 under sedentaria. *Lepidonotus carinulatus* (290/m^2) and *Syllis spongicola* (160/m^2) were the dominant species at this depth zone.

Non-polychaete taxa included crustaceans, molluscs and miscellaneous groups. Among the crustaceans, amphipods constituted more in number followed by decapods and isopods; among the molluscs, gastropods were numerically abundant followed by pelecypods and in the miscellaneous group, sipunculids were the major taxa. As that of polychaetes, non-polychaete taxa is also divided into 3 categories viz, 'abundant', 'moderately abundant' and 'rare'. Percentage occurrence of these groups in different depth zones is given in Table 21.

At 30 m zone, a total of 20 groups/species were present of which crustaceans consisted of 8 taxa, mollusc and miscellaneous group of 6 taxa each. In this depth, only sipunculids were considered as 'abundant'. Ten groups/species included in the 'moderately abundant' category in which amphipod *Eriopisa chilkensis* and gastropod *Nassarius* sp. were the major ones. Nine groups were considered as 'rarely' occurring.

At 50 m zone, 15 groups/species were present of which crustaceans consisted of 6 groups/species, molluscs of 5 group/species and miscellaneous group of 4. Among the 15 groups/species, 3 occurred abundantly (amphipod *Eriopisa chilkensis*, sipunculoids and nemertene worms). Twelve groups/species were moderately occurring in which crabs, bivalves *Mactra* sp. and *Tellina* sp., were the major ones and no taxa was included in the 'rare' category.

At 75 m zone, 31 groups/species were present of which 3 were 'abundant' such as decapod larvae, amphipod *Eriopisa chilkensis* and sipunculids. Thirteen groups/species were 'moderately abundant' of which amphipod *Grandidierella gilesi*, species of Anthurid, bivalve *Sunetta scripta*, oligochaetes, nematods and nemertene worms were the major ones. Fifteen groups/species were considered under 'rare' category.

At 100 m zone, 41 groups/species were present of which 5 were 'abundant' (decapod larvae, amphipod *Grandidierella gilesi,* gastropod *Nassarius* sp., nematodes, and sipunculids) and 17 were moderately occurring of which *Atys* sp. and olygochaetes were important ones and 19 groups/species were considered as 'rare'. At 150 m zone, 28 groups/species werepresent of which 2 (decapods an nematodes) were abundant and 26 were moderatly abundant. Beyond 150m depth, 9 groups/species were presnt and all were moderatly abundant.

6.2.2. Community structure

6.2.2.1. Post-monsoon

6.2.2.1.1. Community structure of Polychaetes

Community structure indices of polychaete species (Table 22) in the study area varied from 1 to 41. More number of species as well as higher abundance was observed in the southern transects where number of species varied from 4 to 41 and abundance (density) varied from 80 to 4730 /m^2 compared to the northern transect stations where species number varied from 1 to 23 and abundance varied from 30 to 3860/ m^2.

6.2.2.1.1.1. Species richness (Margalef's index, d)

Depth wise average of community structure indices based on polychaete species during post-monsoon season is presented in Fig. 37. Average values of species richness increased from 30 m to 75 m and then decreased (Fig. 37a). In southern transects, relatively high richness was observed and Margalef index varied between 0.68 and 5.85 and in northern transects generally lower richness was observed which varied between 0.29 and 2.88 (Table 22). Transect wise richness in different depth zones presented in Fig. 38 showed that at 30 m zone richness was fluctuating transect wise and highest richness was observed off Veraval followed by Ratnagiri and lowest off Porbandar. At 50 m zone, richness first increased up to off Mumbai then decreased to Porbandar with highest richness off Mumbai and off Veraval, and lowest off Mormugao. At 75 m depth zone, high richness was observed in the southern transect stations and low in the northern transect stations. Maximum richness was observed off Ratnagiri from where richness decreased towards the north and minimum richness was observed off Porbandar. At 100 m depth zone species richness decreased towards north except off Dwaraka where a slight increase was observed. Highest value was observed off Mormugao and lowest off Veraval. At 150 m depth also, even though, richness was low, high value was observed off Ratnagiri and low value off Porbandar and no richness was observed off Dwaraka. In general, comparatively high richness was observed in the southern transect especially after 50 m depth.

6.2.2.1.1.2. Evenness (Heip's index, J')

Depth wise average values in the study area showed that (Fig. 37b) evenness was generally increasing from 30 m to 75 m depth then decreased however high evenness was observed at greater depths beyond 50 m. Evenness in the southern transects showed a higher uniformity in the distribution of individual organisms among the various species and ranged between 0.21 and 0.96 (Table 22). Uniformity observed was close to the maximum uniformity at most of the stations. In northern transects also a closeness to the maximum uniformity in the distribution of total abundance among various species was observed and evenness ranged from 0.48 to 0.98. In the study area average evenness was 0.78 with very low variation (C. V. %= 28.15%). Evenness distribution in different depth zones showed that (Fig. 39), at 30 m zone, evenness increased to north with lowest value off Mormugao and highest off

Porbandar. At 50 m depth zone, fluctuating results were observed with lowest value off Veraval and highest off Mumbai. At 75 m depth zone, generally high evenness was observed with an increasing trend towards north. Lowest value was observed off Mormugao and highest off Veraval and Porbandar. At 100 m zone, comparatively high evenness was observed with the lowest value off Mormugao and highest off Dwaraka. At 150 m zone, high evenness was noticed off Ratnagiri and low values were recorded off Porbandar. Comparison with off Dwaraka was not possible due to the occurrence of only single species. In general evenness was fluctuating however, high evenness was observed in the northern transect (Off Dwaraka).

6.2.2.1.1.3. Diversity (Shannon index, H')

Average values showed that diversity generally increased up to 75 m and then decreased with a drastic fall in 150 m zone (Fig. 37c). Regarding the species diversity, a pattern similar to species richness was obtained. Diversity and ranged between 0.7 and 4.92 in the southern transects (Table 22) and in the northern transects, at all stations diversity was less than that of southern transects but more stable and ranging between 0.92 and 3.38. For the study area average diversity obtained was 2.53 with very low spatial variation (C. V. % = 47.63%). Diversity distribution in different depth zones showed (Fig. 40) fluctuating results at 30 m depth zone, however high values observed in northern transect with lowest diversity off Mormugao and highest off Veraval. At 50 m depth, even though diversity was fluctuating, comparatively high value was observed in the southern transect. At 75 m depth zone, diversity decreased towards north. Highest diversity was observed off Ratnagiri and lowest off Porbandar. At 100 m depth also, a decreasing trend was observed towards north except a high value off Dwaraka. Highest diversity was recorded off Mormugao and lowest off Veraval. At 150 m depth zone, high diversity was observed off Ratnagiri and low off Porbandar and no diversity off Dwaraka due to the presence of single species. In general, diversity in different depth zones showed a general decrease towards north beyond 50 m depth.

6.2.2.1.1.4. Dominance (Pielou's index)

Average values showed that dominance was decreased from 30 m to 75 m depth then it increased to deep with highest value at 150 m depth (Fig. 37d). Very low species dominance was observed in the southern transects (ranged from 0.04 to 0.82) in most of the stations whereas in the northern transects, most of the stations comparatively higher values were noticed (ranged from 0.1 to 1.0) thus showing an inverse relationship with species richness and diversity in general. Species dominance was very low (X = 0.31) with high spatial variation (C.V. %= 82.43%). Dominance at different depth zones showed that (Fig. 41) at 30 m zone, eventhough dominance was fluctuating with transect, relatively high dominance was observed in south and decreasing to north with off Mormugao having highest value followed by off Mumbai and lowest off Veraval. At 50 m zone, it was fluctuating with comparatively high dominance off Veraval and low off Mumbai. At 75 m depth, a slight increase in dominance was observed towards north with minimum value found off Ratnagiri and maximum value off Porbandar. At 100 m zone, a similar trend was observed with an increasing dominance towards north except off Dwaraka. Lowest dominance was observed off Mormugao and highest off Veraval. At 150 m depth zone, an increasing trend was noticed towards north as that of 75 m and 100 m zone with lowest dominance observed off Ratnagiri and highest off Dwaraka. The dominance observed off Dwaraka was due to the presence of a single species. In general increased dominance was observed in the northern transect.

6.2.2.1.2. Community structure of groups

Community structure of groups showed that number of groups varied from 1 to 10 with benthic abundance of 40 to 4820. In the southern transects number of species varied from 1 to 10 and density varied from 90 to 4820/m^2 and in the northern transects number of species varied from 2 to 7 and density varied from 40 to 4100/m^2.

6.2.2.1.2.1. Richness (Margalef's index, d')

Community structure based on groups is presented in Fig. 42. Depth wise average values showed (Fig. 42a) high richness in the shallow depth zone (30 m) and decreasing gradually to deeper zone (150 m). Richness in the southern transects varied from 0.14 to 1.08 and in the northern transects it varied from 0.15 to 0.72 (Table 23). Transect wise richness in various depth zones showed that (Fig. 43) at 30 m zone, richness was fluctuating with highest value off Ratnagiri and lowest off Mumbai. At 50 m depth zone also it was fluctuating with comparatively high richness off Ratnagiri and Veraval, and low values off Porbandar and Mumbai. At 75 m depth zone, comparatively high richness was noticed in the northern transect station and highest value was observed off Veraval and lowest off Ratnagiri. Here a deviation from the previous depth zones noticed (30 m and 50 m), was the low richness off Ratnagiri. At 100 m depth zone, richness was low in most transects except for a high value off Mormugao, and from off Ratnagiri a general increase was observed towards north. At 150 m depth zone, richness decreased towards north with highest value recorded off Ratnagiri and lowest off Dwaraka. In general, at 75 m and 100 m depth zones, high richness was observed in northern transects while at 150 m depth zone, reverse trend was noticed and at rest of the depth zones the trend was fluctuating.

6.2.2.1.2.2. Evenness (Heip's index, J')

Depth wise average values showed that evenness was more in the deeper depth stations especially at 100 m and low in the shallow depths with lowest value observed at 30 m (Fig. 42b). Evenness in the southern transects varied from 0.07 to 0.61 and in the northern transects it varied from 0.14 to 0.83 (Table 23). Transect wise evenness distribution in various depth zones is presented in Fig. 44. At 30 m depth zone, evenness was fluctuating with comparatively high values at northern transect station especially off Veraval and low evenness in southern transect stations especially off Mormugao. At 50 m depth, comparatively high values were recorded off Mumbai and Ratnagiri and low evenness in the rest of transects. At 75 m depth zone, comparatively high evenness was observed off Veraval and low off Ratnagiri. Due to the presence of a single species no evenness could be calculated off Mormugao. At 100 m depth zone a general increase in evenness towards north with highest value off Dwaraka and lowest off Mormugao. At 150 m depth zone, evenness was more off Porbandar and low off Dwaraka and Ratnagiri. In general high evenness was observed in the northern transect stations.

6.2.2.1.2.3. Diversity (Shannon index, H')

Depth wise average values showed that diversity increased towards deeper zones with minimum value at 30 m depth zone and maximum at 100 m zone (Fig. 42c). In the southern transects diversity varied from 0.08 to 1.25 and in the northern transects it varied from 0.19 to 1.40 (Table 23). Diversity distribution in various depth zones is presented in Fig. 45. Transect wise diversity showed that, at 30 m depth zone, it was fluctuating with comparatively high value off Veraval and low off Mumbai. In 50 m depth zone also fluctuating trend was observed. High diversity was recorded off Ratnagiri and it decreased towards north and minimum diversity was observed off Porbandar. At 75 m depth zone, comparatively high diversity was observed at north with maximum value off Veraval and minimum off Ratnagiri. No diversity could be calculated off Mormugao due to lack of non-polychaete taxa. At 100 m depth zone, diversity reduced from off Mormugao to off Mumbai then increased to off Dwaraka with highest diversity recorded off Dwaraka and lowest off Mumbai. At 150 m depth zone, diversity was more off Porbandar and low off Dwaraka and Ratnagiri. In general, diversity among different transects fluctuated however, northern transects recorded comparatively higher diversity.

6.2.2.1.2.4. Dominance index (Pielou's index, λ')

Depth wise average values showed that dominance generally decreased to deep with maximum value at 30 m depth zone and minimum at 100 m zone (Fig. 42d). Dominance in the southern transects varied from 0.59 to 1.0 and in the northern transects stations it varied from 0.45 to 0.94 (Table 23). Transect wise dominance distribution in various depth zones is presented in Fig. 46. At 30 m depth zone, high dominance was observed at most transects, especially in the southern transects with maximum dominance off Mumbai and minimum off Veraval. At 50 m depth zone, dominance was fluctuating, with highest value observed off Mormugao and Porbandar and lowest off Ratnagiri. At 75 m depth zone, high dominance was observed at southern transects and low in the northern transects. Highest dominance was observed off Mormugao (due to a single group, polychaete) and lowest off Veraval. At 100 m depth zone also, high dominance was observed in the southern transects and low in the northern transects. Maximum value was observed off Mumbai and minimum off Dwaraka. At 150 m depth zone, more or less similar dominance was observed with a slight decrease off Porbandar. In general dominance was more in the southern transect stations than northern transect stations.

6.2.2.2. Pre-monsoon

6.2.2.2.1. Community structure of Polychaetes

Community structure indices of polychaete during pre-monsoon season (Table 24) showed that number of species varied from 7 to 50 and abundance varied from 290 to 8825in the southern transects. More number of species as well as higher abundance was observed in the southern transects. In the northern transect stations least number of species observed and it varied between 1 to 34 and abundance varied from 50 to 1700.

6.2.2.2.1. 1. Species richness (Margalef's index, d)

Depth wise of average species richness at different depth zones based on average values is presented in Fig. 37a. Average values showed that richness was more in the 75 m followed by 100 m zones and low in the other depth zones and drastically reduced beyond 150 m. Species richness varied from 0.89 to 5.39 in the southern transect and 0.19 to 4.55 in the northern transects (Table 24). Average richness for the study area was 2.67 with high variability of 464.36%. Transect wise species richness at each depth zones is presented in Fig. 38. At different depth zones, richness was generally more in the northern transect stations and northward increase in the species richness was obvious in the 30 m depth zone. In 50 m zone, transect wise trend was fluctuating with high values off Mormugao and Mumbai and low off Ratnagiri. In 75 m zone, Ratnagiri recorded high species richness and off Mumbai the lowest. At 50 m and 75 m depth zones even though species richness was fluctuating, comparatively high average values were observed in the northern transect stations. At 100 m zone, a northward increase was observed and at 150 m zone, only 3 observations were made and richness fluctuated with relatively high value off Dwaraka. In >150 m zone, since only two observations were done no comparison was possible. Generally during this season northern transect stations recorded high species richness especially at 30 and 100m depths.

6.2.2.2.1. 2. Evenness index (Heip's index, J')

Average values showed high evenness in the lower depths and a general decrease towards deeper depths with highest value at 30 m and lowest at >150 m (Fig. 37b). Species evenness was more consistent in the southern transect with least value of 0.64 and highest value of 0.95 (Table 24). Since this index measures the closeness to maximum evenness, it could be stated that stations with highest evenness value, distribution is more close to the maximum uniformity. In the northern transects, this index varied between 0.28 and 0.90. Average evenness in the in the study area was 0.73 which is also high indicating a less dominance tendency for Polychaetes species. Since Heip's index varied over a large scale, the spatial variation was very high (C. V. %=462.77%). Transect wise evenness distribution in each depth zones (Fig. 39) showed that at 30 m zone, evenness was fluctuating with highest value off Ratnagiri and lowest off Mormugao. At 50 m depth zone also evenness was fluctuating as that of previous zone and high evenness was observed off Ratnagiri and low off Mormugao. At 30 m and 50 m zones, even though trend was fluctuating, average values showed comparatively high evenness in the northern transect stations. At 75 m zone also evenness was fluctuating with comparatively high evenness observed in the northern transect stations than southern transect stations. Maximum evenness was observed off Veraval and minimum off Mumbai. At 100 m zone, northern latitude stations observed comparatively high evenness and southern transect stations off Mormugao and Ratnagiri had low evenness. At 150 m zones, high evenness was observed off Mumbai and Porbandar but low off Veraval. Beyond 150 m depth, only 2 observations made, and no comparison was possible. In general, at most of the depth zones comparatively high evenness was observed in the northern transect stations.

6.2.2.2.1.3. Species diversity (Shannon index, H')

Depth wise average diversity for polychaete species (Fig. 37c) showed that it was generally high from 30 m to 100 m depth zones and beyond 100 m zone diversity reduced sharply with maximum diversity at 75 m. Species diversity showed a more consistent pattern of distribution in southern transects than northern transects (Table 24). In the southern transects it ranged between 1.84 and 4.35. In the northern transects relatively high diversity was observed in most of the stations than southern transects and it varied from 0.28 to 4.38 and showed a more patchy distribution (Table 24). Average diversity for the study area was 3.14 with high spatial variation (C. V. % =463.43%). Transect wise diversity distribution in each depth zones is given in Fig. 40. At 30 m zone a gradual increase towards north was observed with minimum diversity off Mormugao and maximum off Dwaraka. At 50 m depth zone, more or less similar diversity was observed in most transects with high value off Mumbai and exceptionally low value off Ratnagiri. At 75 m depth zone, diversity was fluctuating along transects and maximum diversity was observed off Ratnagiri and minimum off Mumbai. At 100 m zone, a general increasing trend was noticed towards north with lowest value off Mormugao and highest off Veraval. At 150 m zone also northern latitude station (off Dwaraka) recorded maximum diversity. Exceptionally low diversity met with off Veraval as an exception from the previous zone. At >150 m zone only two observations were made, and no comparison was possible. In general northern transect stations recorded more species diversity in most of the depth zones.

4.2.2.2.1. 4. Species dominance (Pielou's index, Lambda')

Depth wise average values showed that, more or less similar dominance up to 100 m and beyond that high dominance was observed (Fig. 37d). Pielou's index, which measures the probability for two organisms selected at random to come from the same species showed that at stations with higher diversity, simpson's index is very low. In the southern transects dominance was low and varied from 0.08 to 0.37 whereas in the northern transects, it was high and varied from 0.07 to 1.0 (Table 24). In the study as a whole, dominance was 0.2344, which again was highly varying with space. (C. V. = 475.1%). Transect wise dominance at different depth zones showed that (Fig. 41) at 30 m zone, fluctuating trend was observed with high value off Mormugao and low value off Dwaraka. At 50 m zone, more or less similar dominance was observed except off Mumbai where lowest dominance was observed. At 75 m zone, generally low dominance was observed with comparatively high value off Mumbai and low values off Ratnagiri and Dwaraka. At 100 m depth zone generally a northward decrease was observed with highest value off Mormugao and lowest off Veraval. At 150 m zone, a fluctuating trend was observed with high value off Veraval and low value off Dwaraka and >150 m zone only two observations were made and therefore no comparison was possible. In general, during pre- monsoon, no regular transect wise trend was observed.

4.2.2.2.2 Community structure based on groups

Community structure for groups (Tale 25) showed that number of groups varied from 2 to 13 in the southern transects and 1 to 13 in the northern transects and density varied from 570 to 10090 in the southern transects and 10 to 2430 in the northern transects.

6.2.2.2.2.1. *Richness (Margalef's index, d)*

Depth wise average richness based on groups is presented in Fig. 42a. Group wise richness showed slightly different trend as that of species richness with high average richness in the deeper depth except at >150 m. Group richness in the southern transects varied from 0.12 to 1.53 and in the northern transects it varied from 0.7 to 1.61 (Table 25). Transect wise richness in different depth zones is presented in Fig. 43. Results showed that at 30 m zone, richness was more in the northern transect stations than in the southern transect stations and the highest value was observed off Dwaraka and lowest off Mumbai. At 50 m zone, with an exceptional low value off Mormugao, richness decreased from off Ratnagiri to veraval. At 75 m depth, richness was fluctuating with maximum value observed off Mumbai and minimum off Veraval. Average values showed more or less similar richness in the southern and northern transect stations at this depth zone. At 100 m depth zone, richness was more in the northern transects than in the southern transects with lowest value off Mormugao and highest off Dwaraka. At 150 m depth, comparatively high richness was observed off Mumbai and low off Dwaraka with a general decrease towards north. Below 150 m depth no comparison was possible due to insufficient observation. Generally, at 30 m and 100 m depth zones, richness was more in the north and in 50 m and 150 m it was more in south and at 75 m zone it was more or less similar in northern and southern transects.

6.2.2.2.2.2. *Evenness (Heip's index, J')*

Evenness was low in shallow depths and comparatively high evenness was observed beyond 75 m depth zone (Fig. 42b). Evenness in the southern transects varied from 0.04 to 0.69 and in the northern transects it varied from 0.27 to 0.81 (Table 25). Transect wise evenness distribution in different depth zones showed that (Fig. 44) at 30 m depth zone, slightly higher values were observed off Mormugao, and Ratnagiri and low values in the rest of transects. At 50 m depths, fluctuating results were observed, with high value off Ratnagiri and low values off Mormugao.

Average values of northern and southern transect stations showed more or less similar values in both areas. Low evenness was observed at 75 m depth zone, with comparatively high values in the northern transect stations. In 100 m zone, fluctuating trend was observed, and average values showed comparatively high evenness in the northern transect stations. At 150 m zone, evenness varied with transects and comparatively high value was observed off Veraval and low value off Dwaraka and off Mumbai. In >150 m zone, no comparison was possible due to insufficient observation. In general, no regular transect wise trend was observed.

6.2.2.2.2.3. Diversity (Shannon index, H')

Depth wise average values showed that diversity was more in the deeper depth zones with highest value in 150 m zone and lowest in 50 m zone (Fig. 42c). Diversity in the southern transects varied from 0.04 to 2.27 and in the northern transects it varied from 0.71 to 2.26 (Table 25). Transect wise diversity distribution in different depth zones showed that (Fig. 45) at 30 m depth zone, generally northern transect stations have comparatively high diversity than southern transect stations however, maximum (off Ratnagiri) and minimum (off Mumbai) values met with southern stations only. At 50 m zone, with an exceptionally low diversity observed off Mormugao, generally diversity decreased to north with minimum value off Mormugao and Dwaraka and maximum off Ratnagiri. At 75 m depth zone, northern transect generally noticed higher diversity and southern transect low diversity with an exceptional high diversity off Mormugao. Lowest value was found off Mumbai and highest value off Dwaraka. At 100 m depth zones, with an exceptional high diversity observed off Mumbai, diversity increased towards north. Minimum diversity was observed off Mormugao and maximum off Mumbai. At 150 m depth zone, diversity was fluctuating and maximum was observed off Veraval and minimum off Dwaraka. At >150 m zone, no comparison was possible due to insufficient samples. In general, northern transect showed more diversity as that of species.

6.2.2.2.4. Dominance (Pielou's index)

Depth wise average values showed that dominance was low at 100 m and 150 m and high in the rest of the depth zones, especially at 50 m zone (Fig. 42d). Dominance in the southern transects varied from 0.31 to 0.99 and in the northern transects it varied from 0.29 to 1.0 (Table 25). Transect wise dominance recorded in different depth zones showed that (Fig. 46) at 30 m depth zone, fluctuating trend was observed with maximum dominance off Mumbai and minimum off Ratnagiri. At 50 m depth zone also, fluctuating trend was observed with high dominance observed off Mormugao and Dwaraka and low off Ratnagiri. In both these depth zones (30 m and 50 m), minimum dominance was observed off Ratnagiri. At 75 m depth zone, dominance was fluctuating. It increased up to off Mumbai then decreased to off Dwaraka. Minimum value was observed off Dwaraka and maximum value off Mumbai. At 100 m depth zone, southern latitude stations of Mormugao and Ratnagiri noticed higher dominance and rest of transects have low dominance. Highest dominance was observed off Mormugao and lowest off Mumbai. At 150 m depth zone, only three observations were made and no regular trend was observed with highest dominance off Dwaraka and lowest off Veraval. At >150 m depth zone, no comparison was possible due to reduced number of observations. Generally no regular transect wise trend was observed for dominance.

6.2.2.3. Seasonal comparison

The composition of Macrobenthos showed that during both seasons polychaetes were dominated with 86% during post-monsoon and 80% during pre-monsoon. Crustaceans increased from post-monsoon (4%) to pre- monsoon (6%), molluscs decreased from 8% to 5% during the post-monsoon and pre- monsoon seasons respectively. The miscellaneous group showed a drastic change between the two seasons, during post-monsoon it was 0.7% and increased to 8% during pre-monsoon. Generally during post-monsoon, groups/species were low in all the depth zones. During both the seasons sedentarians showed major contribution over errant type. Of the total 166 species of polychaetes identified from the study area during two seasons, sedentarian polychaetes consisted of 106 species and errant type were low in number represented by 60 species. During post-monsoon *Prionospio pinnata* was an 'abundant' species in all depth zones except at 150 m zone where it was 'moderately abundant' while in pre monsoon, *Ancystrosillis constricta* and *Prionospio pinnata* were considered as 'abundant' species in all depth zones, except at 150 m and >150 m zones. *Cossura coasta* was abundant upto 75 but beyond that moderately or rarely abundant during both season. Altogether only 8 species were considered as 'abundant' out of 76 species during post-monsoon whereas 17 polycheate species were 'abundant' out of 133 species during pre- monsoon.

During post-monsoon altogether 23 families were present of which 9 families belonged to errantia and 14 families to sedentaria. During pre- monsoon 34 families were observed in which errantia was composed of 11 families and sedentaria of 23. Among errantia, major families were Eunicidae and Pilargidae. During post-monsoon Eunicidae showed dominance over Pilargidae while during pre-monsoon, Pilargidae dominated the Eunicidae. Among sedentarians, during post-monsoon there was a distinct dominance of Spionidae over other families but in pre- monsoon Cirratulidae contributed more followed by Spionidae.

Among non-polychaete group, the 'abundant' groups/species were less in number during both seasons. Crustaceans constituted mainly by decapods followed by amphipods during post-monsoon where as amphipods dominated during pre-monsoon. Among molluscs, pelecypods were more followed by gastropods during post-monsoon and the trend was reversed during pre- monsoon. In miscellaneous group, sipunculids were comparatively high in number during post-monsoon, while during pre- monsoon sipunculids and nematods were the major taxa.

Statistical analysis showed that seasonal difference was observed in different depths and it varies with depth. In 30 m depth, evenness, diversity and dominance ictors for polychaete and groups were significantly different between two seasons Table 26 a& b) but at 50 m community structure indices remain same in two seasons p>0.05). At 75 m zone, richness and evenness have significant difference between he two seasons for polychate species and groups. At 100 m depth zone, richness and venness of polychaete; richness and diversity of group were significantly differed rom the post-monsoon. But at 150 m depth zone no significant difference was bserved in biotic parameters.

.2.3. Similarity indices

Bray-Curtis (1975) similarity index was applied based 4th root transformed ata for grouping of stations based on density of polychaetes and total bethic fauna ermed as group similarity) and grouping of polychaete species and benthic groups or post-monsoon and pre-monsoon season.

.2.3.1. Post-monsoon

Grouping of stations based on polychaete density during post-monsoon season howed 4 clusters of stations at 40% similarity (Fig. 47). Cluster 1 and 2 consist of 2 tations each, cluster 3 of 8 stations and cluster 4 consisted of 3 stations. The cluster formed based on abundance of polychaete and common species were *Sthenelais* *va*, *Nephtys dibranchis*, *Prinospio cirrifera*, *P. polybranchiata*, *Magelona cincta*, *M. capensis*, *Cirratulus chrysoderma*, *C. cirratus*, *Scolaricia dubia* and *Capitella capitata*. In cluster 2, species occur together were *Anciystrosyllis constricta*, *Malacocirus indicus*, *Prinospio cirrifera*, *Cirratulus afer* and *Cossura coasta*. In cluster 3, major species were *Prionospio pinnata*, *P. cirrifera, Cirratulus cirratus* and *Cossura coasta*. In cluster 4 common species occurring were *Prinospio cirrifera*, *P. polybranchiata* and *P. pinnata*.

For benthic groups, all the stations were linked at 40 % similarity (Fig. 48). At higher levels of similarity (>60%) 3 clusters were formed, cluster 1 grouped at 68% similarity, cluster 2 formed at 70 % similarity and had 2 sub clusters, one formed at

% similarity, second one at 78%. Subcluster 1 form 2 subclusters, one at 95% similarity and other at 100% similarity. Cluster 3 formed at 60% similarity and having 2 subclusters, subcluster 1 formed at 68% and subcluster 2 at 66% similarity. Station 'N23' is highly dissimilar from other stations in its pattern of distribution of benthic groups. Clusters 1 was formed based on the distribution of polychaete, pelecypods, decapods, amphipods and sipunculids. Cluster 2 formed mainly on the abundance of pelecypods and in this cluster polychaetes are low in number. Cluster 3 formed mainly based on the depth as a major factor as most of the stations were shallow depth stations.

Bray-Curtis similarity index applied on grouping the polychaete species into 9 distinct clusters at 40% similarity level (Fig. 49). Cluster 1 consisted of 3 species (*Pygospio elegans*, *Glycinde kameruniana*, *Malacocirus indicus*). Clusters 2, 4 and 9 formed of 2 polychaete species each. Cluster 2 formed of polychaete species *Paraonides lyra lyra* and *Maldane sarsi,* In cluster 4, *Prinospio sexoculata* and *Paraheteromastes tenuis* were found and Cluster 9 formed of *Pisionidens indica* and *Tharyx dorsobranchialis*. Third cluster composed of 6 species (*Notomastus aberans*, *Aricidea fauveli, heteromastides bifidus, Notomastus fauveli, Schroederella pauliani* and *Terebellides stroemi*); cluster 5 is the largest cluster consisted of 9 species (*Magelona cincta*, *Anciystrosyllis constricta*, *Cossura coasta, Prionospio pinnata, Magelona capensis, Capitella capitata, Prionospio polybrabchiata, P. cirrifera* and *Cirrtulis cirratus*). Cluster 6 formed of 5 species (*Cirratulus afer*, *Steraspis scutata*, *Lumbrineries aberans*, *L. hartmani* and *Prinospio ehlersi*); cluster 7 consisted of 8 species (*Ophiodromous* sp., *Syllis amica*, *Amphrete acutifrons*, *Goniada emerata*, *Amphicteis gunneri, Mediomastes capensis, Nephtyis dibranchis, and Cirratulus chrysoderma*) and cluster 8 composed of 7 species of polychaetes (*Lumbrineries latreilli, Scolaricia dubia, Eunice antennata, Pycnoderma congoense, Megalomma vesiculosum*, *Sthenelais boa* and *Paraonides lyracapensis*).

Grouping based on Bray-Curtis similarity index calculated for major groups as delineated three major clusters of benthic groups (Fig. 50). Cluster 1 formed of venile fishes and nudibranchs at 90% similarity, cluster 2 consisted of sipunculids, sopods, platyhelminthus, nematodes, echiroides at 40 % similarity and Cluster 3 onsisted of gastropods, pelecypods, decapods and amphipods.

2.3.2. Pre-monsoon

Bray-Curtis similarity index during pre-monsoon showed 4 clusters at 40% imilatiry (Fig. 51). Clustering pattern showed definite north-south differentiation as ndicated by clusters1, 2 and 3. Cluster 1 consisted of northern transect stations, lusters 2 and 3 were consisted of southern stations and clusters 4 was a linking etween stations at southern and northern transects.

For benthic groups, similarity index showed that all the stations except N11 nd N12 are linked at 40% similarity (Fig. 52). At 50% similarity, 3 clusters are btained. Unlike in the case of polychaete species, the clusters obtained are not ifferentiating between north and south but for cluster 3, which is a lone southern egion except for station N21 and cluster 1 which is a lone northern transect except or station S23.

Based on grouping of polychaete species during pre-monsoon, 10 clusters of olychaete species formed (Fig. 53) at 40% similarity level of which clusters 1, 4 and 9 were formed at >60% similarity level. Cluster 1 consisted of *Perineries cavifrons* nd *Pectinaria* sp. Cluster 4 was composed of *Hesionidae* sp. and *Spio bombyx* and luster 9 consisted of *lepidonotus carinulatus* and *Syllis spongicola*.

Similarity index for benthic groups delineated 5 clusters at 40% and 50% imilarity levels (Fig. 54). Cluster 1 consisted of some unidentified polychaetes and ryozoans which were present in a very high OM rich station at 100 % similarity. Cluster 2 formed of chyronomid larvae and unidentified eggs at 60% similarity level. At one station (S36) both of them occurred at 100% and at that station texture was ominated with sand. Cluster 3 clusterd at 50% similarity and have 2 sub clusters one at 60% and other at 55% similarity. Olygochaetes, pelecypods, decapods, amphipods gastropods and nematodes were grouped at 60% similarity level and isopods, sipunculids and nemertene worms grouped at 55% similarity. Cluster 4 formed at 50% similarity and consisted of tanaedacenas, ophuiroids and seaurchin. Cluster 5 formed at 45% similarity and holothuria, cumacea and juvenile fishes were coming under this cluster.

4.3. Discussion

Faunal composition showed that polychaete was the dominant group contributing 86% and 80% during post-monsoon and pre- monsoon seasons respectively. Earlier workers also reported the dominance of polychaetes in the infaunal benthos along the west coast of India (Kurian, 1971; Damodaran, 1973; Parulekar and Wagh, 1975; Ansari *et al* 1977; Harkantra and Parulekar 1981; Divakaran *et al*, 1981; Prabhu *et al*, 1993; Harkantra and Parulekar, 1994). In the present study there was a dominance of spionids especially during post-monsoon season. Harkantra and Parulekar (1994) who studied the benthos of Rajapur Bay, west coast of India also reported the dominance of spionids and suggested that they were the more competitive species. They reported dominance of depositr feeder, *Prionospio pinnata* among spionids. Joydas (2002) also reported dominance of spionids in the continental shelf of west coast of India while, Prabhu *et al* (1993) noticed the dominance of *Neries* sp. in the nearshore sediments off Gangolli, west coast of India. Ingole *et al* (2002) studied the macrobenthic communities of the coastal waters of Dabhol observed similar results and suggested that polychaetes dominance in all the stations and were mainly belonging to the family Spionidae but Golapakrishnan and Nair (1998) could not find any polychaete dominance and reported dominance of molluscs in the subtidal regions off Mangalore.

Present study showed increased richness and diversity during pre-monsoon season compared to post-monsoon season. This may be due to the increased surface production produced from the injection of nutrients to the surface layers during winter convection (Bhattathiri *et al.*, 1996; Madhu,2005). Vizakat *et al.,* (1991) reported an increase in faunal abundance from pre-monsoon (February-May) to post-monsoon (October-January), which suggested that colonization of shallow water benthic communities gets enhanced with cessation of southwest monsoon associated with stability of salinity in coastal waters. They reported 29 species belonging to polychaete , crustacea, molluscs and other groups. Polychaetes were mainly composed of burrowing deposit feeders of family Maldanidae, *Axiothella obockensis* and surface deposit feeding spionids, *Prionospio pinnata* and carnivorous species, *Glycera alba.*

It is to be noted that there was a change in the faunal composition as depth increased. Polychates together with miscellaneous groups decreased with depth but crustaceans showed more representation at greater depths. Altogether 76 species were present during post-monsoon and 133 species during pre monsoon. Of this, only 8 species were present at all depth zones (excluding >150m zone) during post-monsoon and 23 species during pre- monsoon season. Polychaete species *Cossura coasta* was the only species present at all 5-depth zones during pre-monsoon while during post-monsoon *Prinospio pinnata*, *P. polybranchiata* and *Cossura coasta* were present at all 5-depth zones.

The depth wise and transect wise data showed that sedentarians dominated errantia in both seasons in all transects as also observed by Joydas (2002). Sedentarians were mainly composed of *Prionospio pinnata, P. polybrannchiata, Magelona cincta, Cirratulus cirratus, Cossura coasta, Amphicteis gunneri* and errantians by *Ancistrocyllis constericta.* However, earlier workers (Harkantra and Parulekar, 1981; Prabhu, 1992) reported dominance of errant polychaetes in the near shore waters along the west coast.

Among the non-polychaete groups, molluscs (8.9%) dominated the crustacea (3.6%) during post-monsoon whereas crustaceans were the major group (6.5%)

llowed by molluscs (5.9%) during pre- monsoon. Dominance of crustaceans were ported by Harkantra *et al* (1980), Harkantra and Parulekar (1981) and Joydas 002) in the west coast. Previous studies also showed the dominance of molluscs in rtain areas (Neyman, 1969; Gopalakrishnan and Nair, 1998) but Joydas (2002) uldnot find any molluscsan dominance along the northwest coast of India.

During both seasons, the average number of species slightly increased to igher depth zones (75 m) and then decreased. Some families lost their importance in eper depths. Families like Pilargidae, Spionidae, Cirratulidae, Paraonidae and umaspidae were most important in shallow depth zones during both seasons and st their importance as depth increased. Beyond 150 m depth, only members of amily Spionidae, Cirratulidae and Cossuridae were represented even though in low umber. Joydas (2002) also observed reduction in representation of certain families nd representation of family Spionidae, Cirratulidae and Paraonidae beyond 150 m epth.

Generally species richness based on polychaetes was increased from 30 m to 5 m depth and then decreased with highest richness in 75 m depth during both asons and drastic reduction was observed beyond 150 m. High species richness served in the lower depths was mainly constituted by polychaetes, which in turn ould be attributed to the favorable environmental conditions like sediment texture, M in the form of food and sufficient oxygen. The reduction observed beyond 150 m an be due to suboxic or anoxic conditions in that area. Joydas (2002) also observed w richness and diversity beyond 150 m and added that the decrease cannot be due lack of food, and the only limiting factor appears to be DO. High evenness served from 30 m to 100 m showed more or less stable environmental conditions, hich may be supporting high richness and diversity during pre- monsoon season in se depths. Gray (1981) and, Harkantra and Parulekar (1994) reported that high ecies diversity reflect the stability of the environment. High dominance in 150 m nd beyond that showed that few species could survive under unfavorable conditions.

was observed that richness was more in the shallow depths especially during post-onsoon, however, the high richness found in the deeper depths during pre-monsoon as due to the presence of crustaceans and molluscs, which preferred sand ominating environment. Even though polychetes showed low richness and diversity n deeper areas, non-polychaete taxa especially crustaceans showed high diversity in e deeper depths except beyond 150 m (Joydas, 2002). Sanders (1968) after studying e benthic fauna of shallow areas and continental slope of the Arabian Sea also ported high diversity in deeper depths. Jumars (1976) and Gage (1979) confirmed ndings of Sanders with respect to high number of species in the deeper depths.

Similarity indices based on polychaete density during post-monsoon showed at stations were clustered with depth as a major factor. In the four different lusters, in addition to the depth factor, textural and other environmental factors emperature, salinity and DO also affects the cluster formation. Similarity of stations ased on groups showed that polychaetes, pelecypods, decapods and amphipods were e major groups responsible for the cluster. All the stations were shallow depth ations (30 and 50 m) with high clay content may impart its effect on the clustering.

During post-monsoon similarity based on polychaete showed 9 clusters and e first cluster formed by the polychaete species Prionospio, Glycera and Malacocirus in the station S14 which is a sand dominating station. The second cluster s a low sandy area with moderate OM may supports the organisms present in the luster. In cluster 3 different opportunistic species were occurring in low number. ow sandy texture with low OM may be supporting cluster 4 while high clay with ow to medium OM supporting the 5^{th} cluster. Cluster 6 is a medium OM with clayey ubstratum and cluster 7 is grouped as low OM area. Cluster 8 delineated as high andy area with moderate OM and cluster 9 dominated with sand having moderate OM and may resulted in the cluster formation.

Cluster based on groups showed 3 clusters, and cluster 1 formed based on uvanile fishes and nudibranches which was supported by clayey substratum with relatively high OM. Cluster 2 composed of 5 groups of which nematodes, platyhelminthus and echuiroides were major components and the cluster was supported with high clayey substratum (>80%) and high OM. Cluster 3 consisted of stations with relatively more fine fractions and medium OM with moderate DO.

During pre-monsoon season stations clustered based on polychaete density showed the influence of latitude on the clusters, as cluster 1 is formed of northern transect stations and cluster 2 and 3 constituted stations of southern transect. Cluster 1 is a very high OM region (>3%). Cluster 2 formed of stations with fine sediment and high to very high OM, which caused decreased benthic abundance. Cluster 3 is also a southern transect cluster consisted of stations with high percentage of sand, low OM with moderate density. Cluster 4 grouped as stations which links between northern and southern stations and all the stations having moderately high amount of polychaetes.

Clusters formed based on group density showed 3 clusters, cluster 1 formed mainly of northern transect station and all were from below 75m depth with high DO and moderate temperature. This cluster composed of polychaetes, decapods, amphipods and sipunculids. Cluster 2 was formed mainly due to the presence of polychaetes, amphipods, decapods in which amphipods were occurring in high abundance. Cluster 3 grouped as high temperature and DO with moderately high clay stations which supports high density of polychaetes, decapods and amphipods.

Clusters based on polychaete species showed only 3 clusters and were obtained at >60% similarity. Cluster 1 with relatively more DO and moderate clay. Stations in the cluster 4 were all at around 75 m depth and having moderate temperature. Cluster 9 is a high sand rich station with low OM.

Dendrogram for groups showed 5 clusters at different similarity levels and high OM forms the cluster 1 while sandy sediment may be the reason for the cluster 2. The cluster 3 formed of 50% similarity and one of the subcluster formed at 60% similarity where most of the stations have sand dominating texture supporting the crustaceans and molluscs. Cluster 4 is clustered with moderately high and very high DO with moderate temperature. Clusters 5 formed of stations with high DO and relatively high OM with moderate temperature might supports cumacea, juvenile fish and holothurians and formed the cluster.

Hence, during post-monsoon and pre-monsoon season, eventhough the some stations were clustered with slightly low similarity, all the clusters were formed based on the interactions of different species and groups which in turn influenced by depth, latitude, temperature, salinity, DO and sediment charecteristics.

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Family	30 m	50 m	75 m	100 m	150 m	Percentage
Aphroditidae	0	2	20	2	0	0.53
Amphinomidae	0	0	2	0	0	0.04
Pisionidae	0	0	12	0	0	0.27
Pilargidae	26	8	8	3	7	1.16
Hesionidae	6	2	2	0	0	0.22
Syllidae	0	2	2	2	0	0.13
Neridae	0	0	4	0	0	0.09
Nephtyidae	12	10	4	0	0	0.58
Glyceridae	4	2	4	8	0	0.41
Eunicidae	48	40	30	8	0	2.81
Errantia %						**6.00**
Spionidae	1836	782	134	105	33	64.24
Magelonidae	194	238	22	8	0	10.28
Cirratulidae	68	92	48	20	3	5.14
Disomidae	0	0	2	0	0	0.04
Orbiniidae	4	0	16	0	0	0.44
Paraonidae	48	8	36	2	3	2.16
Cossuridae	122	52	14	3	33	4.99
Capitellidae	102	22	20	17	0	3.57
Maldanidae	8	2	4	3	0	0.39
Sternaspidae	12	38	4	2	0	1.24
Flabelligeridae	0	0	8	0	0	0.18
Ampharetidae	8	4	2	0	0	0.31
Terebellidae	6	0	22	0	0	0.62
Sebellidae	0	0	8	0	0	0.18
Sedentaria %						**94.00**

Table 16 – Average abundance of polychaete family during post monsoon season

Polychaete species	30m	50m	75m	100m	150m
ERRANTIA					
Aphroditidae	0	0	0	0	0
Sthenelais boa	0	20	40	17	0
Amphinomidae	0	0	0	0	0
Notopygos sp.	0	0	20	0	0
Pisionidae	0	0	0	0	0
Pisionidens indica	0	0	40	0	0
Pilargidae	0	0	0	0	0
Ancistrosyllis constricta	60	80	60	17	33
Hesionidae					
Ophiodromus sp.	20	20	20	0	0
Syllidae	0	0	0	0	0
Syllis amica	0	20	20	0	0
S. spongicola	0	0	0	17	0
Syllis sp.	0	0	0	0	0
Nereidae	0	0	0	0	0
Ceratonereis erythraensis	0	0	20	0	0
Neries sp.	0	0	20	0	0
Nephtyidae	0	0	0	0	0
Nephtyis dibranchis	20	40	40	0	0
N. spirocirrata	0	20	0	0	0
Glyceridae	0	0	0	0	0
Glycera longipinnis	20	0	0	50	0
Glycinde kameruniana	0	0	20	17	0
Goniada emerata	20	20	20	0	0
Eunicidae	0	0	0	0	0
Lumbrineries aberans	60	60	20	0	0
L. hartmani	40	60	20	50	0
L.bifilaris	20	0	0	0	0
L.latreilli	0	20	20	0	0
Eunice afrapunctata	0	0	20	0	0
E. siciliensis	0	0	0	17	0
E. antennata	0	0	40	0	0
Ramphobrachium capensis	0	0	20	0	0
Protodorvillea biarticulata	0	0	20	0	0
Notocirrus australis	0	0	20	0	0
Diapatra sp.	0	20	0	17	0
SEDENTARIA					
Spionidae					
Prinospio pinnata	100	100	80	83	67
P.polybranchiata	80	80	80	67	33
P. sexoculata	0	40	20	17	0

Table 17. Percentage occurrence of polychaete species duringpost-monsoon season

Table 17. contd..

P.ehlersi	20	60	0	33	0
P.cirrifera	60	100	100	50	0
Pygospio elegans	0	0	0	33	0
Spiophanes kroyeri	0	0	20	0	0
S. bombyx	0	0	0	17	0
Malacoceros indicus	0	0	60	17	0
Spionid sp.	0	0	20	0	0
Magelonidae	0	0	0	0	0
Magelona cincta	60	40	60	17	0
M.capensis	80	60	40	33	0
Cirratulidae	0	0	0	0	0
Cirratulis cirratus	80	80	60	67	0
C.bioculatus	0	20	0	0	0
C.gilchrist	0	20	0	0	0
C.chrysoderma	20	20	40	17	33
C.concinnus	0	0	0	0	0
Cirriformia afer	20	40	40	17	0
Tharyx dorsobranchialis	0	20	40	0	0
Disomidae	0	0	0	0	0
Disoma sp.	0	0	20	0	0
Orbiniidae	0	0	0	0	0
Scolaricia dubia	20	0	60	0	0
Schroederella pauliani	20	0	20	0	0
Paraonidae	0	0	0	0	0
Paraonides lyracapensis	0	20	40	0	0
P.lyralyra	40	20	20	0	33
Paraonis gracilis gracilis	0	0	40	0	0
Aricidea capensis	20	20	20	17	0
A.fauveli	40	0	0	0	0
Cossuridae	0	0	0	0	0
Cossura coasta	100	80	80	17	67
Capitellidae	0	0	0	0	0
Capitella capitata	100	80	40	50	0
Heteromastides bifidus	60	0	20	0	0
Notomastus aberans	20	0	20	0	0
N.fauvelli	40	0	20	0	0
Paraheteromastes tenuis	20	60	20	33	0
Heteromastus filiformis	20	0	0	0	0
Mediomastes capensis	20	0	20	0	0
Maldanidae	0	0	0	0	0
Maldane sarsi	40	20	20	17	0
Maldenella capensis	40	0	0	0	0
Axiothella jarli	0	0	20	0	0
Maldane sp.	0	0	0	0	0

Table 17. Contd..

Sternaspidae	0	0	0	0	0
Steraspis scutata	40	60	20	17	0
Flabelligeridae	0	0	0	0	0
Pycnoderma congoense	0	0	40	0	0
Ampharetidae	0	0	0	0	0
Amphrete acutifrons	20	20	0	0	0
Amphicteis gunneri	0	20	20	0	0
Amphicteis sp.	0	0	0	0	0
Phyllocomus hiltoni	20	0	0	0	0
Terebellidae	0	0	0	0	0
Terebellides stroemi	20	0	20	0	0
Lanice conchilega	0	0	20	0	0
Streblosoma persica	0	0	20	0	0
Lysilla sp.	0	0	20	0	0
Pista foliigera	0	0	20	0	0
P.quadrilobata	0	0	20	0	0
Artacama proboscidea	20	0	0	0	0
Sabellidae	0	0	0	0	0
Megalomma vesiculosum	0	0	40	0	0
Desdemona ornata	0	0	20	0	0
Total species	**37**	**34**	**59**	**27**	**6**
Errantia	**8**	**11**	**19**	**8**	**1**
Sedentaria	**29**	**23**	**40**	**19**	**5**
Abundant species	**6**	**7**	**4**	**1**	**0**
Moderately occurring species	**12**	**10**	**18**	**10**	**6**
Rare species	**19**	**17**	**37**	**16**	**0**

Taxa	30 m	50 m	75 m	100 m	150 m
CRUSTACEANS					
Decapoda sp.	80	20	0	33	0
Sergestid	20	0	0	17	0
Megalopa	60	0	0	17	0
Lobster	20	20	0	33	0
Caridian prawns	80	20	60	17	0
Acetes	0	0	0	17	0
Amphipoda	0	0	0	0	0
Melita zeylanica	0	0	0	17	0
Eriopisa chilkensis	40	20	20	0	0
Quadriovisio bengalensis	20	20	0	0	0
Grandidierella gilesi	40	0	20	0	0
Isopoda	0	0	0	0	0
Anthuridae	20	0	20	0	0
Ostracoda	20	20	0	0	0
MOLLUSCS	0	0	0	0	0
Cardium sp.	20	20	0	33	33
Bivave	0	0	0	0	0
Mactra sp.	40	20	20	33	67
Tellina sp.	20	60	0	17	100
Siliqua sp.	0	0	0	17	0
Sunetta scripta	0	0	20	17	33
Gastrpod	0	0	0	0	0
Nassarius sp.	40	0	20	17	0
Prunum sp.	0	0	0	17	0
Bulla sp.	0	0	0	17	0
Atys sp.	0	20	0	0	0
MISCELLANEOUS GROUPS	0	0	0	0	0
Nematodes	20	0	0	0	0
Sipunculoides	60	20	20	0	0
Juvenile fish	0	20	0	0	0
Platyhelminthes	20	20	0	0	0
Nudibranches	0	20	0	0	0
Echiroides	20	0	0	0	0
Total groups	**18**	**14**	**8**	**15**	**4**
Abundant species	**2**	**0**	**0**	**0**	**1**
Moderately abundant species	**6**	**1**	**1**	**4**	**3**
Rare species	**10**	**13**	**7**	**11**	**0**

Table 18 - Percentage occurrence of groups in various depth zones during post-monsoon

Family	30 m	50 m	75 m	100 m	150 m	>150 m	Percentage
Aphroditidae	8	15	20	26	160	145	4.17
Pisionida	0	0	2	8	0	0	0.11
Phyllodocidae	14	13	40	2	0	10	0.88
Pontodoridae	6	0	0	0	0	0	0.07
Iospilidae	0	0	0	2	0	0	0.02
Alciopidae	0	0	2	0	0	0	0.02
Pilargidae	56	235	152	132	105	20	7.81
Hesionidae	0	10	4	4	0	0	0.20
Syllidae	4	3	36	160	145	80	4.77
Nereidae	4	3	4	8	20	5	0.49
Nephthydae	14	40	112	10	0	0	1.96
Glyceridae	12	40	32	20	0	0	1.16
Eunicidae	46	115	256	48	130	0	6.64
Errantia %							**28.31**
Spionidae	274	290	532	212	15	35	15.15
Magelonidae	38	45	80	24	20	10	2.42
Cirratulidae	30	782.5	712	202	30	10	19.71
Orbinidae	8	33	38	18	0	0	1.08
Paraonidae	34	100	28	16	0	0	1.99
Ophelidae	0	130	16	2	0	0	1.65
Cossuridae	146	155	42	96	15	5	5.12
Scalibregmidae	0	2.5	4	0	0	0	0.07
Capitellidae	100	70	118	334	5	15	7.16
Arenicolidae	6	3	0	0	0	0	0.09
Maldanidae	6	15	82	4	10	0	1.31
Owenidael	2	0	0	0	0	0	0.02
Sternaspidae	98	70	6	2	0	0	1.96
Flabelligeridae	2	5	14	2	0	0	0.26
Pectinaridae	16	30	0	4	15	0	0.73
Ampharetidae	12	143	358	74	145	10	8.27
Terebellidae	20	90	198	8	0	5	3.58
Sabellidae	0	0	16	10	30	5	0.68
Serpulidae	12	0	20	4	0	0	0.40
Archianeelidae	0	0	0	2	0	0	0.02
Sedentaria %							**71.7**

Table 19 – Average abundance of polychaete family during pre-monsoon

Polychaete species	30m	50m	75m	100m	150m	>150m
ERRANTIA						
Aphroditidae						
Sthenalais boa	0	25	40	20	33	0
Eupanthalis sp.	20	0	0	0	0	0
Pontogenia chrysocoma	0	0	0	20	0	0
Hermonia hystrix	0	0	20	0	0	0
Leanira hystricis	0	25	0	0	0	0
Lepidonotus carinulatus	0	0	20	20	33	50
Lepidonotus sp.	20	25	0	0	0	0
Pisionidae						
Pisionidens indica	0	0	20	20	0	0
Phyllodocidae						
Phyllodoce sp.	0	0	20	0	0	0
Eteone sp.	40	50	40	20	33	50
Pontodoridae						
Pontodora sp.	20	0	0	0	0	0
Iospilidae						
Iospilus sp.	0	0	0	20	0	0
Alciopidae						
Vanadis sp.	0	0	20	0	0	0
Pilargidae	0	25	0	0	0	0
Ancistrosyllis consricta	80	100	100	100	67	50
Hesionidae						
Hesionidae sp.	0	25	40	20	0	0
Syllidae						
Syllis gracilis	0	0	0	0	33	0
S. spongicola	40	0	40	40	67	50
Exogene claviator	0	0	0	20	0	0
E. normalis	0	0	0	0	33	0
Exogene sp.	0	0	20	0	0	0
Sphaerosyllis sublaevis	0	0	0	20	0	0
S. semiverucosa	0	25	0	20	0	0
Pilagobia longicirata	0	0	0	20	0	0
Odontosyllis sp..	0	0	20	0	0	0
Nereidae						
Perineries cavifrons	20	0	0	20	33	0
Platynerid caladonta	20	25	40	20	0	50
Nephtyidae						
Nephthys dibranchis	60	75	60	60	33	0
Glyceridae						
Glycero longipinnis	0	50	20	0	0	0

Table 20. Percentage occurrence of polychaete during pre-monsoon

Table 20. contd..

G. alba	20	25	20	20	33	0
Gonioda emerata	40	25	60	20	0	0
Eunicidae						
Lumbriconeries aberrans	20	75	20	40	0	0
L. hartmani	80	50	60	40	33	0
L.laterali	0	25	20	20	0	0
Lumbrineries sp.	40	0	20	0	0	0
E. indica	0	0	0	0	33	0
Eunice sp.	0	0	20	0	0	0
Euniphis emerita	0	0	20	0	0	0
Protodorvillea biarticulata	0	0	20	20	0	0
Diapatra sp.	0	25	20	0	0	0
Diopatra monroi	0	0	20	0	0	0
Diopatra neopolitana	0	25	0	0	0	0
Epidiopatra sp.	0	0	0	20	0	0
Ophryotrocha puerilis	0	0	0	20	0	0
Dorivilla gardineri	0	25	20	20	0	0
Dorivilla sp.	0	0	20	0	33	0
SEDENTARIA						
Spionidae						
Prinospio pinnata	100	75	100	100	67	0
P.polybranchiata	80	75	60	20	33	0
P. cirrobranchia	60	50	80	60	0	50
P. sexoculata	0	25	0	0	0	0
P.chelersi	0	0	20	20	0	0
P.cirrifera	60	50	80	80	0	50
Prinospio sp.	40	0	0	0	0	0
Pygospio elegans	0	0	20	20	33	0
Spiophane bombyx	0	0	40	20	33	0
Malacocirus indicus	0	0	40	0	0	0
Bocardia sp.	20	0	0	0	0	0
Scolelepis sp.	0	25	0	20	0	0
Magelonidae						
Magelona cincta	60	50	80	80	67	50
M. capensis	20	0	20	0	0	0
Magelona papilicornis	0	0	20	0	0	0
Cirratulidae						
Cirratulis cirratus	20	50	80	80	67	50
C.chrysoderma	0	25	40	0	0	0
Cauleriella capensis	0	25	0	0	0	0
Cirriformia afer	60	50	100	60	33	0
Tharyx dorsobranchialis	0	25	0	0	0	0
T. filibranchia	0	25	0	0	0	0
Tharyx sp.	20	0	40	80	33	0

Table 20. Contd..

Orbinidae	0	0	40	20	0	0
Scolaricia dubia	20	25	20	0	0	0
Schroederella pauliani	0	0	0	0	33	0
Haploscoloplos	20	25	0	20	0	0
Paraonidae						
Paraonides lyralyra	20	50	20	20	0	0
P. gracilis oculata	20	25	0	0	0	0
Paraonid sp.	0	0	20	0	0	0
Aricidea capensis	0	0	20	0	33	0
A.fauveli	40	50	0	20	33	0
A. longobranchia	20	0	0	20	0	0
Aricidea sp.	0	0	20	0	0	0
Opheliidae						
Ophelina acuminata	0	0	20	20	0	0
Cossuridae						
Cossura coasta	80	75	100	60	100	50
Scalibregmidae	0	0	20	0	33	0
Parasclerocheilus capensis	0	25	0	0	0	0
Capitellidae						
Capitella capitata	100	75	60	80	33	50
Heteromastides bifidus	60	25	0	40	0	0
Notomastus aberrans	40	50	20	100	33	0
N.fawvelli	60	0	40	20	67	50
N. latericeus	0	25	0	20	33	0
Paraheteromastes temuis	0	50	0	20	0	0
Mediomastes capensis	20	0	40	20	33	0
Branchiocapitella	0	0	0	20	0	0
Scyphoproctus sp.	60	25	20	20	0	0
Pulella armata	20	0	0	0	0	0
Leiochrides africans	40	0	0	0	0	0
Arenicolidae						
Branchiomaldane sp.	20	25	0	0	0	0
Arenicola sp.	20	0	0	0	0	0
Maldanidae						
Maldane sarsi	40	25	100	40	33	0
Maldane sp.	0	25	0	0	0	0
Euclymene annandalei	0	0	20	0	0	0
Oweniidae						
Owenia fusiformis	20	0	0	0	0	0
Sternaspidae						
Steraspis scutata	60	75	40	20	0	0
Flabelligeridae	0	0	20	0	0	0
Flabelligerid sp.	0	25	20	20	0	0
Diplocirus capensis	20	25	0	0	0	0

Table 20. Contd..

Pectinariidae						
Pectinaria capensis	20	0	0	0	0	0
Pectinaria sp.	40	25	0	20	33	0
Ampharetidea						
Isolda whydahensis	0	0	0	0	33	0
Amphare te agulhasensis	0	25	0	20	0	0
Amphicteis gunneri	40	50	80	100	67	50
Sabellides luderitzi	0	0	20	0	0	0
Sabellides capensis	0	0	0	0	33	0
Terebellidae						
Polycirrus haematodes	0	25	0	0	0	0
P. coccinius	0	0	20	0	0	0
Polycirus sp.	0	25	20	0	0	0
Terebellides stroemi	40	25	0	0	0	0
Stroblosoma persica	0	0	0	20	0	0
Lysilla ubiansis	20	0	0	0	0	0
P. brevibranchia	0	0	20	0	0	0
Telothelepus capensis	0	0	0	0	0	50
Sabellidae						
Euchone rosea	0	0	20	0	0	0
Megalomma vesiculosum	0	0	20	20	0	0
Sabellid sp.	0	0	20	0	0	0
Amphiglena mediterranea	0	0	0	0	0	50
Chone collaris	0	0	20	20	0	0
C. letterstedti	0	0	0	20	33	0
Oriopsis eimeri	0	0	0	0	33	0
Fabricia filamentosa	0	0	0	0	33	0
Serpulidae	20	0	0	0	0	0
Protula tubularia	0	0	20	0	0	0
Serpulid sp.	0	0	0	20	0	0
Vermiliopsis acanthophora	0	0	0	20	0	0
Polygordius	0	0	0	20	0	0
Total species	**52**	**58**	**72**	**66**	**39**	**15**
Errantia	**12**	**18**	**26**	**24**	**12**	**4**
Sedentaria	**40**	**40**	**46**	**42**	**27**	**11**
Abundant species	**6**	**8**	**10**	**9**	**1**	**0**
Moderately abundant species	**21**	**50**	**18**	**9**	**38**	**15**
Rare species	**25**	**0**	**44**	**48**	**0**	**0**

Taxa	30 m	50 m	75 m	100 m	150 m	>150 m
Decapoda	40	25	80	100	100	0
Sergestid	0	0	0	0	33	0
Megalopa	20	0	0	20	67	0
Crab	0	50	0	0	0	0
Alima larvae	0	0	20	0	0	0
Juvenile Lobster	0	0	40	0	33	0
Amphipoda	0	0	0	0	0	0
Corophium triaenonyx	0	0	0	20	0	0
Caprillidae(amphipod)	0	0	0	20	0	0
Melita zeylanica	0	0	20	0	0	0
Eriopisa chilkensis	60	75	80	40	67	50
Quadriovisio bengalensis	40	0	40	40	0	0
Grandidierella gilesi	20	25	60	80	33	0
G.gonneri	0	0	20	20	33	0
Isopoda	0	0	0	20	0	0
Cirrolinea fluviata	0	0	0	20	33	50
Anthuridaea sp.	20	25	60	20	33	0
Cumacea	40	25	20	0	33	50
Mysid	0	0	20	0	0	0
Tanais sp.	0	0	40	40	0	0
Apsudus chilkiensis (tanaidacaea)	20	0	20	40	33	0
Mollusca	0	0	0	0	0	0
Patella sp.	0	0	20	0	33	0
Nucula sp.	0	0	0	0	33	0
Sunetta scripta	0	0	60	20	0	0
Mactra sp.	40	50	40	40	33	0
Glycimeris sp.	0	0	40	20	0	0
Tellina sp.	0	50	40	20	33	0
Siliqua sp.	20	0	0	0	0	0
Solen sp.	0	0	0	40	0	0
Littorina sp.	40	0	20	40	0	0
Prunum sp.	20	0	20	40	0	0
Nerita sp.	0	0	0	40	0	0
Nassarius sp.	60	25	20	80	33	0
Bulla sp.	0	0	20	40	0	0
Turritella sp.	0	0	0	20	0	0
Terebra sp.	0	25	20	40	0	0
Atys sp.	0	0	0	60	33	0
Oliva sp.	0	0	0	20	0	0
Cerithidea sp.	0	0	0	20	0	0

Table 21. Percentage occurrence of groups in various depth zones during pre-monsoon season.

Table 21. contd..

Babylonia sp.	0	0	0	20	0	0
Architectonica sp.	0	0	0	20	0	0
Unidentified worm	0	0	0	40	0	0
Dentalium	0	25	20	40	0	0
Crisis	20	0	40	20	33	0
Miscellaneous groups	0	0	0	0	0	0
Olygochaetes	40	0	60	60	33	50
Nematodes	20	0	60	80	100	50
Sipunculoides	80	75	80	80	33	50
Juvenile fish	40	25	20	20	33	50
Ophiroidea	0	0	20	40	33	0
Echiroides	0	0	0	0	33	0
Holothuria	20	0	0	0	33	0
Sea urchin	0	0	0	20	33	0
Cephalopod	0	25	0	0	0	0
Nemertene worm	40	75	60	40	0	0
Unidentified eggs	0	0	0	0	0	50
Chyronomid larvae	0	0	0	0	0	50
Unidentified worms	0	0	0	0	33	0
Amphioxus	0	0	0	20	0	0
Bryozoa	0	0	0	0	33	0
Total groups	**20**	**15**	**31**	**41**	**28**	**9**
Abundant species	**1**	**3**	**3**	**5**	**2**	**0**
Moderately abundant species	**10**	**12**	**13**	**17**	**26**	**9**
Rare species	**9**	**0**	**15**	**19**	**0**	**0**

Transects	Depth	No. of Species	Density	Richness	Evenness	Diversity	Dominance
Off Mormugao	30	10	4730	1.06	0.21	0.70	0.82
	50	11	1480	1.37	0.56	1.92	0.37
	75	26	740	3.78	0.90	4.22	0.07
	100	20	680	2.91	0.88	3.80	0.09
Off Ratnagiri	30	23	3810	2.67	0.56	2.53	0.32
	50	9	160	1.58	0.91	2.90	0.16
	75	41	932	5.85	0.92	4.92	0.04
	100	10	140	1.82	0.96	3.18	0.12
	194	4	80	0.68	0.91	1.81	0.30
Off Mumbai	30	12	1560	1.50	0.38	1.36	0.65
	50	17	340	2.75	0.95	3.87	0.08
	75	14	300	2.28	0.95	3.62	0.09
	100	5	80	0.91	0.93	2.16	0.24
Off Veraval	100	2	30	0.29	0.92	0.92	0.54
	75	8	120	1.46	0.97	2.92	0.13
	50	22	3860	2.54	0.48	2.12	0.43
	30	23	2080	2.88	0.70	3.16	0.22
Off Porbandar	30	7	340	1.03	0.81	2.27	0.26
	50	14	680	1.99	0.66	2.53	0.30
	75	7	90	1.33	0.97	2.73	0.15
	150	3	100	0.43	0.73	1.16	0.54
Off Dwaraka	200	1	60	0.00	****	0.00	1.00
	100	11	160	1.97	0.98	3.38	0.10

Table 22 - Community indices of polychaetes during post monsoon season

nsects	Depth	No. of Species	Density	Richness	Evenness	Diversity	Dominance
Mormugao	30	5	4820	0.47	0.07	0.17	0.96
	50	4	1530	0.41	0.13	0.25	0.94
	75	1	740	0.00	0.00	0.00	1.00
	100	4	770	0.45	0.33	0.66	0.79
Ratnagiri	30	10	4020	1.08	0.14	0.45	0.90
	50	5	210	0.75	0.54	1.25	0.59
	75	2	942	0.15	0.08	0.08	0.98
	100	2	160	0.20	0.54	0.54	0.78
	150	2	90	0.22	0.50	0.50	0.80
Mumbai	30	2	1580	0.14	0.10	0.10	0.98
	50	2	400	0.17	0.61	0.61	0.74
	75	4	330	0.52	0.29	0.58	0.83
	100	2	90	0.22	0.50	0.50	0.80
Veraval	100	2	40	0.27	0.81	0.81	0.62
	75	4	200	0.57	0.70	1.40	0.45
	50	7	4100	0.72	0.14	0.40	0.89
	30	6	2490	0.64	0.34	0.87	0.71
Porbandar	30	3	360	0.34	0.23	0.37	0.89
	50	2	700	0.15	0.19	0.19	0.94
	75	3	110	0.43	0.55	0.87	0.68
	150	2	120	0.21	0.65	0.65	0.72
Dwaraka	200	2	560	0.16	0.49	0.49	0.81
	100	3	590	0.31	0.83	1.31	0.46

Table 23 - Community indices of groups during post monsoon season

ansects	Depth	No. of Species	Density	Richness	Evenness	Diversity	Dominance
f Mormugao	30	7	860	0.89	0.66	1.84	0.37
	50	31	5285	3.50	0.70	3.45	0.16
	75	19	916	2.64	0.83	3.52	0.14
	100	21	1960	2.64	0.65	2.84	0.27
tnagiri	30	13	290	2.12	0.95	3.53	0.09
	50	10	540	1.43	0.86	2.84	0.17
	75	50	8825	5.39	0.77	4.35	0.08
	100	19	1550	2.45	0.79	3.34	0.14
f Mumbai	30	27	1434	3.58	0.79	3.73	0.13
	50	30	3001	3.62	0.77	3.80	0.12
	75	21	3515	2.45	0.64	2.82	0.21
	100	21	1127	2.85	0.86	3.76	0.10
	120	21	1800	2.67	0.82	3.59	0.11
	150	15	850	2.08	0.75	2.94	0.19
f Veraval	30	26	1005	3.62	0.82	3.87	0.11
	50	21	1122	2.85	0.79	3.48	0.15
	75	18	504	2.73	0.90	3.73	0.09
	100	27	1699	3.50	0.83	3.97	0.09
	150	2	160	0.20	0.34	0.34	0.88
	200	2	210	0.19	0.28	0.28	0.91
f Dwaraka	30	34	1414	4.55	0.86	4.38	0.07
	50	1	50	0.00	0.00	0.00	1.00
	75	27	1235	3.65	0.85	4.02	0.08
	100	27	1320	3.62	0.81	3.84	0.11
	150	28	1700	3.63	0.88	4.21	0.07

Table 24 - Community indices of polychaetes during pre monsoon season

ransects	Depth	No. of Species	Density	Richness	Evenness	Diversity	Dominance
ff Mormugao	30	5	1000	0.58	0.41	0.94	0.70
	50	2	5250	0.12	0.04	0.04	0.99
	75	8	1050	1.01	0.39	1.15	0.65
	100	6	2080	0.65	0.24	0.63	0.81
atnagiri	30	5	570	0.63	0.69	1.59	0.38
	50	7	710	0.91	0.55	1.53	0.50
	75	10	10090	0.98	0.28	0.93	0.76
	100	8	1930	0.93	0.44	1.31	0.58
ff Mumbai	30	5	1600	0.54	0.32	0.74	0.77
	50	8	3320	0.86	0.24	0.73	0.79
	75	12	3790	1.34	0.20	0.71	0.83
	100	12	2130	1.44	0.63	2.27	0.31
	120	13	2540	1.53	0.46	1.69	0.48
	150	10	1230	1.27	0.56	1.86	0.39
ff Veraval	30	9	1190	1.13	0.36	1.15	0.67
	50	6	1210	0.70	0.27	0.71	0.79
	75	7	530	0.96	0.41	1.14	0.67
	100	9	2400	1.03	0.55	1.75	0.47
	150	7	140	1.21	0.81	2.26	0.29
	200	1	10	0.00	0.00	0.00	1.00
ff Dwaraka	30	11	1740	1.34	0.37	1.30	0.64
	75	11	2430	1.28	0.61	2.12	0.31
	100	13	1760	1.61	0.50	1.84	0.49
	150	8	1800	0.93	0.30	0.90	0.75

able 25 - Community indices of groups during pre monsoon season

Depths	Margalef index	Evenness index	Shanon index	Simpson index
30 m	1.4831 (8)	2.4089 (8)	2.3916 (8)	2.2907 (8)
50 m	1.5034 (7)	0.6178 (7)	1.6897 (7)	1.5863 (7)
75 m	0.4284 (8)	3.0785 (8)	0.1245 (8)	0.7493 (8)
100 m	2.8138 (8)	3.6274 (8)	1.5463 (8)	0.8343 (8)
150 m	1.5012 (6)	0.9519 (6)	1.0985 (6)	0.6159 (6)

Table 26a - Seasonal comparison of community structure indices of polychaete Species based on Student's *t* test (Degree of freedom is given in bracket)

Depths	Margalef index	Evenness index	Shanon index	Simpson index
30 m	1.3581 (8)	3.0721 (8)	3.7718 (8)	3.1257 (8)
50 m	0.9595 (7)	0.3133 (7)	0.6162 (7)	0.4465 (7)
75 m	5.6884 (8)	0.1873 (8)	1.7622 (8)	1.0590 (8)
100 m	4.6840 (8)	1.1185 (8)	2.5318 (8)	1.4980 (8)
150 m	2.2399 (6)	0.1060 (6)	1.4810 (6)	1.1192 (6)

Table 26b - Seasonal comparison of community structure indices of groups based on Student's *t* test (Degree of freedom is given in bracket)

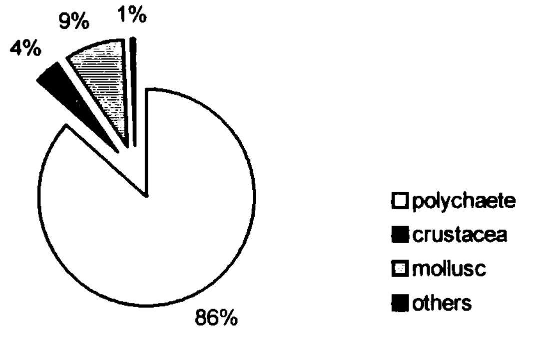


Fig 35 - Faunal composition (%) during post-monsoon

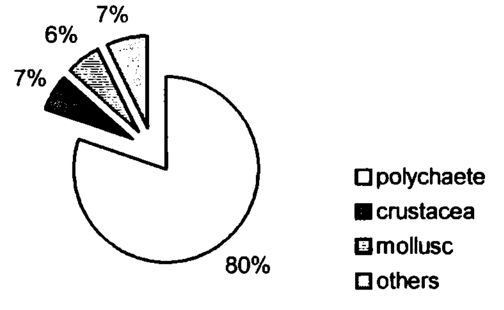


Fig 36 - Faunal composition (%) during pre-monsoon

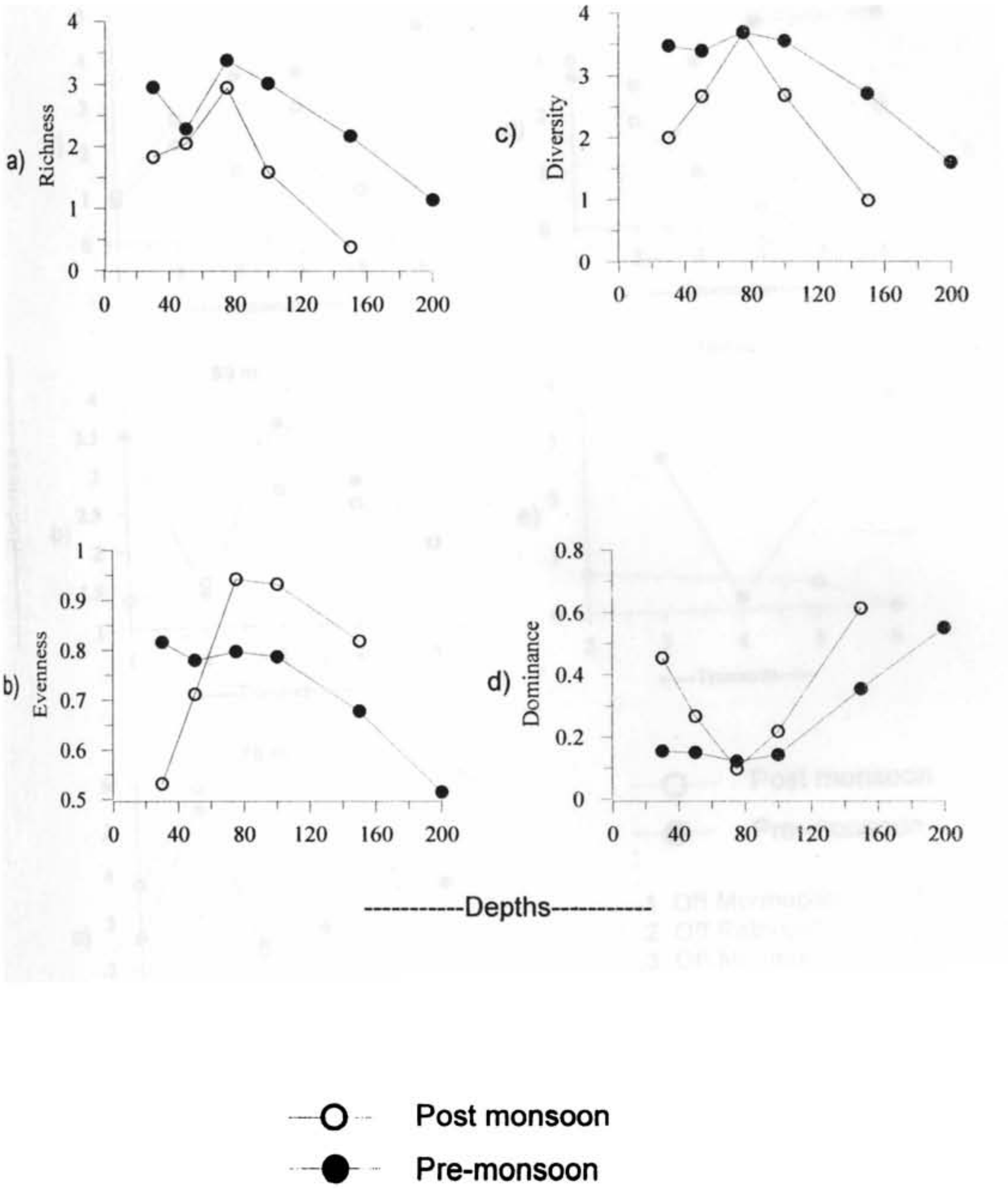


Fig. 37 - Depth wise (average) of community structure based on polychaete species during post-monsoon and pre-monsoon season

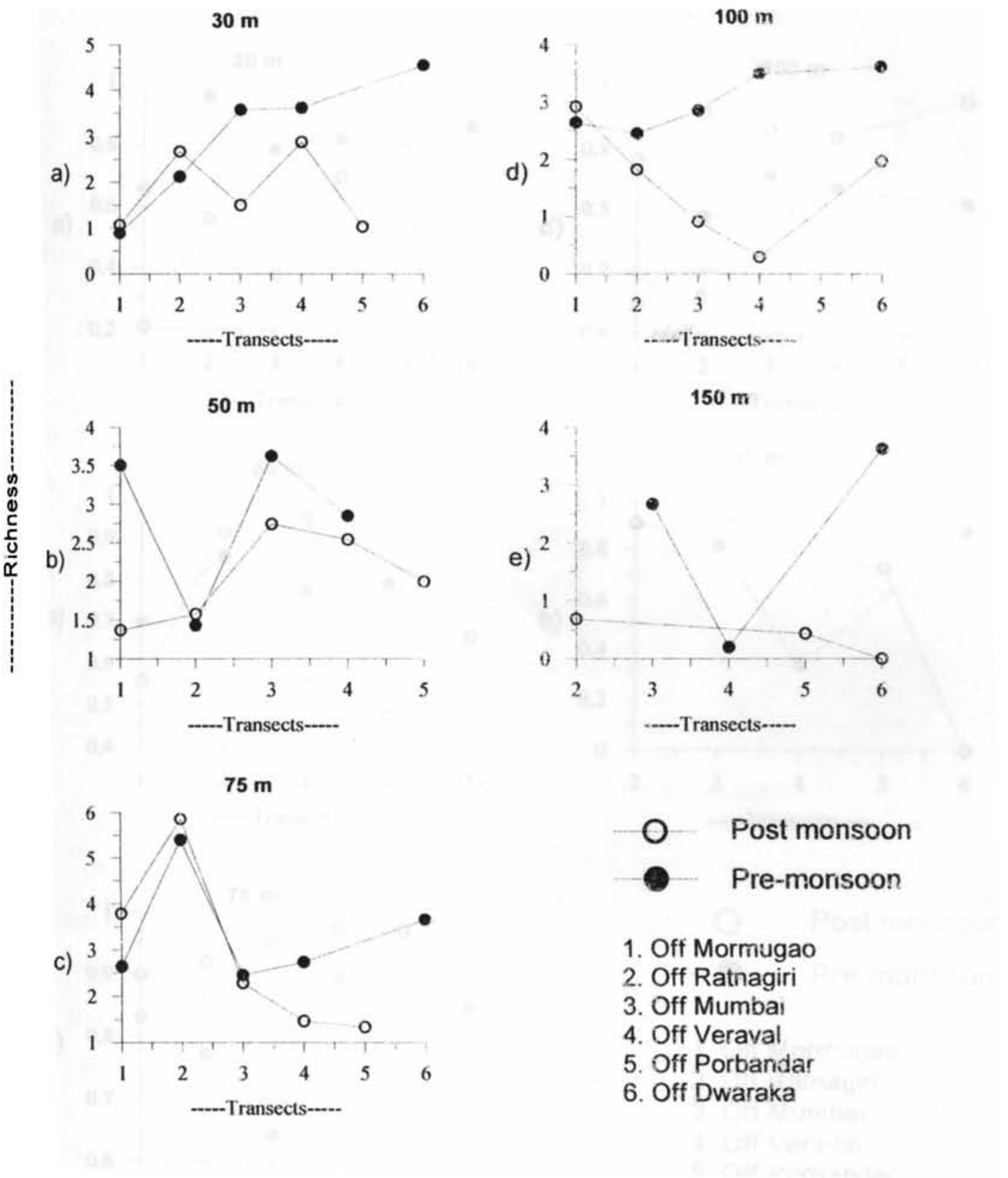


Fig. 38 – Transect wise species richness based on polychaete species during post-monsoon and pre- monsoon season in different depth zones

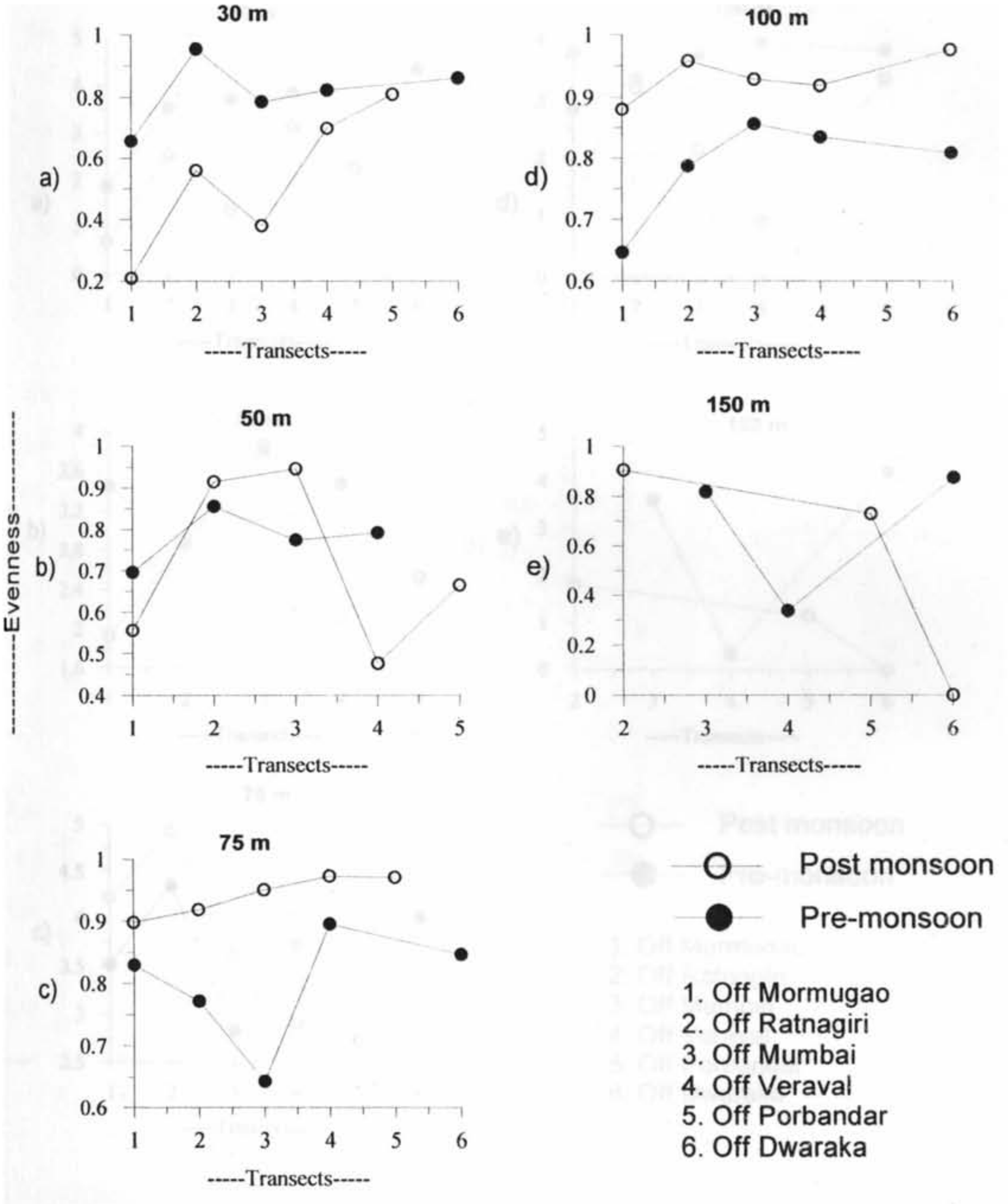


Fig. 39 - Transect wise evenness based on polychaete species during post- monsoon and pre- monsoon season

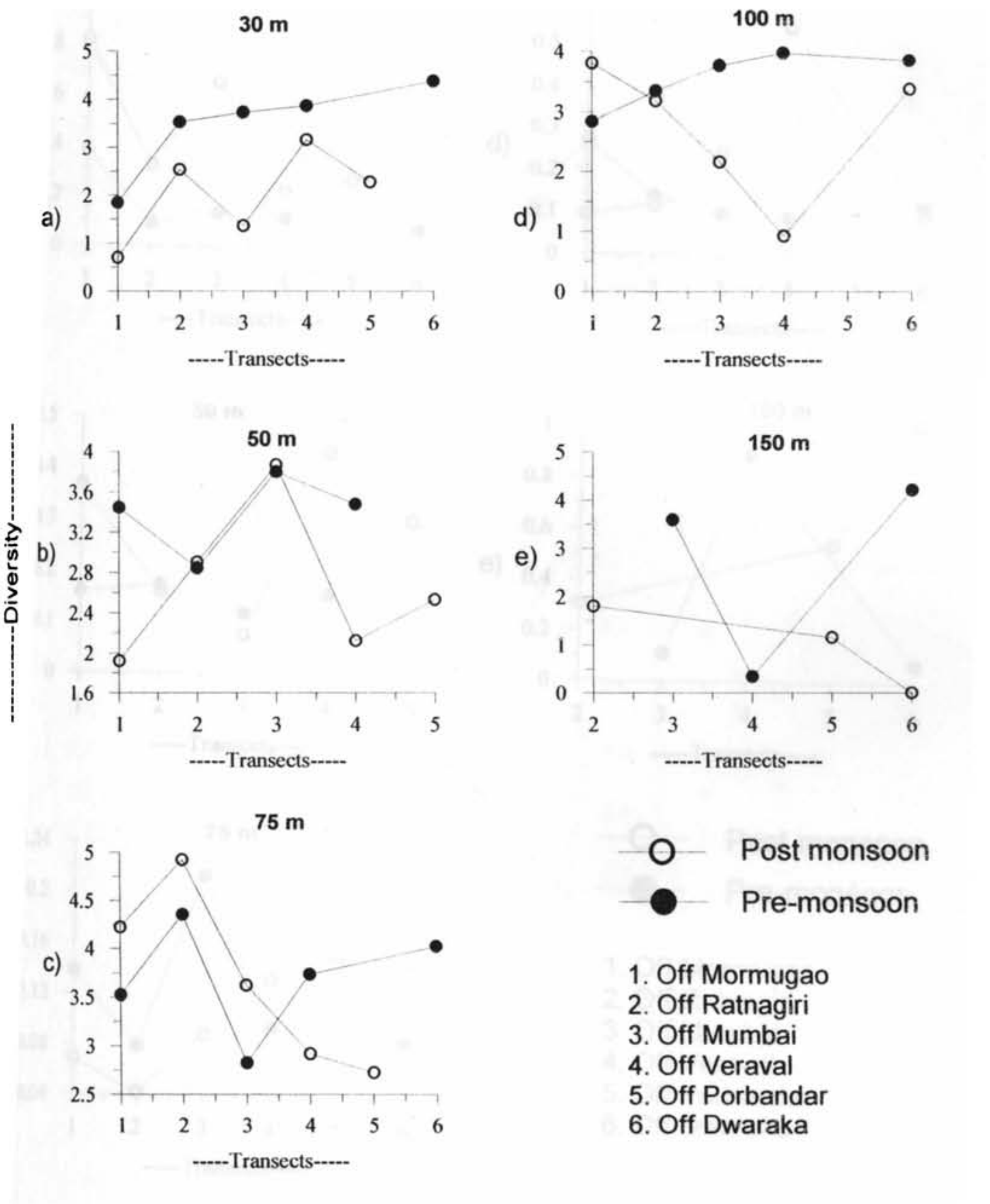


Fig. 40 - Transect wise diversity based on polychaete species during post-monsoon and pre- monsoon season

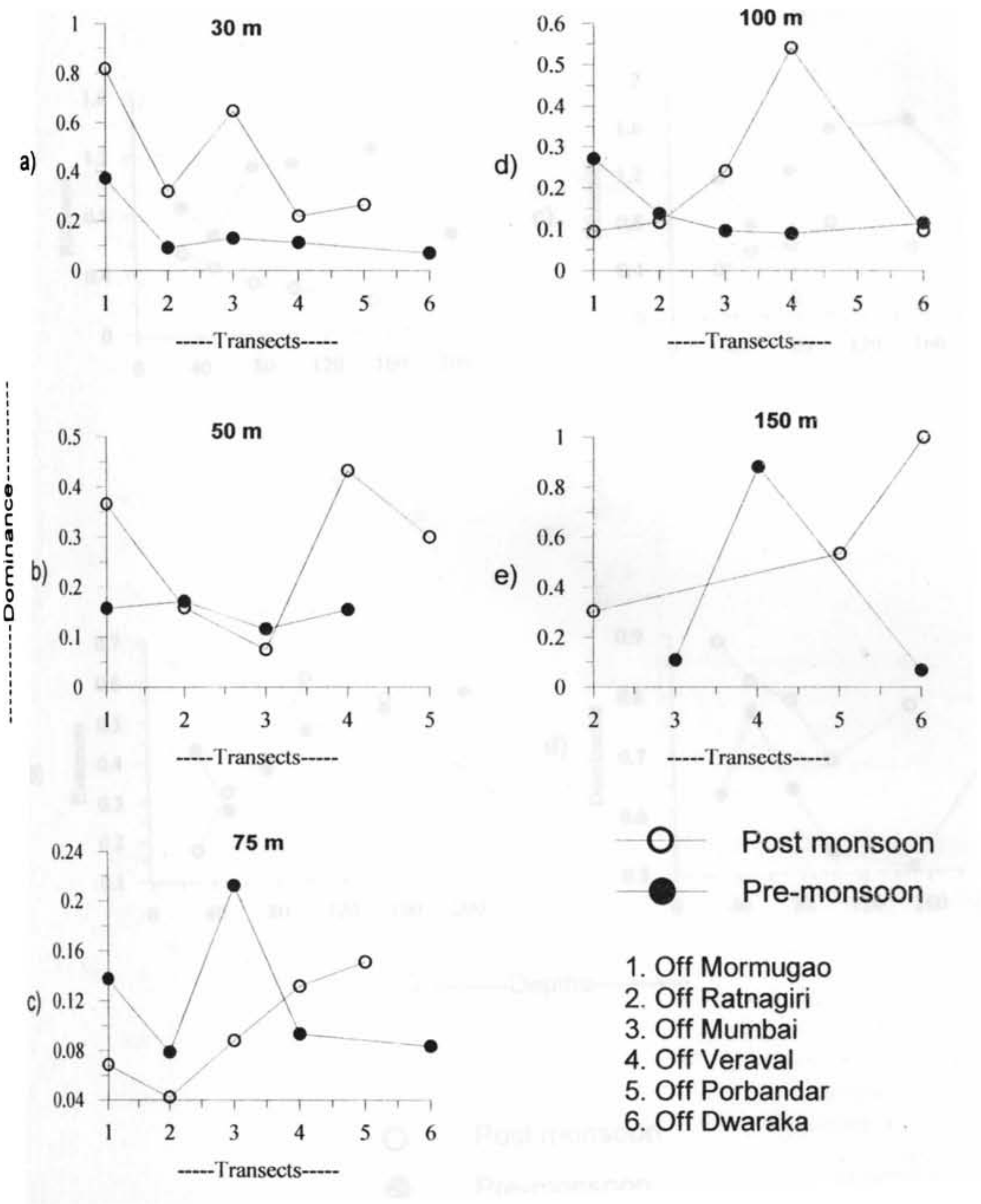


Fig. 41 - Transect wise dominance based on polychaete species during post-monsoon and pre- monsoon season

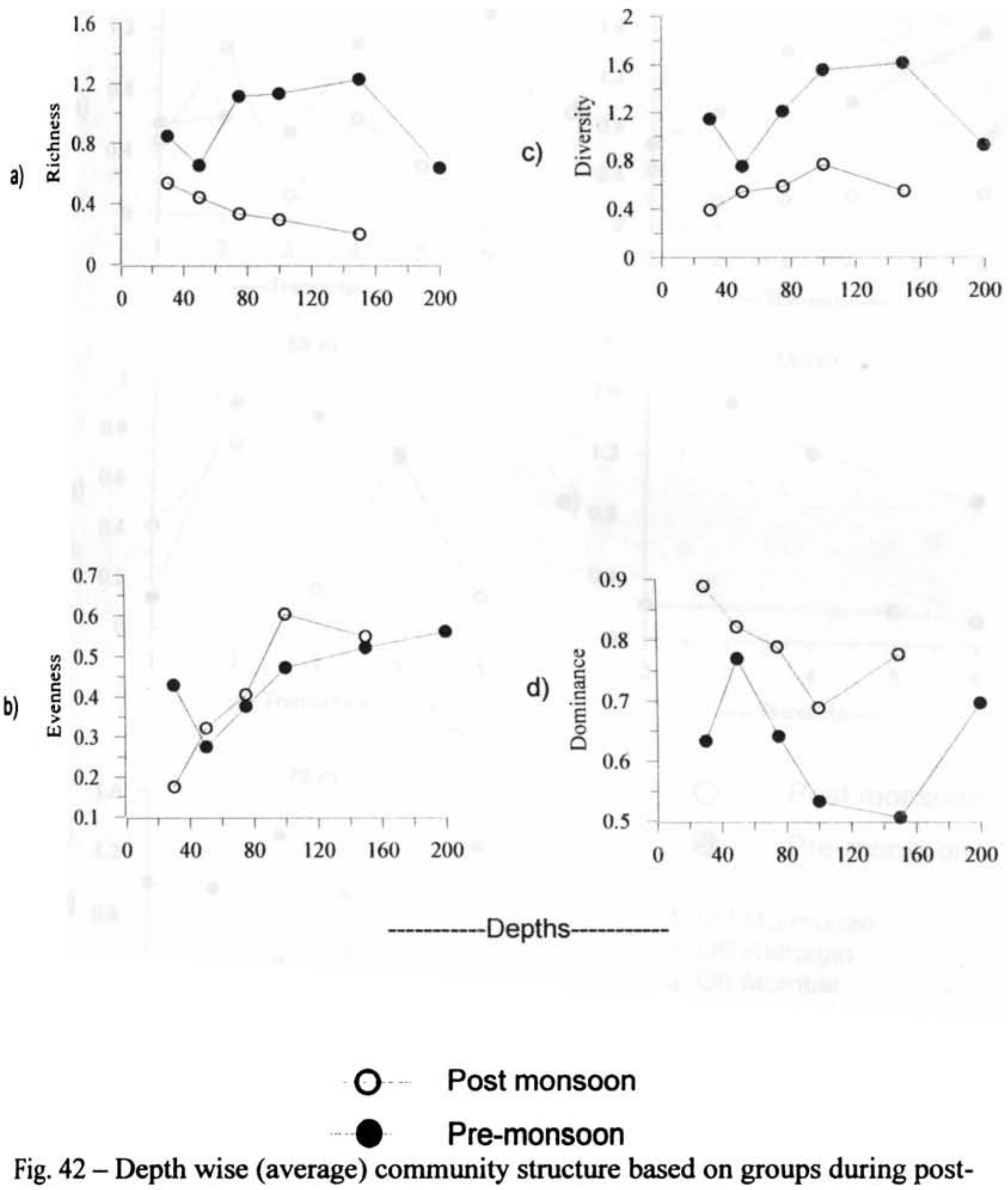


Fig. 42 – Depth wise (average) community structure based on groups during post-monsoon and pre-monsoon season

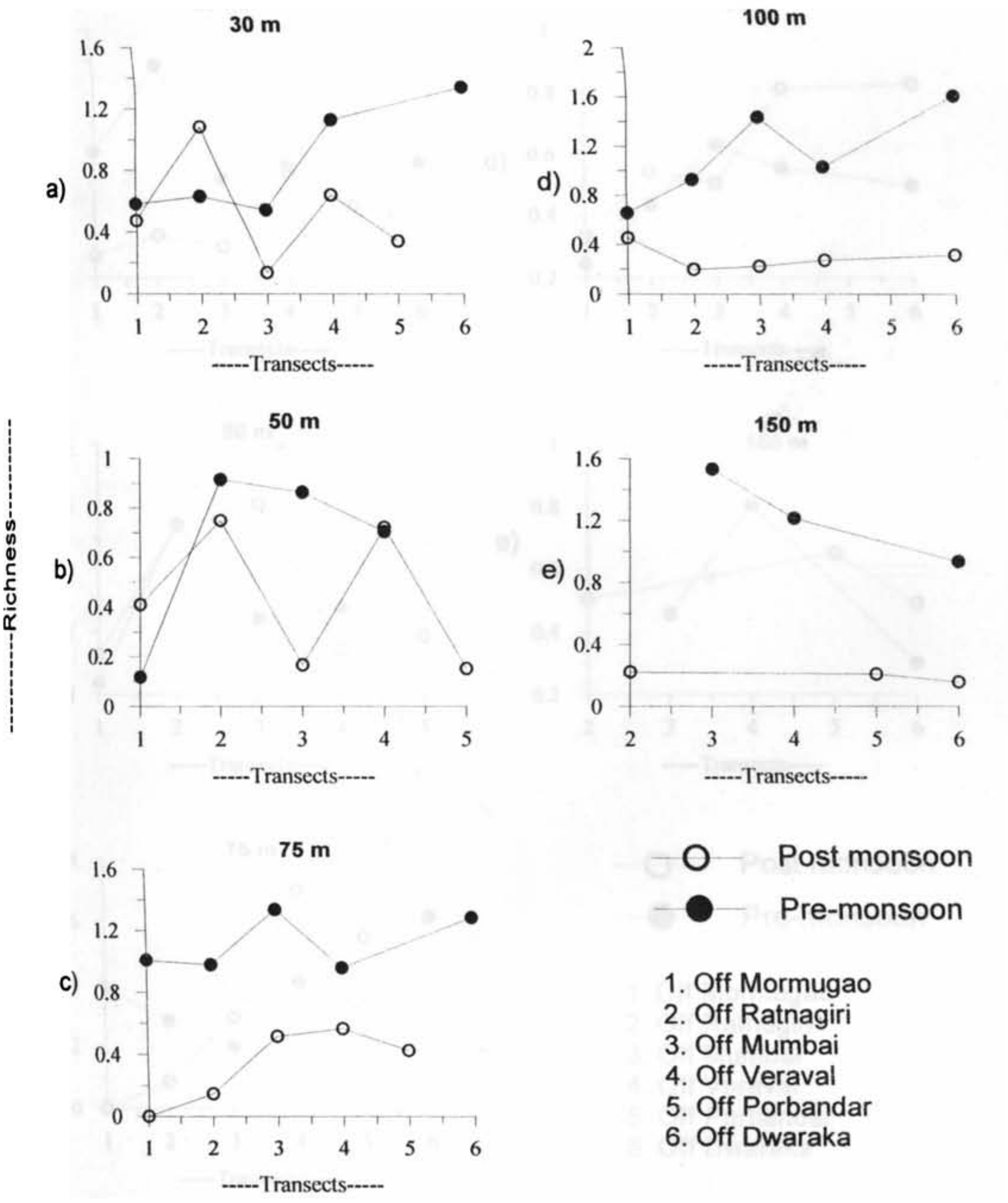


Fig. 43 - Transect wise richness based on groups during post-monsoon and pre-monsoon season during different depth zones

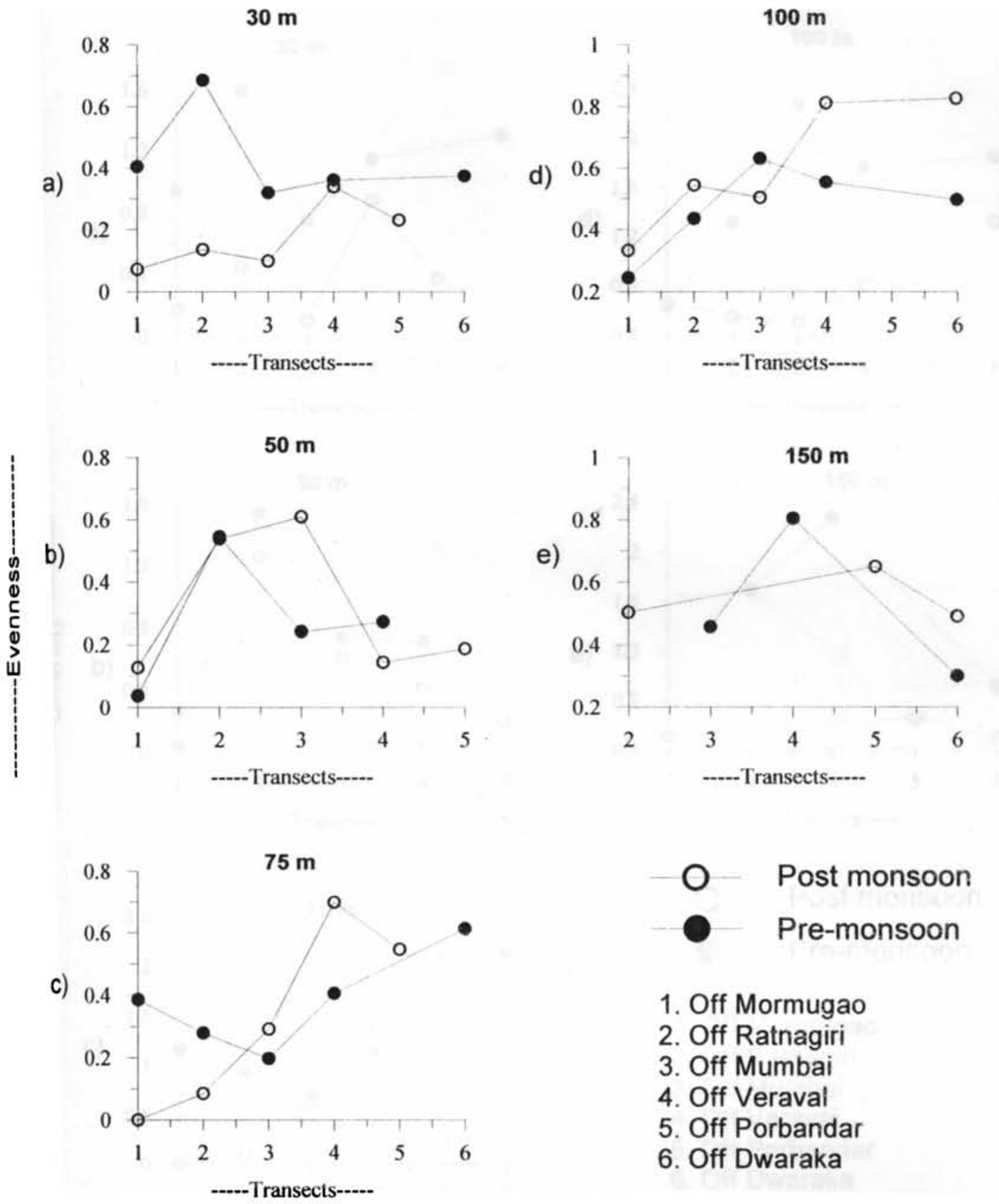


Fig. 44 - Transect wise evenness based on groups during post-monsoon and pre-monsoon season in different depth zones

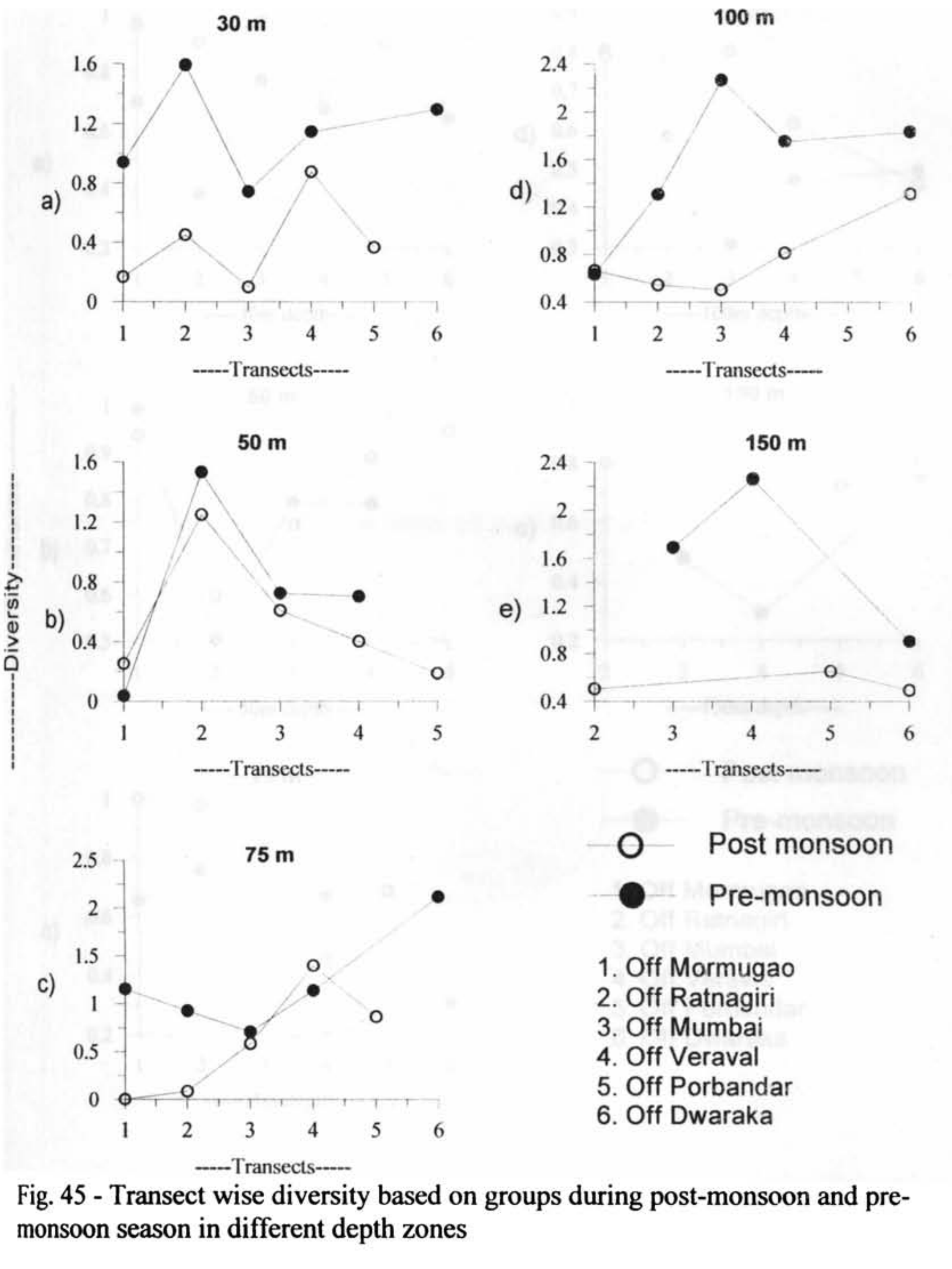


Fig. 45 - Transect wise diversity based on groups during post-monsoon and pre-monsoon season in different depth zones

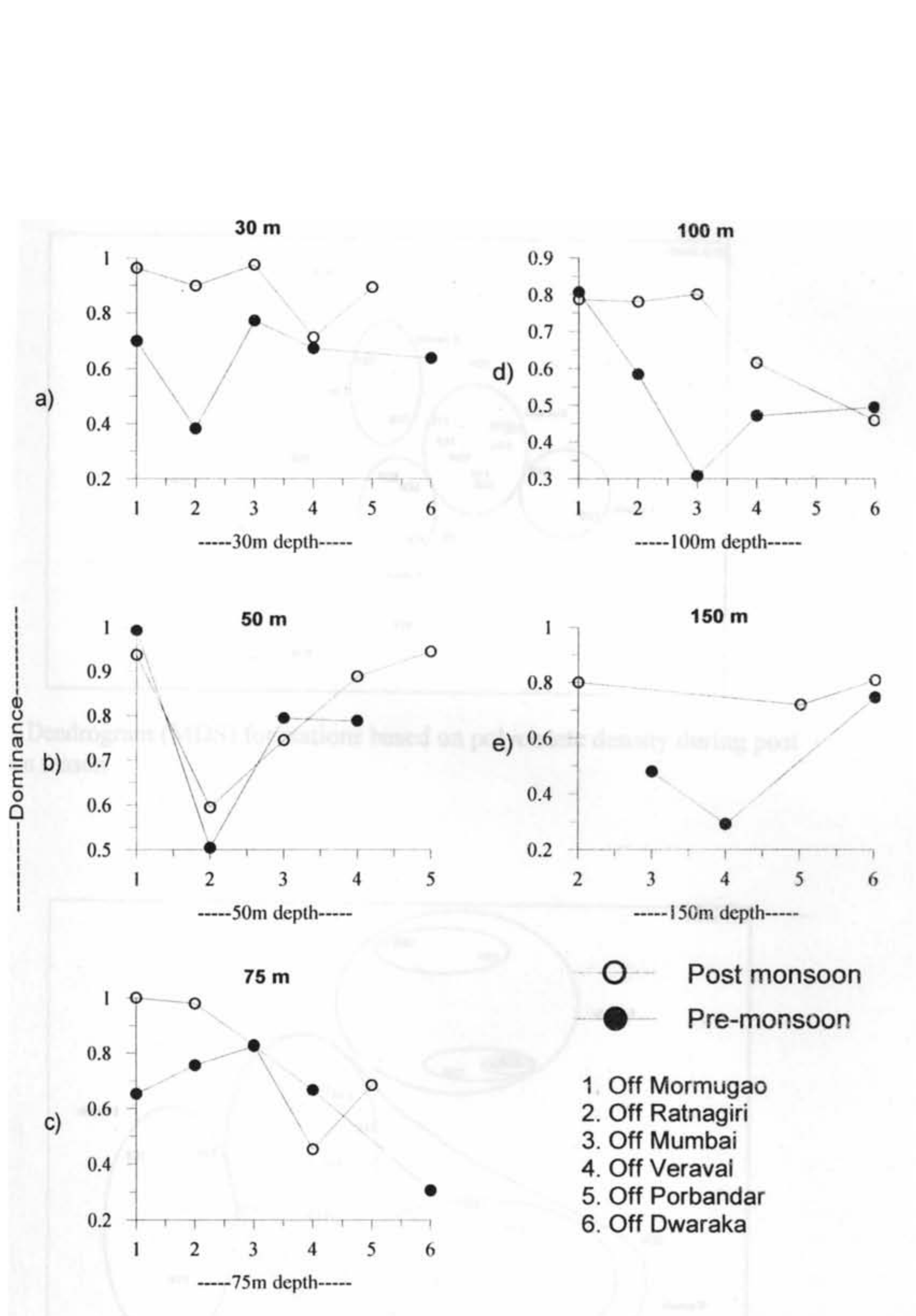


Fig. 46 - Transect wise dominance based on groups during post-monsoon and pre-monsoon season in different depth zones

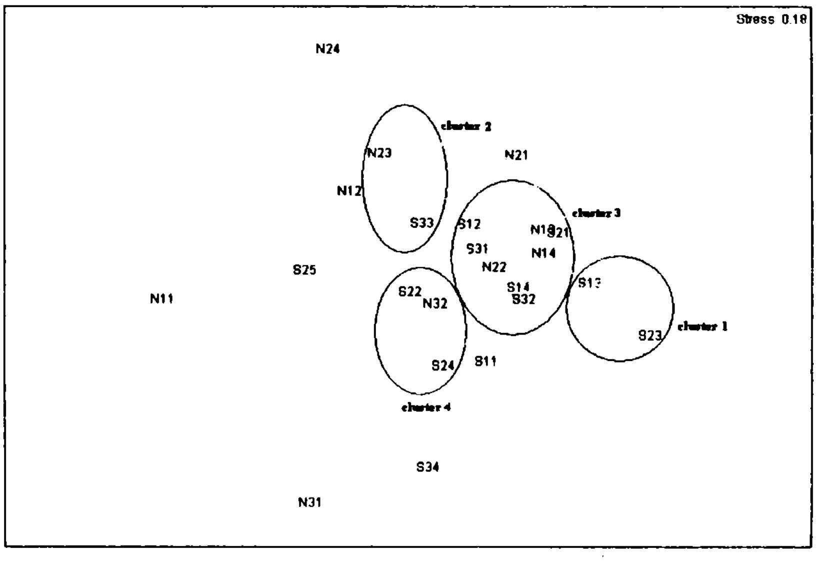


Fig. 47 - Dendrogram (MDS) for stations based on polychaete density during post -monsoon season

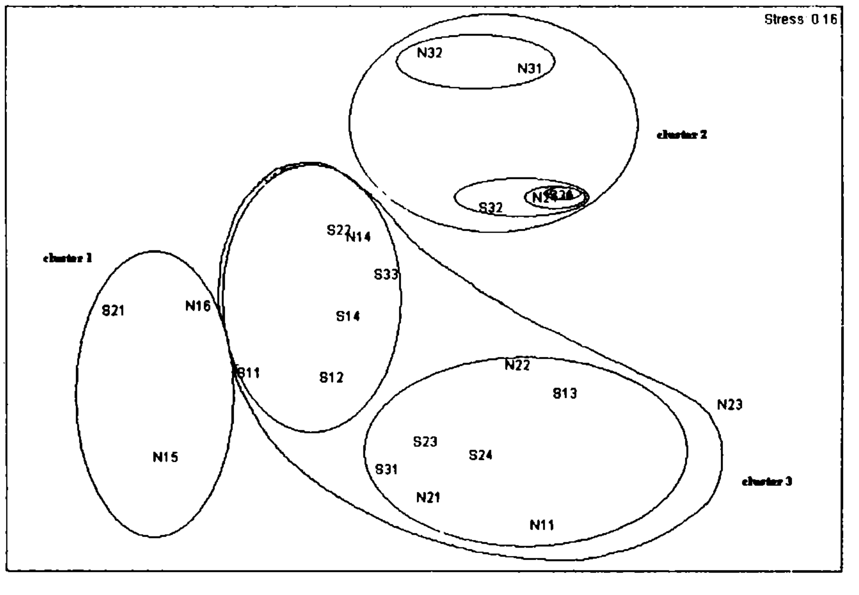


Fig. 48 - Dendrogram (MDS) for stations based on groups during post-monsoon season

S. boa	*Sthenelais boa*	c. cirr	*Cirratulis cirratus*
p. indica	*Pisionidens indica*	c. afr	*Cirriformia afer*
a. constr	*Ancistrosyllis constricta*	s. pauln	*Schroederella paulin*
ohidms	*Ophiodromous sp.*	s. dub	*Scolaricia dubia*
s. amic	*Syllis amica*	a. favl	*A.fauveli*
n.dibrn	*Nephtyis dibranchis*	a. capn	*Aricidea capensis*
g. long	*Glycera longipinnis*	p. grgr	*Paraonis gracilis gra.*
g. emert	*Goniada emerata*	p. lyrly	*P.lyralyra*
g. kamrn	*Glycinde kameruniana*	p. lyrcp	*Paraonides lyracape*
e. antn	*E. antennata*	c. cost	*Cossura coasta*
Diaptr	*Diapatra sp.*	c. capt	*Capitella capitata*
l. latrl	*L.latreilli*	n. favl	*N.fauvelli*
l. abbrn	*Lumbrineries aberans*	n. abrn	*Notomastus aberans*
l. hart	*L. hartmani*	md. capn	*Mediomastes capens*
p. elgn	*Pygospio elegans*	h. bifd	*Heteromastides bifida*
m. indc	*Malacocirus indicus*	p. tens	*Paraheteromastes ten*
p. cirr	*P.cirrifera*	ml. capn	*Maldenella capensis*
p. poly	*P.polybranchiata*	m. srs	*Maldane sarsi*
p. pinn	*Prinospio pinnata*	s. sct	*Steraspis scutata*
p. sex	*P. sexoculata*	p. cong	*Pycnoderma congoen*
p. ehlr	*P.ehlersi*	a. gunn	*Amphicteis gunneri*
m. cinct	*Magelona cincta*	a. acut	*Amphrete acutifrons*
m. capn	*M.capensis*	t. strm	*Terebellides stroemi*
t. dors	*Tharyx dorsobranchialis*	m. vesl	*Megalomma vesiculosa*
c. chry	*C.chrysoderma*		

Abbreviations used in dendrogram for groups and their expansion

Poly	Polychaetes	Nemat	Nematodes
Deca	Decapods	Sipn	Sipunculoides
Amphi	Amphipods	j fish	Juvenile fish
Iso	Isopods	Platyh	Platyhelminthes
Ostr	Ostracods	Nudbr	Nudibranches
Pelyc	Pelecypods	Echurd	Echiroides
Grastr	Gastropods	Nemat	Nematodes

Abbreviations used in dendrogram for groups and their expansion

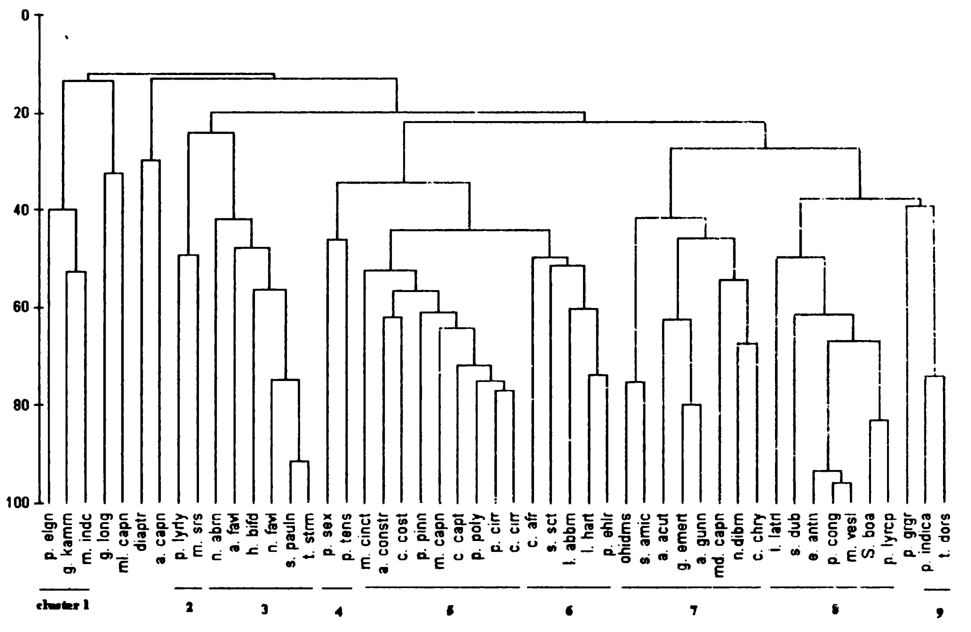


Fig. 49 - Dendrogram for polychaete species during post- monsoon

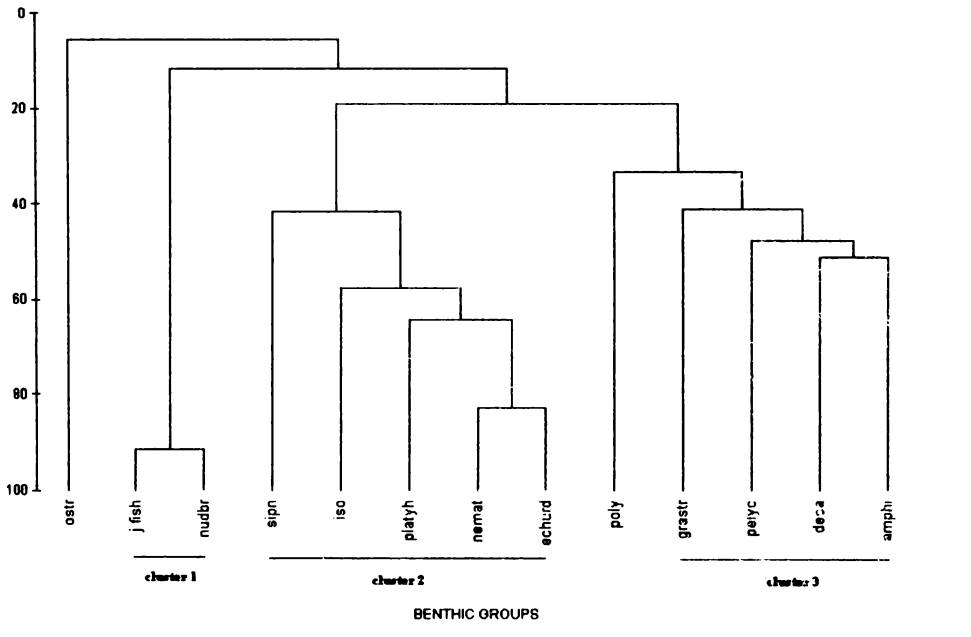


Fig. 50 - Dendrogram for benthic groups during post-monsoon

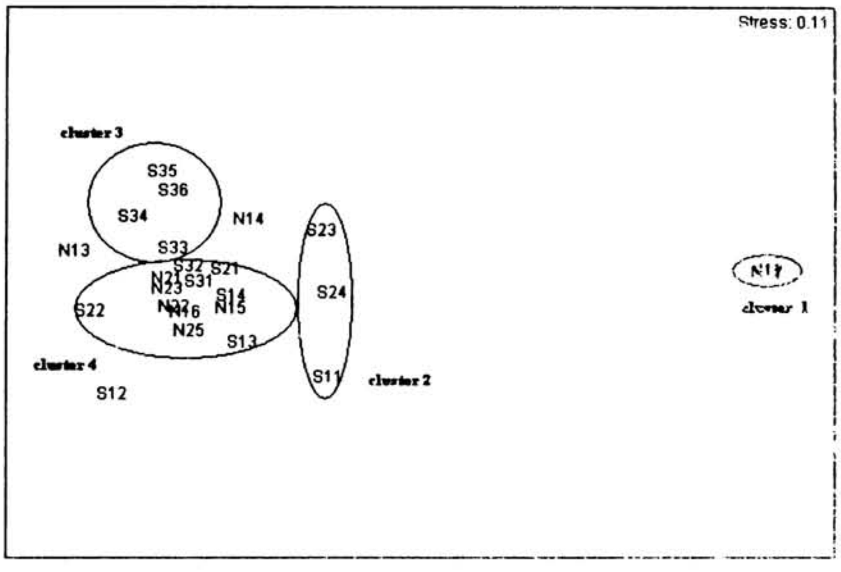


Fig. 51 - Dendrogram (MDS) for stations based on polychaete density during pre-monsoon season

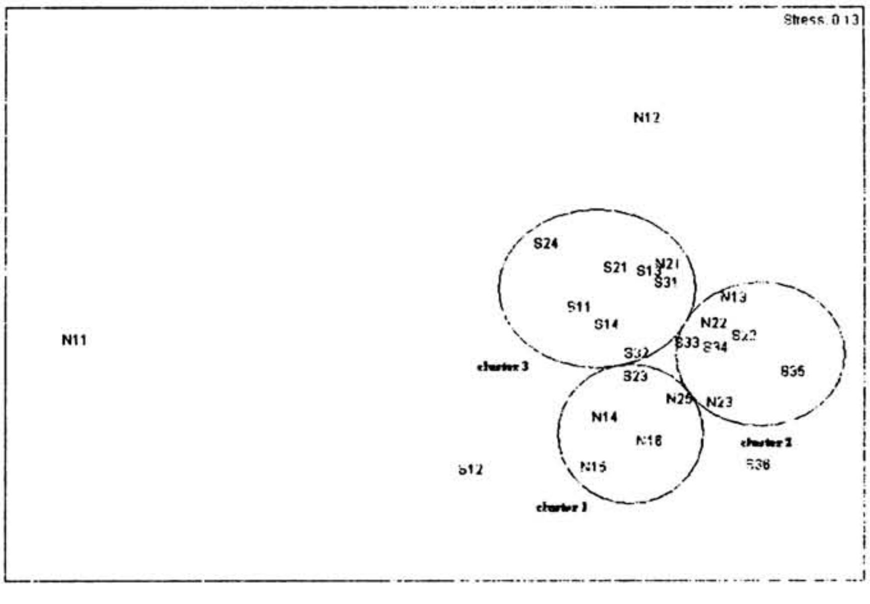


Fig. 52 - Dendrogram (MDS) for stations based on group density during pre-monsoon season

l. carin	*Lepidonotus carinulatus*	tharyx	*Tharyx sp*
S. boa	*Sthenalais boa*	C.chrys	*C.chrysoderma*
etione	*Etione sp*	C. cirr	*Cirratulis cirratus*
a. cons	*Ancistrosyllis consricta*	C. afer	*Cirriformia afer*
hesion	*Hesionidae sp.*	haplosc	*Haploscoloplos*
S.spong	*S.spongicola*	S. dubia	*Scolaricia dubia*
P. caldnt	*Platynerid caladonta*	orbnd	*Orbinidae*
P. cavfr	*Perineries cavifrons*	A.fauvl	*A.fauveli*
N. dibran	*Nephthys dibranchis*	p.grac	*P.lyralyra*
G. long	*Glycero longipinnis*	C costa	*Cossura coasta*
g. alba	*glycera alba*	C.capit	*Capitella capitata*
G. emrt	*Gonioda emerata*	N.fawl	*N.fawvelli*
lumbr	*Lumbrineries sp*	S. bmbx	*Spiophane bombyx*
L.later	*L. laterali*	N. abran	*Notomastus aberrans*
L aber	*L. aberrans*	N. latr	*N. latericeus*
L. hart	*L. hartmani*	M. capn	*Mediomastes capensis*
p. tens	*Paraheteromastes temuis*	H bifid	*Heteromastides bifidus*
D. gardn	*Dorivilla gardineri*	scypho	*Scyphoproctus sp.*
P. eleg	*Pygospio elegans*	M. sars	*Maldane sarsi*
P.cirrif	*P.cirrifera*	S. scut	*Steraspis scutata*
P.poly	*P.polybranchiata*	flbgd	*Flabelligerid sp.*
P. pinn	*Prinospio pinnata*	pectnr	*Pectinaria sp*
p. cirro	*P. cirrobranchia*	A. gunnr	*A.gunneri*
M. cinct	*Magelona cincta*	T. strmi	*Terebellides stroemi*

Abrevations used in dendrogram for groups and their expansion

poly	Polychaetes	j fish	Juvenile fish
deca	Decapods	ophurd	Ophiroidea
amphi	Amphipods	echrd	Echiroides
iso	Isopods	holoth	Holothuria
Cuma	Cumacea	s urchn	Sea urchin
mysd	Mysid	cephpd	Cephalopods
tand	Tanaidacea	nemert	Nemertene worm
pelcy	Pelecypods	unideg	Unidentified eggs
gastr	Gastropods	chyrmd	Chyronomid larvae
scaph	Scaphopods	iunid	Unidentified polychaetes
olygo	Olygochaetes	ampx	Ampheoxus
nemat	Nematodes	bryoz	Bryozoa
sipun	Sipunculoides		

Abbreviations used in dendrogram for groups and their expansion

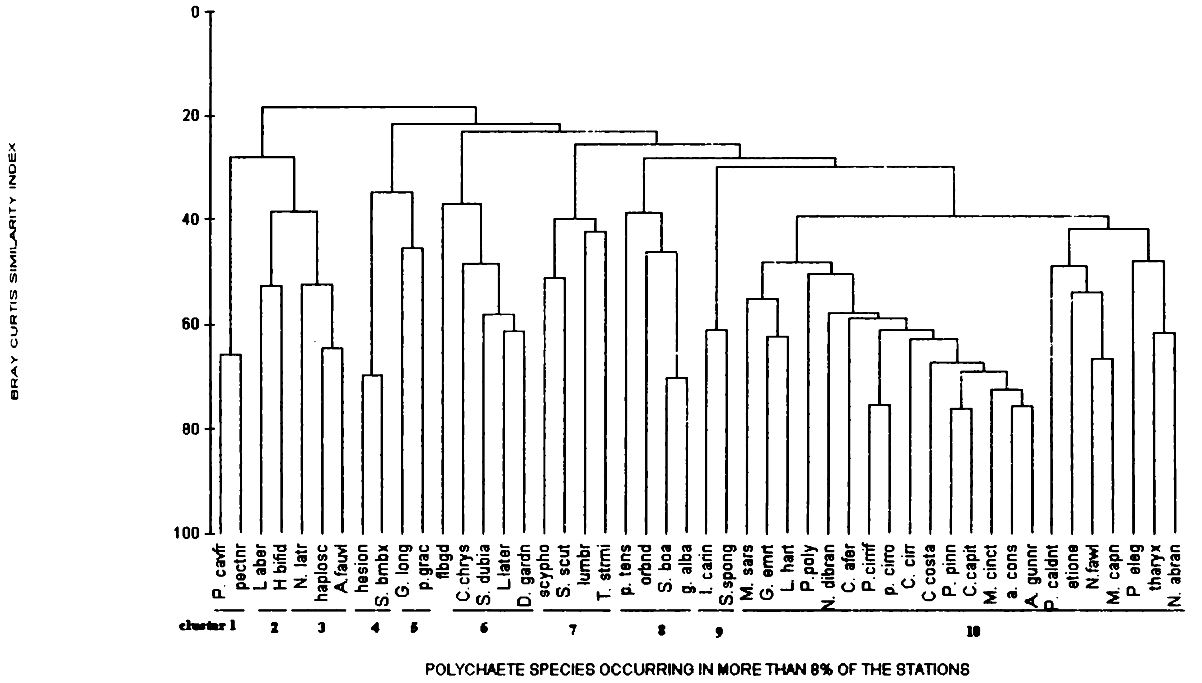


Fig. 53 - Dendrogram for polychaete species during pre-monsoon

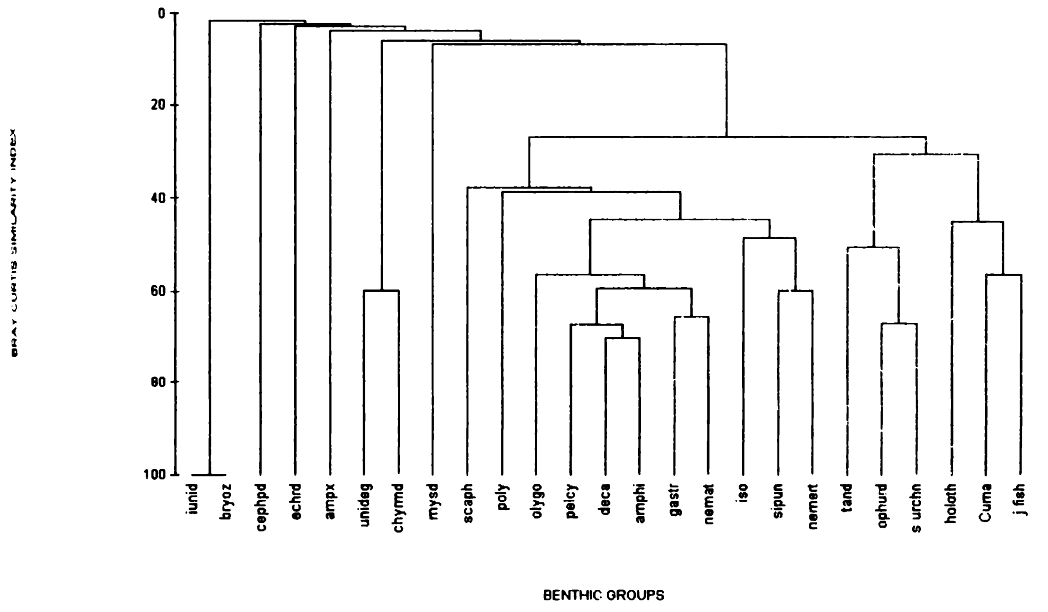
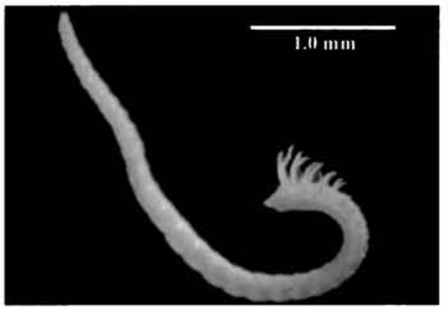


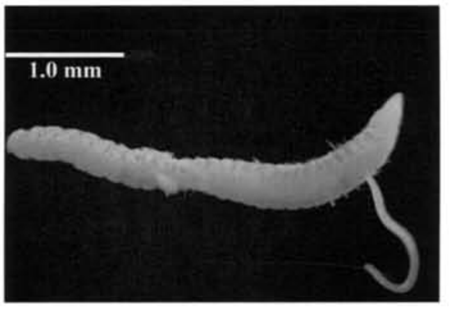
Fig. 54 - Dendrogram for benthic groups during pre-monsoon



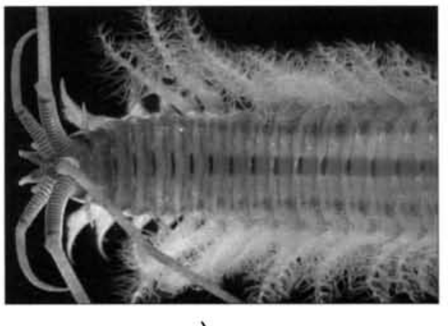
a)

b)

c)

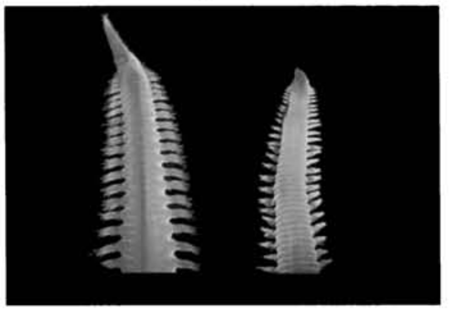


d)



e)

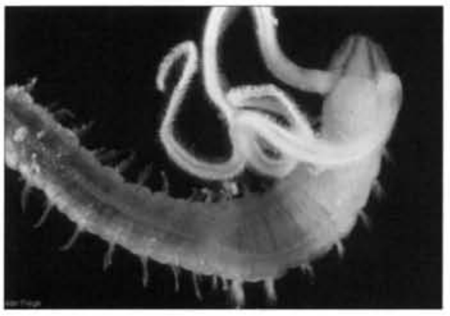
f)



g)

h)

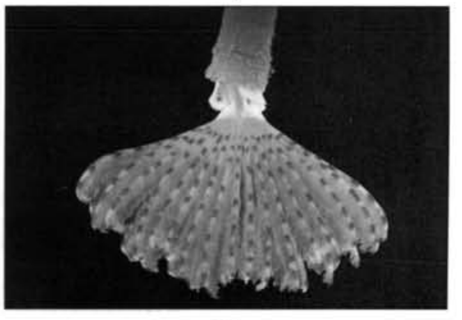
Plate 5 *a) Prinospio sp.* *b) Capitella sp.* *c) Syllis sp.* *d) Cossura sp.*
e) Diopatra sp. *f) Cirratulus sp.* *g) Glycera sp.* *h) Nephtys sp.*



a)

b)

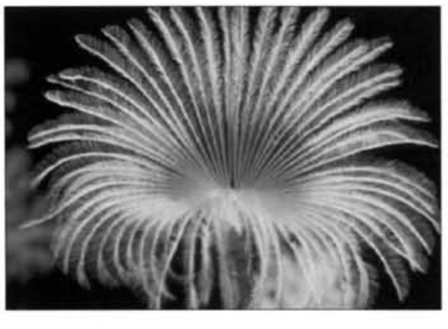
c)



d)

e)

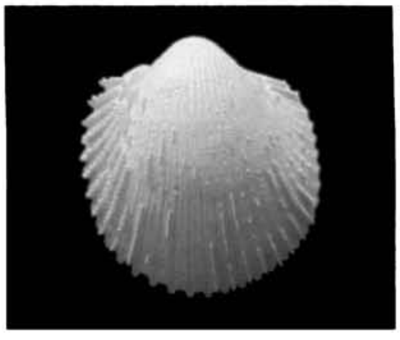
f)



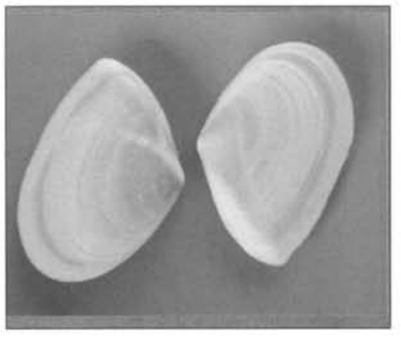
g)

h)

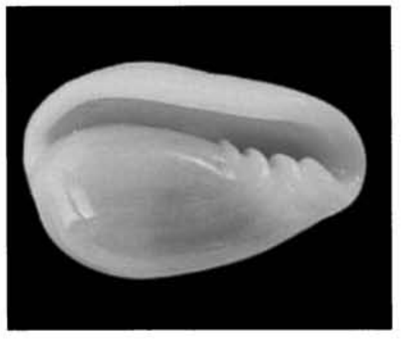
Plate 6 *a) Magelona sp.* *b) Arenicola sp.* *c) Sabella sp.* *d) Sabella sp.*
e) Serpula sp. *f) Serpula sp.* *g) Serpula sp.* *h) Serpula sp.*



a) b)



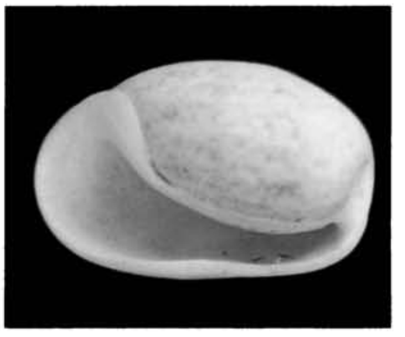
c) d)



e) f)

Plate 7 *a) Cardium sp.* *b) Cardium sp* *c) Tellina sp.*
d) Mactra sp. *e) Prunum sp.* *f) Prunum sp.*

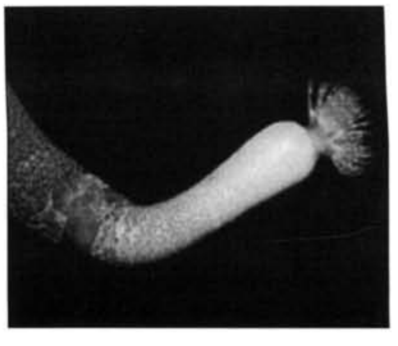
a)



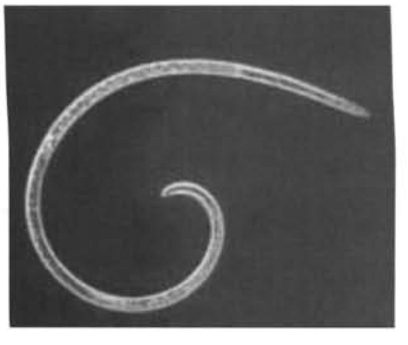
b)

c)

d)



e)



f)

Plate 8 *a) Atys sp.* *b) Bulla sp.* *c) Nudibranch*
d) Grandidierella sp. *e) Sipunculid* *f) Nematod*

Chapter 7.

Ecological relationships

7.1. Introduction

Abundance and diversity of benthic organisms are controlled by various environmental parameters such as temperature, salinity, DO, OM and sediment texture. Depending upon the habitat and the community inhabits, the intensity in the influence of these factors also varies. All factors have a positive correlation at its optimum levels and influence negatively beyond this limit and this optimum limit varies with organisms. Based on the habitat, like intertidal zone, littoral and deep sea, organisms develop many adaptations to cope up with the environmental conditions.

Arabian sea is unique for its seasonally oscillating monsoon system and associated features (Qasim, 1982). Northern Arabian Sea is peculiar in its negative water balance, which result in the formation of several low and high water masses

(Gupta and Naqvi, 1984). It is also a unique feature in its land locked boundary in the north and predominant oxygen minimum zone prevailing in that area. All these have an effect on the benthic community and previous studies in the estuarine and coastal waters have shown the effect of various environmental factors on benthic distribution (Varshney *et al*., 1988; Harkantra and Parulekar, 1991&1994; Ansari *et al*., 1994; Harkantra and Rodrigues, 2003) and the destruction of benthic fauna associated with fresh water influx during monsoon and their re-colonization (Harkantra and Parulekar, 1981, Vizakat *et al.,* 1991).

7.2. Hydrography

7.2.1. Temperature

From the hydrographic data a decrease in temperature with increase in depth and also a northward increase was evident during post-monsoon. Similar to the distribution of temperature, total benthic biomass also showed a decrease towards deeper depth zones during post-monsoon, which clearly indicated the influence of temperature on benthic production. Similar to the total biomass, biomasses of polychaetes and miscellaneous groups also decreased with depth. Molluscs showed comparatively high values at 30 m and 50 m while crustaceans were abundant at 30 and 50 m with some exceptionally high values at deeper depths (100 m). Results revealed that temperature appears to influence the entire benthic community. Correlation analysis (Table 27) showed a positive relation of total biomass ($r=0.600$, $p<0.01$) and biomasses of polychaetes ($r=0.503$, $p<0.05$), molluscs and miscellaneous groups ($r=0.452$, $p<0.05$) with temperature. Crustaceans also showed positive correlation with temperature during this season, even though some exceptionally high values were observed in deeper stations. During pre-monsoon, temperature increased from 30 m to 50 or 75 m and then decreased to deeper depths and it also showed a decrease towards north. During this season, low value of total biomass was observed in 30 m and high values at 50 m and 75 m depths followed by a decrease showing the positive effect of temperature. As that of total biomass, biomass of polychaetes and miscellaneous groups were generally high in shallow and middle depths (up to 75 m) and low in deep, while crustaceans and molluscs exhibited a different trend. Correlation analysis also (Table 27) showed positive correlation with total biomass, biomass of polychaetes, molluscs and miscellaneous groups but showed a negative correlation with crustaceans. No obvious latitudinal relationship was noticed during both the seasons with temperature even though high biomass was observed in the north during both the seasons. There was a positive correlation of density of polychaetes, crustaceans, miscellaneous groups and total density with temperature and all are at significant level during post-monsoon (Table 28). But negative relation was encountered with the density of molluscs. During pre-monsoon, positive correlation was observed with density of polychaete and mollusc and total density whereas negative relation was found with crustaceans and miscellaneous groups (Table 28).

Effect of temperature on the community structure of polychaete species and all the groups combined are given in figs. 55 & 56 during post-monsoon and pre-monsoon season respectively. During post-monsoon, species richness and diversity of polychaetes (Fig. 55 a-d) showed positive correlation with temperature, evenness was not much affected by temperature and dominance was negatively correlated with temperature. Community structure based on groups (Fig. 55 e-h) showed that richness and dominance were positively dependent on temperature and evenness and diversity were negatively influenced by temperature. During pre-monsoon, species richness, evenness and diversity of polychaetes (Fig. 56 a-d) showed positive correlation, but dominance showed a negative correlation with temperature. Richness, diversity and evenness based on groups (Fig. 56 e-h) showed negative correlation with temperature and dominance showed a positive relation.

Sanders and Hessler (1969) reported water temperature as a factor responsible for pronounced changes in the macrofaunal composition at depths from 100 to 300 m along Gay Head-Bermuda transect and they inferred that this depth range represents the upper boundary of the deep sea macrobenthos. Parulekar and Ansari (1981) reported important role of temperature in the distribution and abundance of macrobenthos in the Andaman Sea. Joydas (2002) observed a decrease in temperature with increasing depth associated with decrease in faunal biomass and abundance in the shelf waters of west coast of India. Sarma and Mohan (1981) who studied the interstitial fauna off Bhimilipatnam, east coast of India, observed a direct correlation of organisms with temperature. They added that temperature affects the abundance of organisms indirectly by controlling salinity and DO content of the interstitial waters.

7.2.2. Salinity

Salinity increased with depth in the southern transects of Mormugao and Ratnagiri while in rest of transects it decreased to deeper depth during post-monsoon. As that of salinity, total biomass, biomass of polychaetes, molluscs and miscellaneous groups were also decreased towards deeper stations however, crustaceans were more in shallow and deeper depths during post-monsoon. Correlation analysis also showed that (Table 27) during post-monsoon, biomass of total benthos, polychaetes, molluscs, and miscellaneous groups were also positively correlated while crustaceans were negatively correlated. During pre-monsoon, salinity was low in shallow depths and was more in the higher depths in the southern transects (Off Mormugao, Ratnagiri and Mumbai) and in northern transects it was high in shallow depths. Total biomass in southern transects during pre-monsoon, was low in 30 m and increased to 50 m and 75 m then decreased towards deep while in northern transects biomass was more in shallower stations including the 30 m and showed a positive relation with salinity. As that of total biomass, biomass of polychaetes was also low in 30 m and it increased to 50 m and 75 m in the southern transects. Total biomass in the northern transects stations (Off Veraval and Dwaraka) also showed a similar pattern with salinity distribution. Miscellaneous groups showed a more or less similar pattern with salinity in the northern and southern transects. But crustaceans and molluscs were more in deeper stations. Correlation analysis (Table 27) showed positive correlation with total biomass, biomass of polychaetes, crustaceans and miscellaneous groups and negative correlation with molluscs. Latitudinally, salinity showed an increase towards north in most of the depth zones during both seasons and benthic biomass was also more in the northern stations during both seasons. This may be due to the influence of salinity on benthic production. Comparatively high salinity was observed during pre-monsoon, which corroborates with the high biomass in that season. During post-monsoon polychaete density and total density was negatively correlated with salinity (Table 28), but density of crustaceans, molluscs and miscellaneous groups showed positive correlation with salinity of which the relation with molluscs is at significant level ($r=0.505$. $p<0.05$). During pre-monsoon, total density and density of individual groups were also positively correlated of which relation with crustaceans was significant ($r=0.421$, $p<0.05$) (Table 28).

Effect of salinity on the community structure of polychaete species and all the groups combined are given in figs. 57 & 58 during post-monsoon and pre-monsoon season respectively. During post-monsoon, species richness, evenness and diversity were negatively correlated with salinity while dominance was positively correlated (Fig. 57 a-d). Community structure based on groups (Fig. 57 e-h) showed that evenness and diversity were positively correlated while richness is not much affected by salinity and dominance was negatively influenced by salinity. During pre-monsoon, species richness and diversity were positively correlated while dominance was negatively correlated and evenness have not much controlled b salinity (Fig. 58 a-d). Community structure based on groups (Fig. 58 e-h) showed similar relationships as that of species.

Many workers have suggested that salinity had a strong relation with benthos. Harkantra and Parulekar (1991), Vizakat *et al.*,(1991) and Harkantra and Parulekar (1994) reported decreased population of benthos during monsoon months and its recolonisation after the monsoon indicated the role of salinity in benthic production. Ingole and Parulekar (1998) stated that salinity could act as a community regulator determining the physiological activity of marine organisms. They observed two maxima in faunal abundance first in December and second in March. This agrees with the present study as high benthic biomass was observed during pre-monsoon and it might be due to the second recolonisation after the post-monsoon season with increasing salinity as observed by the above authors along with other ecological parameters. Temperature and salinity of the sea water were regarded as important regulators of the reproductive cycle of marine invertebrates (Kinne, 1977; Ingole and Parulekar, 1998) and those marine species inhabiting the tropical region generally have very narrow range of temperature tolerance since they normally live in a temperature regime that is closer to their upper tolerance limit. Therefore important variables controlling the distribution and abundance of benthic organisms in the tropical regime were salinity (Parulekar and Dwivedi, 1974; Alongi, 1990;) and sediment stability (Wildish and Kristmanson, 1979; Warwick and Uncles, 1980).

7.2.3. Dissolved oxygen (DO)

During both seasons DO decreased towards deeper depths and showed anoxic condition especially in the northern transect. In shallow depth zones, DO was low in southern transect and comparatively high in the northern transect. Increasing trend of biomass towards north showed positive correlation with high DO in the north. But in the deeper depths (beyond 100 m) DO drastically reduced and northern latitude stations recorded very low values. The lowest biomass was also observed in the deeper depths (beyond 100 m) during both seasons. This could be due to the anaerobic or suboxic condition prevailing in that region which could not be tolerated by most of the organisms. It was also noted in the present study that, DO was comparatively high during pre-monsoon and low during post-monsoon. This high DO value during pre-monsoon might also have positively influenced high benthic biomass in this season when compared to post-monsoon. Correlation analysis showed that (Table 27), during post-monsoon, total biomass and biomass of polychaetes, molluscs and miscellaneous groups were positively correlated with DO while crustaceans were negatively correlated. During pre-monsoon, total biomass and biomass of polychaetes and miscellaneous groups were positively correlated with DO whereas crustaceans and molluscs were negatively correlated. For density, correlation analysis showed that (table 28) all benthic groups were positively correlated with DO except molluscs during post-monsoon season, and the relation between crustaceans were at significant level ($r=0.423$, $p<0.05$) but during pre-monsoon, crustaceans and molluscs were negatively correlated with DO while total density and density of polychaetes and miscellaneous groups were positively correlated (Table 28).

Effect of DO on the community structure of polychaete species and all the groups combined are given in figs. 59 & 60 during post-monsoon and pre-monsoon season respectively. During post-monsoon, DO had no effect on species richness, but evenness and diversity was positively correlated and dominance was negatively correlated with DO (Fig. 59 a-d). Community structure based on groups (Fig. 59 e-h) showed that richness and diversity was positively controlled by DO while dominance was negatively correlated, DO did not show much control over evenness. During pre-monsoon, species richness, evenness and diversity were positively controlled by DO while dominance was negatively controlled by DO (Fig. 60 a-d). Community structure based on groups (Fig. 60 e-h) showed that richness and evenness were not much controlled by DO where as negatively influencing on diversity and positively on dominance.

Decrease of benthos with DO agrees with earlier reports. Neyman (1969) noticed a decline in benthic organisms in the northern shelf of west coast of India at the depth of 75 to 200 m and this was attributed to the impact of reduced DO. Parulekar and Ansari (1981) pointed out that low levels of DO especially below 200 m depth in the Andaman waters resulted in low macrobenthic biomass. Rosenberg (1977) reported that low oxygen content causes high physiological stress resulting in considerable impoverishment in the benthic production. Joydas (2002) recorded near anoxic values in the depth >150 m in the northern shelf edge of Arabian Sea characterized by low biomass, density, species richness and diversity which also agrees with present observation.

7.3. Sediment Texture

The results of the sediment analysis showed that clay content predominated in the shallow depths and sand in the deeper depths during both the seasons. Moreover, southern transects recorded sand dominated sediment and northern transects were dominated by fine sediment. Total biomass and biomass of polychaetes, molluscs and miscellaneous groups were high in shallow depths and low in deeper depths thus showing the influence of fine texture. Biomass of crustaceans was higher in deeper depths showing the influence of the sand dominating texture. Correlation analysis showed that (Table 27) during post-monsoon, total biomass ($r = -0.515$, $p<0.05$), biomass of polychaetes ($r = -0.427$, $p<0.05$), molluscs and miscellaneous group were negatively correlated with sand while crustaceans were positively correlated with sand. Clay showed reverse effect and positively correlated with total biomass and with all component groups except crustaceans. During pre-monsoon, total biomass, polychaete biomass and miscellaneous group biomass were negatively correlated with sand, while crustaceans and molluscs were positively correlated (Table 27). With clay, all groups showed the reverse trend. During post-monsoon, correlation analysis showed that (Table 28) density of all the groups were negatively correlated with sand of which total density ($r=-0.499$, $p<0.05$) and density of polychaetes ($r=-0.469$, $p<0.05$) were at significant level. During pre-monsoon, all groups were positively correlated of which relation with crustaceans was significant ($r=0.430$, $p<0.05$) (Table 28). Organisms showed an opposite relation with clay that of sand in both seasons.

Effect of sediment texture on the community structure of polychaetes and all other major faunal groups during post-monsoon (Fig. 61-63) and pre-monsoon (Figs. 64-66) are as follows. During post-monsoon, sand had not much effect on species richness (Fig. 61 a-d). Sand positively influenced species evenness and diversity but negatively influenced dominance. Richness based on groups had not much influenced by sand as that of polychaete species (Fig. 61 e-h). Evenness and diversity was positively correlated while dominance was negatively correlated with sand. Correlation of community structure of silt showed that richness have not influenced by silt, diversity and evenness were negatively influenced and dominance was positively influenced (Fig. 62 a-d). For groups, also a pattern similar to polychate species was noticed (Fig. 62 e-h). Clay showed opposite relation with that of sand (Fig. 63 a-h) on species and groups. During pre-monsoon, sand had not much influence on species richness, evenness, diversity and dominance (Fig. 64 a-d) but community structure based on groups showed richness, evenness and diversity with slight positive correlation with sand (Fig. 64 e-h) whereas dominance showed negative correlation with sand. Community structure based on polychaetes and groups were not much controlled by sily ((Fig. 65 a-h). Clay showed opposite effect as that of sand (Fig. 66 a-h).

Sediment texture influenced the distribution of most of the groups positively as most of the benthic groups depend on the sediment substratum for feeding and attachment. During post-monsoon, sand percentage was high in the deeper depths and clay content was high in the shallow depths. Most of the groups recorded high biomass in the shallow depths and decreased to deep with some stray values for crustaceans. This indicated that during post-monsoon most of the groups were positively correlated with fine sediment and negatively correlated with sand except for crustaceans. The fuanal distribution with respect to texture also (Table 29) showed that during post-monsoon polychaetes was abundant in the silty clay and clayey sediment while crustaceans were more in silty clay and clayey sand. Molluscs preferred silty clay substratum and miscellaneous groups were present only in silty clay and clayey sediment. Thus during post-monsoon most of the benthic groups preferred fine sediment texture with low sand content. This was evident from the decrease of biomass of all benthic groups with the increase in sand except the crustaceans. During pre-monsoon, sand prevailed in the deeper depths and clay content was more in the shallow depths. The abundance of Polychaetes and miscellaneous groups in the shallow depths indicated their affinity to the fine sediment and abundance of crustaceans and molluscs in the deeper stations clearly indicated a positive correlation with sand content. The faunal distribution with respect to different texture also (Table 29) showed that during pre-monsoon, polychaetes preferred fine sediment texture with a mixture of sand and clay. Crustaceans dominated in sandy sediment while molluscs were abundant in the clayey sand and the sandy sediment. This showed the preference of crustaceans and molluscs to the sand dominated sediment.

Results showed that total biomass and biomass of polychaetes and miscellaneous groups were positively correlated with fine sediment and that of crustaceans with coarser fraction. Molluscs prefer sand or a mixture of sand and mud. From statistical analysis (Table 27 &28) it was clear that most of the benthic groups were influenced by sediment texture in their distribution even though it was not at a significant level. So it can be stated that sediment texture is not the single controlling factor, texyure together with other ecological factors controls the benthic distribution.

Earlier works also reported the preference of benthos to the substrata. Neyman (1969) observed that polychaetes, bivalves and echiuroidea were abundant in the muddy bottom of the west coast of India. Ansari *et al.*, (1977) stated that polychaetes prefer muddy sand and were completely absent in the clayey sediment. Pelecypods prefer fine sediment with high percentage of silt and clay and they have also noticed that amphipods depend on the availability of OM rather than the type of sediment. Savich (1972) also observed the dependence of benthos to the substratum. Parulekar and Wagh (1975) studied the benthos of northeastern Arabian shelf and suggested that bottom deposits of sand with a mixture of clay or silt form an ideal substrate for polychaetes and bivalves. They also inferred that substratum, along with OM act as an important ecological factor in the distribution of bottom fauna along the north west coast of India. Eggleton (1931) found complete absence of bottom animals on a substratum of clean sand, but he added that a dense population could exist if there is a strong current bringing in nutrients or the productivity of the water column above is high. Panikkar and Aiyar (1937) observed the absence of animals on substrata of thick clay and their abundance on loose substratum. Kurian (1967) observed that sandy deposits had high abundance of benthos at some places while in others, production was low in similar deposits and suggested that type of substratum cannot be considered independently as a major ecological factor determining the distribution and abundance of bottom fauna. Harkantra *et al.*, (1982) found the dominance of polychaetes in the silty sand and low in the clayey sediment while bivalves were more in the sandy clay and suggested that seston feeding animals were mainly restricted to sandy areas with low percentage of silt and clay whereas detritus feeders and deposit feeders were restricted to muddy areas. A specificity of faunal density to the type of substratum largely depends on feeding habits. Presumably fine particles of clay results in the clogging of filter feeding apparatus of the filter feeders hence its avoidance from inhabiting the fine particle size substrata.

Sanders (1968) and Boesch (1973) suggested that in a given geographical area, sandy substratum harbour high standing stock of benthic fauna besides supporting a more diversified community than muddy sediment. Devassy *et al.*,

(1987) also found high population density in the shallow areas where the texture was sandy and low density in higher depths where the texture was muddy in nature. Ingole *et al.*, (1992) reported that variation in benthic standing crop might be due to the changes in sediment texture and variation in depth. Thomas (1970) stressed the importance of substratum in controlling the abundance of marine organisms and stated that the abundance of sediment covering coarser bottom has pronounced effect on benthic biota. Ansari *et al.*, (1994) reported that the sandy sediments support high biomass and Ingole *et al.*, (2002) noticed that medium sand grain size support a good benthic crop. From the present study and the earlier reports it can be stated that type of substrata influences benthic abundance and distribution.

7.4. Organic matter (OM)

In the study area OM was generally high in the shallow depths (30m and 50 m) and low beyond 50 m with some exceptions especially in the northern transects during both the seasons. During post-monsoon, total biomass and biomass of polychaetes, molluscs and miscellaneous groups were more in lower depths (up to 50 m) while crustaceans were more in shallow depths (30 m and 50 m) with some exceptions in deeper depths. Correlation analysis (Table 27) showed that during post monsoon season total biomass, biomass of polychaetes, and miscellaneous groups were negatively correlated with OM while crustaceans and molluscs were positively correlated, of which relationship of molluscs was at a significant level ($r=0.457$, $p<0.05$). During pre-monsoon, total biomass, biomass of polychaetes and miscellaneous groups were more in shallow depths while molluscs were more in deeper depths and crustaceans were more in middle depths (75 m) and deeper depths. Correlation analysis (Table 27) showed that total biomass and biomass of all component groups were negatively correlated with OM. During post-monsoon, total density and density of polychaetes and molluscs were positively correlated, crustaceans and miscellaneous groups were negatively correlated while during pre-monsoon, all the faunal groups were negatively correlated (Table 28).

Effect of OM on the community structure of polychaetes and all the groups combined during post-monsoon and pre-monsoon season respectively is given in Fig. 67 and 68. During post-monsoon, species richness, evenness and diversity were negatively correlated with OM while dominance was positively correlated (Fig. 67 a-d). Community structure based on groups (Fig. 67 e-h) showed a positive correlation for richness, evenness and diversity with OM but negatively correlated with dominance. During pre-monsoon, richness, evenness and diversity were negatively correlated while dominance was positively correlated with OM (Fig. 68 a-d). Community structure based on groups (Fig. 67 e-h) showed a negative correlation with richness and diversity but not much controll on evenness and dominance.

In general no consistent relationship with OM was observed, however benthos were usually low in places with very high OM (>3%). The relationship between benthic abundance and percentage of OM has been studied by many workers (Bader, 1954; Sanders, 1968; Ganapati and Raman, 1973). Sanders *et al.*, (1965), Varshney *et al.*, (1988) and Joydas (2002) could not observe any consistent relationship between OM and faunal abundance. Bader (1954) while studying the abundance of bivalves in relation to percentage of organic carbon observed a decrease in population when the OM was more than 3%, which is comparable with the present study. He pointed out that beyond this concentration, products of bacterial decomposition and decline in the available oxygen become the limiting factors. Harkantra *et al.*, (1980) observed that organic carbon was related to the textural characteristics of the sediment and also observed a decrease in benthic animals when the OM was high (>4%). Hence OM seems to be one of the limiting factors controlling the distribution and abundance of benthic population. Ganapati and Raman (1973) who studied the pollution in Visakapatnam harbour found that discharge of domestic waste into the harbour waters led to the anoxic condition, which adversely affected the organisms. This is due to the accumulation of OM (6%) in the substrate and emanation of H_2S, resulting anoxic condition to the marine life. Parulekar and Wagh (1975) stated that suspended OM and substratum act as important ecological factors controlling the distribution of benthos along the northeastern Arabian shelf. Vizakat *et al.*, (1991) observed the role of OM of the sediment as one of the factors controlling the distribution and abundance of sediment dwelling benthic fauna. Prabhu *et al.*, (1993) showed a direct relationship of echiurids and polychaetes with the amount of OM while Ansari *et al.*, (1994) opined that moderate organic enrichment has a biostimulating effect on benthic community and high organic enrichment will lead to eutrophication and unsuitable environment conditions for the benthic life. Gopalakrishnan and Nair (1998) also reported that slightly higher OM (1.97%) enhanced the benthic production. Kumar and Antony (1994) studied the impact of environmental parameters on polychaetes in the mangrove swamps of Cochin and noticed no direct correlation between polychaete fauna and OM. From the present study it can be stated that benthos were not significantly related to OM but get adversely affected if it goes beyond a level (3%).

Most of the polychaete families had their representation in the shallow depths and got reduced below 100 m. Sedentarians were more in all depths than errantia during both the seasons showing their ability to withstand the adverse conditions. All the families showed more occurrences in the shallow and middle depths especially at 75 m when compared to other depths. Below 75 m depth, spionids, cirratulids, eunicids and glycirids showed better occurrence. Beyond 100 m spionids, cossurids and cirratulids are the only representatives. In errantia pilargids alone were found at 150 m depth zone. During pre-monsoon among sedentarians, spionids and capitillids were high in occurrence in the >150 m zone than other groups.

High representation of spionids and capitellids at all depths may be due to their ability to withstand adverse environmental conditions. It is well established that capitillids are used as indicators of organic pollution owing to their ability to live in the organic rich environment with high OM. The present study also confirms the above fact. Joydas (2002) observed the dominance of spionids and cirratulids in the low oxygen environments. Ingole *et al.,* (2002) noticed the dominance of spionids in the coastal waters of Dabhol, west coast of India. Among spionids, *Prinospio pinnata* was the most abundant species. The abundance of spionids in the deeper depths showed that these organisms have a low metabolic rate and can withstand adverse conditions. The decrease in temperature with increase in depth supports the above statement.

7.5. Multiple regression analysis

Step up predictive multiple regression model for biomass and density of polychaetes, crustaceans, molluscs, miscellaneous groups and total benthos from the environmental factors during post-monsoon and pre-monsoon season was carried out.

A total of 8 parameters were measured among which a set of highly correlated 6 factors were selected during post-monsoon and pre-monsoon season as the input variables along with their first order interaction effects. This model selects the one, which could explain the maximum variability from a set of 64 models for each of the three transformations viz,

1. original values of density/biomass on original values of the input factors
2. original values of density/biomass on $\log_{10}$ of input factors
3. $\log_{10}$ of density/biomass on $\log_{10}$ of input factors

In each case, the factors were standardized to standard normal variables as

$$\frac{y-\bar{y}}{\sigma_y}, \quad \frac{x-\bar{x}}{\sigma_x}$$

This prediction model is fitted in two ways 1) considering only the individual effect of the factors and 2) considering the individual effects of the input factors as well as their first order interaction effects. The factors having relatively high correlation with the polychaetes, crustaceans, molluscs, others and total density/ total biomass and which are mutually independent (having insignificant r with each others) are considered as the input factors for the model. Various transformations for dependant variable, y (benthic density/biomass) and independent variables, x (environmental parameters), considered are 1) $\log_{10}$, square root and original form for both y and x, the best one among these fitted is selected as the one which explained maximum variability. From the fitted model, the ecologically most important model parameters are selected according to their relative importance (Snedecor and Cochran, 1967).

Water quality as well as sediment texture contribute insignificantly when considered independently. Hence combined effects of these factors were used to make model, which explain maximum variability. Model best suited to explain maximum variability of benthic biomass are given in Table 30&31 and benthic density are given in Table 32&33.

7.5.1. Macrobenthic biomass

Multiple regression analysis carried out to predict the important factors influencing the benthic biomass during post-monsoon and is given in Table 30. For polychaetes biomass, best model explained about 76% of variability at 0.1% level of singificance ($p<0.001$), and the important model parameters predicting the polychaete biomass ranked on their relative importance were temperature*DO (*- denotes the interaction effects between two variables), temperature*depth, depth, temperature, DO*depth and DO. For crustacean biomass, important parameters were clay*saliniy, saliniy, DO, clay*DO, salinity*DO and clay and the model explained 29% of variation at 5% level of singificance ($p<0.05$). For molluscs, the most important parameters were graded as OM, saliniy, OM*temperature, temperatue, OM*salinity and temperature*saliniy. This model could explains only 31% of the variaions in the spatial distribution of the mollusc bomass at 5% significance level ($p<0.05$). For miscellaneous groups, relatively most importhant parameters predicting their distribution were clay*salinity, sand*salinity, temperature*salinity, clay*temperature, clay, sand, temperature, sand*temperature, sand*clay and salinity. The model explains 61% of the variations in the miscellaneous group biomass at 5% singificance ($p<0.05$). For total benthic biomass the model could explain 84% of the variations at 1% level of singificance ($p<0.01$). The most important parameters of this model were salinity*depth, temperature, temperature*depth, depth, salinity, DO, salinity*DO, clay, DO*depth, clay*depth, temperature*salinity, clay*DO and temperature*DO.

Best model for predicting the variations in the benthic biomass during pre-monsoon season is given in Table 31. For polychaete biomass the best model explains about 40 % of the total variability at 5% singificance ($p<0.05$) level. The important factors explaining the polychaete biomass during this season were DO, temperature*DO, salinity*DO, salinity, temperature, sand*temperature and sand*salinity. Model for crustacean biomass explains 52% of the total variability at 5% singificance level ($p<0.05$). The relatively most important factors were DO*OM, sand, sand*DO, silt*depth, depth, silt, OM, silt*DO, sand*depth, DO*depth, sand*silt, sand*OM, DO, OM*depth and silt*OM. For the biomass of molluscs the best model could explain 62% variation at 1% level of significance. Silt*depth, depth*DO, silt*DO, Depth, DO and silt were the important factors graded in their order which could explain maximum variability in mollusc biomass. For miscellaneous groups the best model explains 67% of the spatial variation at 5% singificance level ($p<0.05$). Most important factors were silt*DO, DO, clay, silt*clay, depth*DO, depth, silt, clay*depth, clay*DO and silt*depth. For total biomass, model explains about 39% of the spatial variation in the distribution at 5% level of singificance ($p<0.05$). The order of importance of factors could be given as DO, sand, sand*salinity, salinity*DO, sand*DO and salinity.

7.5.2. Macrobenthic density

Predicticve regression model to determine the factors most influencing the benthic density during post monsoon season is given in Table 32. For polychaete density, the model could explain 69% of the spatial variation at 1% significance level ($p<0.01$). Important factors predicting the variations were depth, silt, sand*silt, silt*depth, sand and sand*depth. For crustacean density, model could explain about 83% of the variation at 1% level of singificance ($p<0.01$). The relatively most important factors were temperature*depth, DO*depth, sand*depth, depth, temperature, silt*temperature, sand*temperature, sand*DO, sand, DO, silt*DO, temperature*DO, sand*silt, silt*depth and silt. For molluscan density, model could extract about 33% of the total spatial variation at 1 % level of significance ($p<0.01$) and only temperature and sand and its combined effect could expalin the maximum variability. For density of miscellaneous groups, model explains about 54% of the total variation at 1% significance level ($P<0.01$) and the relatively more important factors were depth and DO and its combined effect. For the total benthic density, model explaining about 71% of the variability with significance at 1% level ($P<0.01$). Relatively most important factors were graded as depth, silt, DO*depth, sand*DO, sand, silt*depth, sand*depth, DO, sand*silt and silt*DO.

Predicticve regression model to determine the parameters most influencing the benthic density during pre-monsoon season is given in Table 33. For polychaete density, the model explained 93% variation at 0.1% significance level ($p<0.001$). The most important factors predicting the polychaete density were silt*temperature, DO, sand, temperature*depth, temperature*DO, sand*depth, depth, silt*depth, temperature and sand*temperature. Important factors predicting the variations in crustacean density were salinity, sand*salinity, sand*OM, OM, sand, and salinity*OM. This model could explain 61% of the variability at 1% significance level (p<0.01). For the density of molluscs, the model explained 83% variation at 1% significance level (p<0.01). The relatively more important factors were sand*silt, sand, clay, sand*clay, silt*depth, silt*temperature, silt, salinity, clay*temperature, sand*salinity and sand*temperature. For miscellaneous groups, silt*salinity, salinity, silt, OM, salinity*OM and silt*OM were the important parameters influencing the miscellaneous group density and the model could predict the maximum variation of 51% at 1% significance level (P<0.01). For the total benthic density, model explains 88% variation at 1% level of significance (P<0.01). The most important factors were salinity*sand, sand*temperature, salinity, temperature, sand, salinity*depth, depth, sand*depth, temperature*depth and temperature*salinity.

From the results it is shown that generally three or more factors influencing the benthos especially in the benthic biomass. For the density of molluscs and miscellaneous groups a minimum of two environmental factors influencing significantly and for the rest of the groups more than two parameters have their influence and in any case, no single parameter alone influence production, abundance and distribution of benthos. For polychaete biomass, temperature and DO were influencing during both seasons and for crustaceans DO had its influence during both the seasons. For miscellaneous groups clay is common during both season and for total biomass, salinity and DO are the important factors during both seasons. For of density, sediment texture especially sand and depth of the station had significant influence during both season. So it was obvious that temperature, salinity, DO, texture, depth and their combined effects are significantly influencing the benthos and no single factors could be considered as an ecological master factor which corroborates the findings of Harkantra and Parulekar (1991).

7.6. Trophic relationships

It is well recognized that benthic production is one of the tools for measuring the biological productivity of an area (Ansari *et al.*, 1977; Parulekar *et al.*, 1982).

Macrobenthos, by feeding on meiobenthos and OM, and forming food for higher forms like fishes remain an important component of the food web. Among the benthic animals, polychaetes are the principal components (Longhrust and Pauly, 1987). Benthic organisms, which inhabit the bottom of the sea largely, form the food for the most of the commercially important bottom dwelling finfishes and shellfishes (Savich, 1972). Hence their prey-predator relationship, benthic biomass and its production data help in the estimation of demersal fishery resources based on the hypothetical food pyramid or bioenergy flow (Odum, 1973). The standing crop of macrobenthos is not only important to the demersal fishes which directly feed on them, but also to many pelagic species that are restricted to shallow waters during some period of their life (Kurian, 1971). So estimation of benthic standing crop production is necessary for the assessment of demersal fishery (Damodaran, 1973, Harkantra *et al.*, 1980). An analysis of benthic biomass distribution and demersal fish catch showed a positive correlation as areas with high benthic biomass were found supporting greater density of bottom fishes (Harkantra *et al.*, 1980). West coast shelf region of India showed high demersal fish catch particularly in the near shore region of south west coast which was largely due to the upwelling phenomenon (Warren, 1992). In addition to their importance in fishery resources, some of the burrowing benthic organisms like polychaetes and amphipods are regarded as the efficient bioturbators and recyclers of nutrients.

Meiofauna once thought to be the trophic dead end (Mc Intyre and Murison, 1973) are now known as an important component in the diets of fish (Bell, 1980; Hodson *et al.*, 1981; Coull and Palmer, 1984; Coull *et al.*, 1995; Greg *et al.*, 1998). There has been much controversy in the interaction between meiofauna and higher trophic levels. McInture and Murisin (1973) and Heip and Smol (1975) suggested that primarily meiobenthic predators consume meiobenthic prey species and thus were not available to higher trophic levels. McIntyre (1964) and Marshal (1970) stated that there is competition for food between macro and meiofauna and that meiofauna serve primarily as rapid metazoan nutrient regeneration. However, Feller and Kaczynski (1975) and Sibert *et al.*, (1977) showed that juveline salmon feed almost exclusively on meiobenthic copepods, Odum and Heald (1972) reported that meiobenthic copepods comprise 45% of the north American Grey mullot gut contents. Sikora (1977) has reported that nematods provide a significant portion of the *insitu* food of the grazing grass shrimp, Palaeomonetes pugis. Ahlstrom (1968) stated that in oceanic stations larvae of Myctophidae and Gonostomatidae dominated whereas in the intermediate zone diversified larval forms in large numbers including the larvae of several demersal fishes (20%). Mukundan (1971) also reported significant number of eggs and larvae from august to December mostly carangids, clupeoids and soles. Present study has observed relatively high density and biomass of macrobenthos and meiobenthos during pre-monsoon season than post-monsoon. Studies made on fish larvae of the west coast of India by Binu (2003) showed high abundance of fish larvae during pre-monsoon season than post-monsoon season. Majority of the benthic invertebrates have no direct commercial or recreational value, but provides much of the food for bottom feeding species that are themselves important in the commercial fisheries of the region.

According to the present study, the average benthic biomass along the northwest coast for the two seasons was 4.16 g/m^2 or 4160 kg/km^2. Using the conversion factor developed by Parulekar *et al.*, (1980), the dry weight for the total benthos was 451.12 kg/km^2 and dry weight in terms of carbon (34.5 % of the dry weight) was 155.64 kg C/km^2. Annual production would be twice of the standing crop (Sanders, 1956) so it is about 311.28 kg C/km^2/yr.

Average meiobenthic biomass for both seasons was 2.88 mg/10 cm^2 (2880 kg/km^2). Assuming that ratio of dry weight to wet weight as 1:4 (Gerlach, 1971, Wieser, 1960), the dry weight obtained from wet weight was 720 kg/km^{2}and carbon content (34.5% of dry weight) will be 248.4 kg C/km^2. Most of the meiofauna has got a life span of about 3 months (Sajan, 2003), and then the annual production will be of 993.6 kg C/km^2/yr

The area covered in the present study is approximately 55000 km^2. An average biomass of 4.16 g/m^2 when converted to annual benthic production (Slobodkin, 1962) gives a value of 8.32 g/m^2/y. The benthic production in terms of wet weight in the study area of 55000 km^2 will be 0.46 million tones. Since transfer of energy to the next trophic level is approximately 10 %, production transferred to the tertiary level will be 0.046 million tonnes.

Meiobenthic annual production will be 11520 kg/km2 (2880 kg/km2 *4) and production from the study area will be 0.6336 million tones. So the total benthic production (macro+meio) will be 1.0936 miilion tones. Considering an ecological transfer efficiency of 10 %, benthic potential will be 0.10936 million tones.

According to Somvanshi (1998) present exploitation is 1.875 million tons/y along the west coast of India. Assuming that 92.9 % of which is supported by continental shelf within 200 m depth zone the production will be 1.75 million tons (m. t.) of which demersal fishery contribute 49% (Sudarsan *et al.*, 1990), the benthic fish production in the continental shelf will be 0.8558 m. t. Considering the area of the western continental shelf is 75000 km^2, which supports 0.8558 m. t. benthic fish production, the average demersal fish production in the northwest continental shelf will be about 0.5159 m. t. In the present study, annual benthic potential yield is 0.10936 m t, which can support 21.2% of the current demersal fishery yield of 0.5159 m t. Limitations of the present study were the sampling was done in the 30-200 m and benthic biomass below 30 m depth has not included in the present study. Moreover, epifauna and microfuana, which also contributed significant role to benthic production, were not taken into consideration.

Average surface primary production obtained in the near to the coast from the two seasons was 20.43 mg C/m^3/d and surface chlorophyll *a* production was 0.64 mg/m^3 and off coast stations surface primary production was 9.50 mg C/m^3/d and surface chlorophyll *a* was 0.36mg / m^3 (Madhu, 2005). So annual surface primary production will be 745.70 g $C/m^3/y$ in the near shore region and 346.75 g $C/m^3/y$ off coast station with an average of 547 g $C/m^3/y$ in the continental shelf. Considering the 20% of the surface production reaches the bottom (Damodaran, 1973), about 109 g $C/m^3/y$ is available for benthos. This showed that the primary production of the overlying water was not a limiting factor for benthic production.

7.7. References

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	Polychaetes	Crustaceans	Molluscs	M.G.*	Total
N=23			Post monsoon		
Temperature	0.503*	0.009	0.220	0.452*	0.600*
Salinity	0.302	-0.361	0.159	0.061	0.261
DO	0.419*	-0.073	0.085	0.042	0.372
Sand	-0.427*	0.066	-0.382	-0.303	-0.515*
Silt	0.251	0.101	0.118	-0.169	0.194
Clay	0.397	-0.105	0.388	0.392	0.513*
OM	-0.182	0.039	0.457*	-0.056	-0.075
N=24			Pre-monsoon		
Temperature	0.408*	-0.255	0.007	0.005	0.316
Salinity	0.216	0.165	-0.081	0.315	0.319
DO	0.363	-0.254	-0.312	0.391	0.394
Sand	-0.142	0.309	0.335	-0.300	-0.161
Silt	-0.026	-0.299	-0.278	0.368	0.054
Clay	0.287	-0.241	-0.299	0.144	0.236
OM	-0.028	-0.263	-0.039	-0.118	-0.107

Table 27 - Correlation of benthic biomass with environmental parameters during post monsoon and pre-monsoon seasons
(M.G.*- Miscellaneous group)

	Polychaetes	Crustaceans	Molluscs	Others	Total
N=23			Post monsoon		
Temperature	0.492*	0.509*	-0.342	0.460*	0.480*
Salinity	-0.207	0.215	0.505*	0.138	-0.140
DO	0.170	0.423*	-0.282	0.324	0.167
Sand	-0.469*	-0.325	-0.226	-0.379	-0.499*
Silt	0.354	0.224	0.317	0.073	0.386
Clay	0.411	0.291	0.152	0.399	0.435*
OM	0.103	-0.156	0.235	-0.062	0.113
N=24			Pre-monsoon		
Temperature	0.429*	-0.066	0.331	-0.098	0.397
Salinity	0.126	0.421*	0.119	0.314	0.189
DO	0.170	-0.180	-0.042	0.044	0.141
Sand	0.179	0.430*	0.305	0.164	0.236
Silt	-0.256	-0.448*	-0.248	-0.122	-0.300
Clay	-0.048	-0.299	-0.283	-0.167	-0.103
OM	-0.215	-0.385	-0.033	-0.387	-0.270

Table 28 - Correlation of benthic density with environmental parameters during post monsoon and pre-monsoon seasons

Faunal groups	Sandy	Silty sand	Clayey sand	Silty clay	Clayey	Mixed type
			Post-monsoon			
Polychaetes	140	806	120	1605	1310	100
Crustaceans	9	40	70	82	34	0
Molluscs	8	10	10	131	12	20
Miscellaneous groups	0	0	0	13	18	0
Total	157	856	200	1831	1374	120
			Pre-monsoon			
	Sandy	**Clayey sand**	**Clayey silt**	**Sandy clay**	**Silty clay**	**Mixed type**
Polychaetes	1692	2763	683	3390	1229	935
Crustaceans	324	110	35	170	140	25
Molluscs	150	188	75	50	87	125
Miscellaneous groups	252	112	83	30	196	25
Total	2418	3173	876	3640	1652	1110

Table 29. Texture wise distribution of fauna during post and pre-monsoon season

riables	Best model	F ratio	Variability explained	Input variables
lychaetes	$Y=-0.3443+0.3299x_1-0.02308x_2$ $-0.6078x_3+1.5693(x_1x_2)$ $+0.7079(x_1x_3)-0.2573(x_2x_3)$	$F_{(6,16)}=12.8506$ $P<0.001$	76.37%	X_1- temperature X_2-DO X_3-depth
ustaceans	$Y=-0.2729+0.3832x_1$ $-1.5326x_2+0.9170x_3+1.5463(x_1x_2)$ $-0.4648(x_1x_3)-0.4446(x_2x_3)$	$F_{(6,16)}=2.4936$, $P<0.05$	28.94%	X_1- clay X_2-salinity X_3-DO
olluscs	$Y=0.07516+0.8545x_1$ $+0.3703x_2+0.5557x_3+0.4619x_1x_2$ $+0.3255x_1x_3+0.2657x_2x_3$	$F_{(6,16)}=2.65091$ $P<0.05$	31.04%	X_1- OM X_2- temperature X_3- salinity
iscellaneo groups	$Y=0.02805-0.5857x_1-0.8812x_2$ $+0.4649x_3-0.05419x_4+0.2217x_1x_2$ $+0.2408x_1x_3+4.7418x_1x_4$ $-1.6963x_2x_3+5.4519x_2x_4$ $-2.4650x_3x_4$	$F_{(10,22)}=4.4979$, $P<0.05$	61.38%	X_1- sand X_2-clay X_3-temperature X4-salinity
otal iomass	$Y=0.6742+1.046x_1+2.181x_2$ $-1.5797x_3+1.4573x_4+1.9045x_5$ $-0.03105(x_1x_2)+0.7871(x_1x_3)$ $-0.1706(x_1x_4)+0.6361(x_1x_5)$ $+0.23070(x_2x_3)-0.1475(x_2x_4)$ $+1.9978(x_2x_5)+1.1094(x_3x_4)$ $-2.7111(x_3x_5)-0.9903(x_4x_5)$	$F_{(15,7)}=8.5267$ $P<0.01$	83.69%	X_1- clay X_2-temperature X_3-salinity X_4-DO X_5-depth

Table 30. Multiple regression model based on macrobenthic biomass during post-monsoon

Variables	Best model	F ratio	Variability explained	Input variables
Polychaetes	$Y = -0.25428 + 0.2565x_1 + 0.2259x_2 + 0.6233x_3 + 0.7403x_4 - 0.1944(x_1x_2) + 0.12298(x_1x_3) - 0.23606(x_1x_4) + 0.3789(x_2x_3) - 0.644(x_2x_4) + 0.63097(x_3x_4)$	$F_{(10,13)} = 2.547$ $P < 0.05$	40.22%	X_1- sand X_2- temperature X_3-salinity X_4-DO
Crustaceans	$Y = -0.8179 + 2.1062x_1 + 0.8416x_2 + 0.2755x_3 + 0.7914x_4 + 1.1333x_5 - 0.5865(x_1x_2) - 1.8055(x_1x_3) + 0.0470(x_1x_4) - 0.76885(x_1x_5) - 0.7763(x_2x_3) + 0.01588(x_2x_4) + 1.2070(x_2x_5) - 2.6840(x_3x_4) - 0.6595(x_3x_5) - 0.1956(x_4x_5)$	$F_{(15,8)} = 2.6922$ $P < 0.05$	52.46%	X_1- sand X_2-silt X_3-DO X_4-OM X_5-depth
Molluscs	$Y = 0.453900 - 0.14699x_1 + 0.2683x_2 - 0.7503x_3 - 1.4750(x_1x_2) - 0.9448(x_1x_3) + 1.1978(x_2x_3)$	$F\ (6,17) = 7.245$ $P < 0.01$	61.96%	X_1- silt X_2-depth X_3-DO
Miscellaneous groups	$Y = 0.1177 + 0.3495x_1 - 0.8772x_2 + 0.4661x_3 + 0.8796x_4 + 0.6658(x_1x_2) - 0.1058(x_1x_3) - 1.2171(x_1x_4) + 1.6581(x_2x_3) - 1.3897(x_2x_4) - 0.5564(x_3x_4)$	$F\ (10,13) = 5.6425$ $P < 0.05$	66.87%	X_1- depth X_2- silt X_3- clay X_4- DO
Total biomass	$Y = -0.04094 + 0.4916x_1 + 0.1386x_2 + 0.9140x_3 - 0.4398(x_1x_2) - 0.1849(x_1x_3) - 0.2628(x_2x_3)$	$F\ (6,17) = 3.411$ $P < 0.05$	38.61%	X_1- sand X_2-salinity X_3-DO

Table 31. Multiple regression model based on macrobenthic biomass during pre-monsoon

Variables	Best model	F ratio	Variability explained	Input variables
Polychaetes	$Y=-0.61738+0.66108x_1+1.1605x_2$ $-1.2395x_3-1.0367x_1x_2+0.3925x_1x3$ $+1.0338x_2x_3$	$F_{(6,16)}$ $= 9.2380$ $P<0.01$	69.19%	X_1- sand X_2-silt X_3-depth
Crustaceans	$Y=-0.4605+0.63169x_1+0.03860x_2$ $+1.12689x_3-0.59280x_4-1.171895x_5$ $+0.25938x_1x_2+0.8377(x_1x_3)$ $+0.6909(x_1x_4)+1.6420(x_1x_5)$ $+0.960979(x_2x_3)-0.4328(x_2x_4)$ $+0.09686(x_2x_5)-0.27564(x_3x_4)$ $+4.3659(x_3x_5)+1.6896(x_4x_5)$	$F_{(15,7)}=7.9527$, $P<0.01$	82.58%	X_1- sand X_2-silt X_3- temperature X_4-DO X_5-depth
Molluscs	$Y=0.2720-0.4962x_1-0.5435x_2$ $+0.4699\ (x_1x_2)$	$F_{(3,19)}=4.5843$ $P<0.01$	32.80%	X_1- sand X_2- temperature
Miscellaneou s groups	$Y=-0.3025+0.4736x_1-0.6098x_2-0.6658$ (x_1x_2)	$F_{(3,19)}=9.7484$ $P<0.01$	54.39%	X_1- DO X_2-depth
Total density	$Y=-0.7654+0.6677x_1+1.4236x_2$ $+0.4459x_3-1.6185x_4-0.2037\ (x_1x_2)$ $-1.0041(x_1x_3)-0.52495(x_1x_4)$ $-0.1555(x_2x_3)-0.6091(x_2x_4)$ $+1.1819(x_3x_4)$	$F_{(10,12)}=6.2678$ $P<0.01$	70.54%	X_1- sand X_2-silt X_3- DO X_4-depth

Table 32. Multiple regression model based on macrobenthic density during post-monsoon

ariables	Best model	F ratio	Variability explained	Model input variables
olychaetes	$Y=-0.39818+1.3051x_1-0.19604x_2+0.4327x_3+0.5668x_4+1.4027x_5+0.1434(x_1x_2)+0.3834(x_1x_3)+0.7047(x_1x_4)+0.1885(x_1x_5)-2.0328(x_2x_3)+0.7566(x_2x_4)-0.2612(x_2x_5)-1.1652(x_3x_4)-0.5582(x_3x_5)-0.2739(x_4x_5)$	$F_{(15,8)} = 22.0979$ $P<0.001$	93.23%	X_1- sand X_2-silt X_3-temperature X_4-depth
ustaceans	$Y=-0.20154-0.01638x_1+1.0380x_2-0.15517x_3+0.52826(x_1x_2)-0.28194(x_1x_3)+0.11864(x_2x_3)$	$F_{(6,17)} = 7.0252$, $P<0.01$	61.21%	X_1- sand X_2-salinity X_3-OM
olluscs	$Y=-1.0470+2.3277x_1+1.8504x_2+1.4935x_3-0.06537x_4+1.2503x_5+0.7746x_6-1.9038(x_1x_2)-3.8259(x_1x_3)-1.0162(x_1x_4)+0.8868(x_1x_5)-0.2679(x_1x_6)-0.3695(x_2x_3)-1.9036(x_2x_4)-0.1604(x_2x_5)+0.3007(x_2x_6)-1.7648(x_3x_4)+0.4314(x_3x_5)-2.7214(x_3x_6)+0.3116(x_4x_5)+0.2324(x_4x_6)+0.3348(x_5x_6)$	$F_{(21,2)} = 6.5149$ $P<0.01$	83.43%	X_1- sand X_2-clay X_3-silt X_4-temperature X_5-salinity X_6-depth
iscellaneo s groups	$Y= -0.1815+0.7578x_1+1.04428x_2-0.6648x_3-1.3757 (x_1x_2) +0.08071 (x_1x_3)+0.41832 (x_2x_3)$	$F_{(6,17)} = 5.0640$ $P<0.01$	51.46%	X_1- silt X_2- salinity X_3- OM
otal density	$Y=0.38093+0.1661x_1-0.21821x_2-0.4665x_3+0.14019x_4+0.7749(x_1x_2)+1.2204(x_1x_3)-0.15848(x_1x_4)+0.06368(x_2x_3)+0.1394(x_2x_4)-0.17953(x_3x_4)$	$F_{(10,13)} = 17.141$ $P<0.01$	87.53%	X_1- sand X_2-temperature X_3- salinity X_4-depth

Table 33. Multiple regression model based on macrobenthic density during pre-monsoon

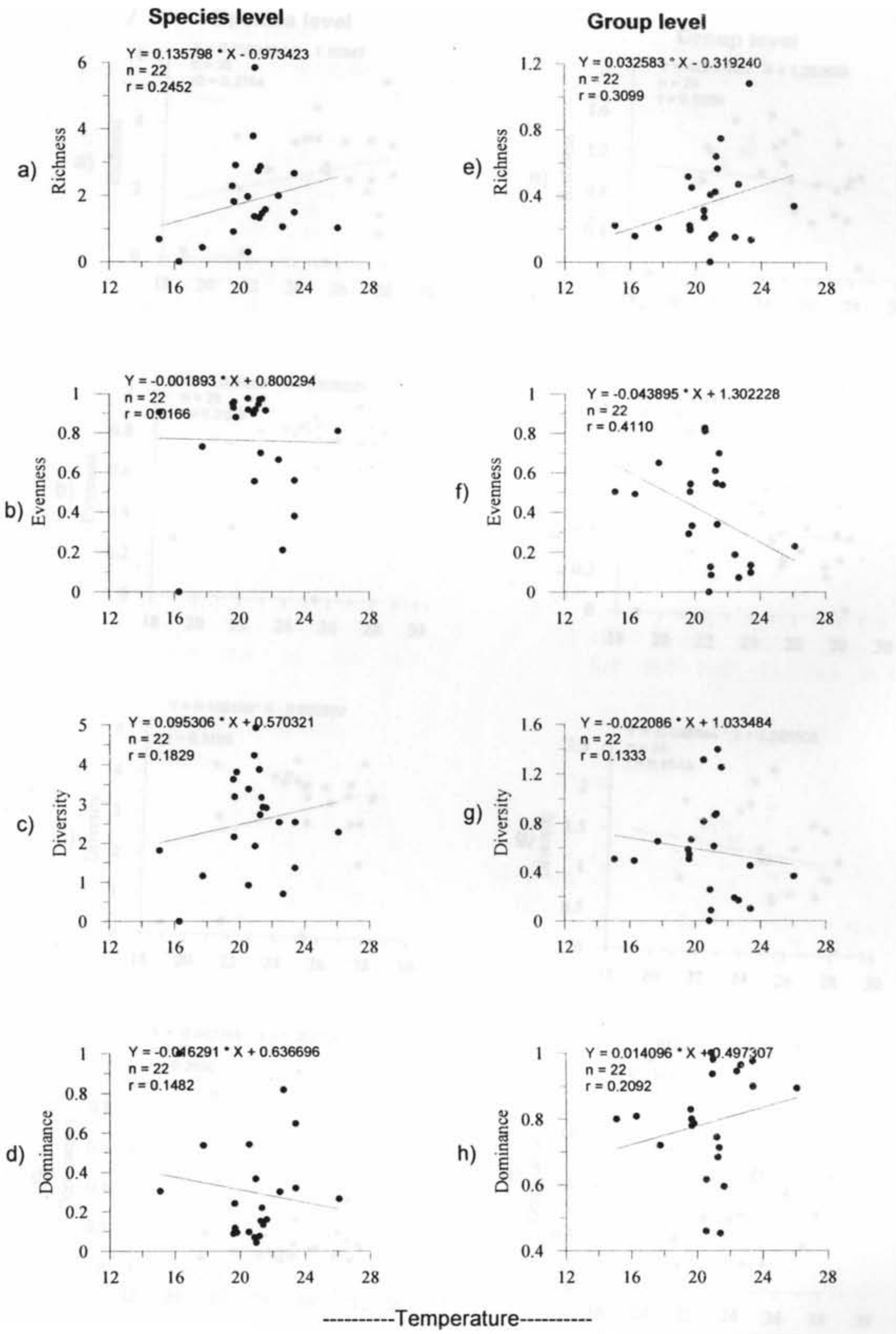

Fig. 55 Correlation of community structure with temperature during post monsoon season

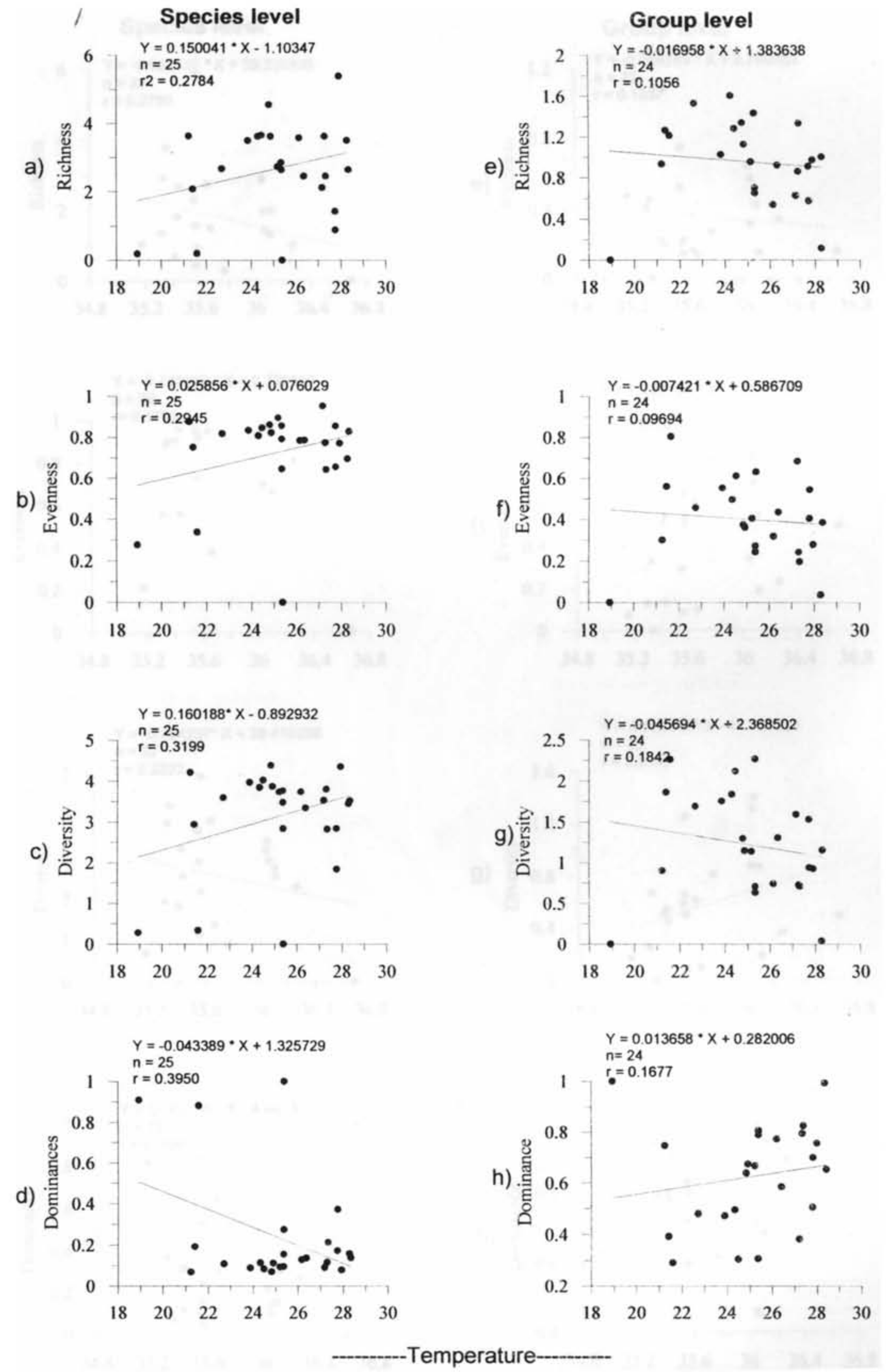

Fig. 56 Correlation of community structure with temperature during pre-monsoon season

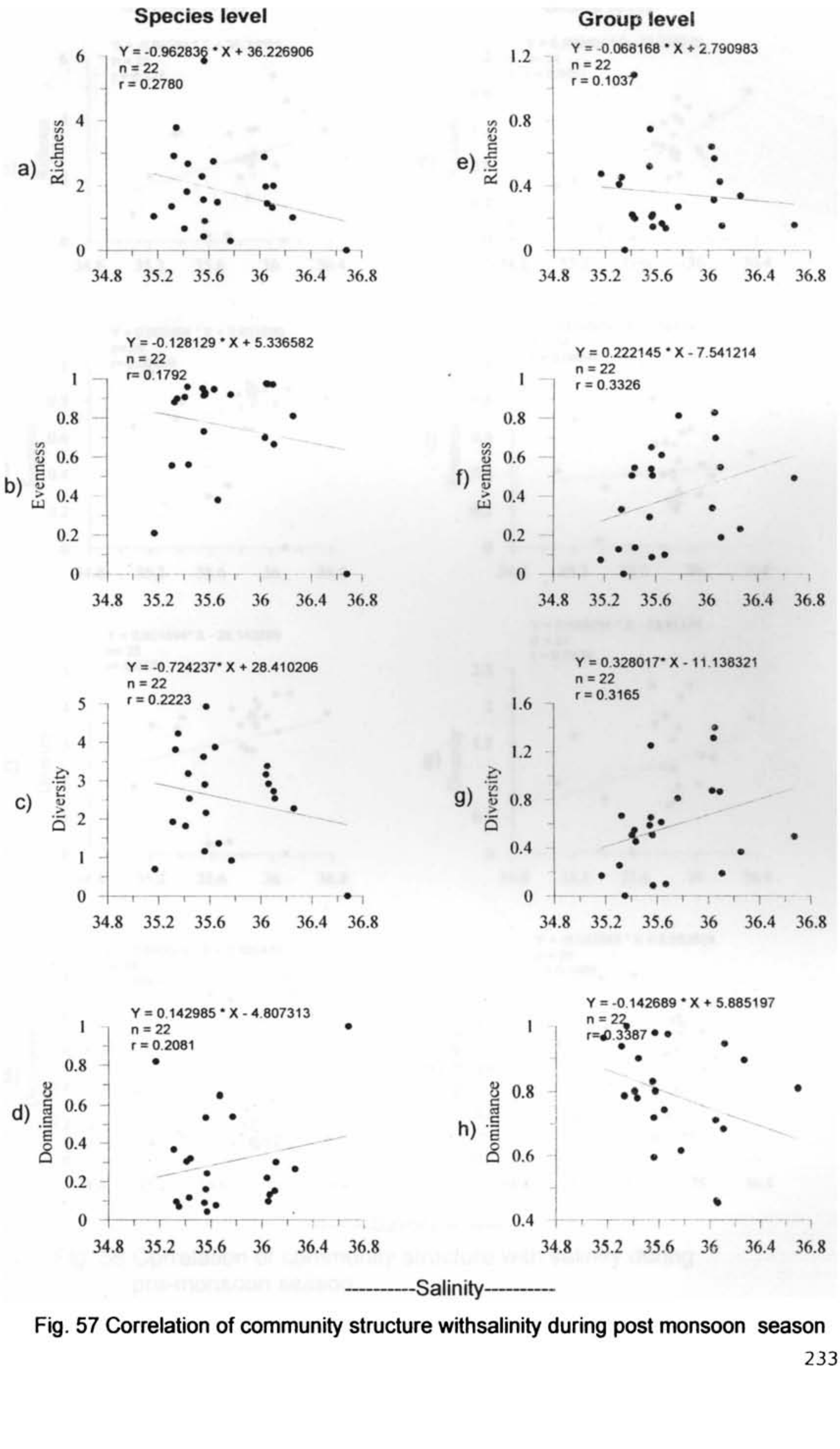

Fig. 57 Correlation of community structure withsalinity during post monsoon season

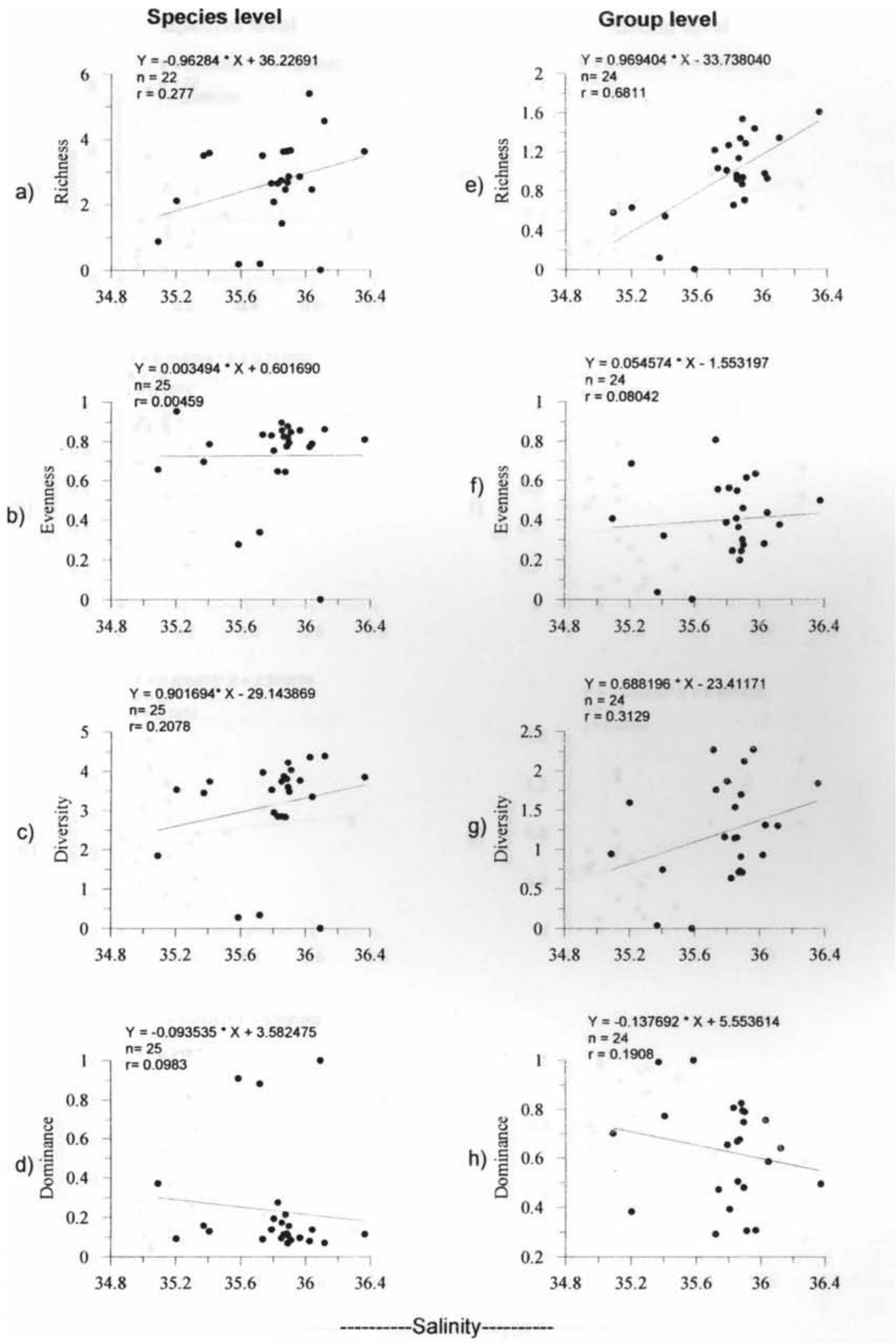

Fig. 58 Correlation of community structure with salinity during pre-monsoon season

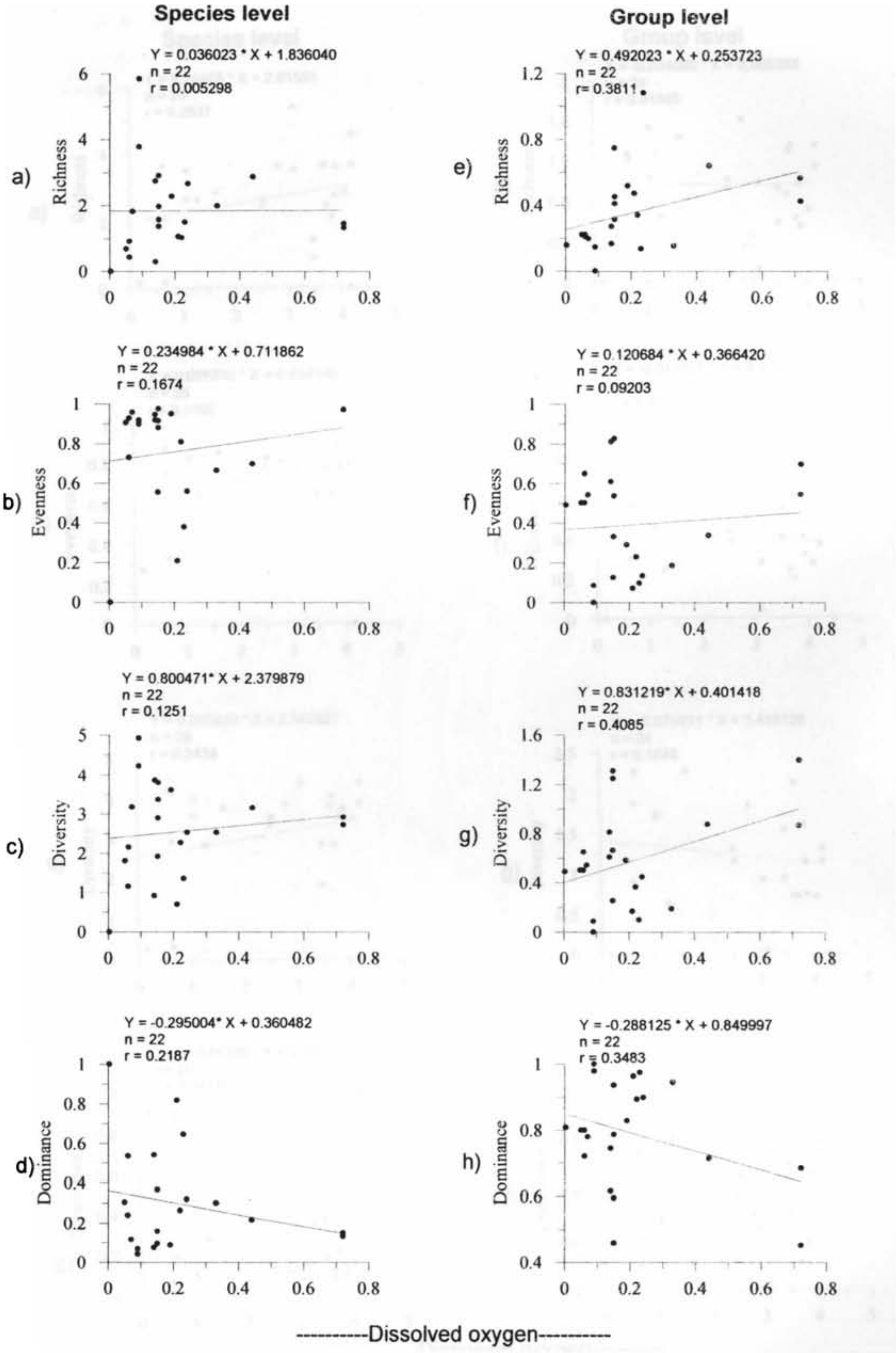

Fig. 59 Correlation of community structure with dissolved oxygen during post monsoon season

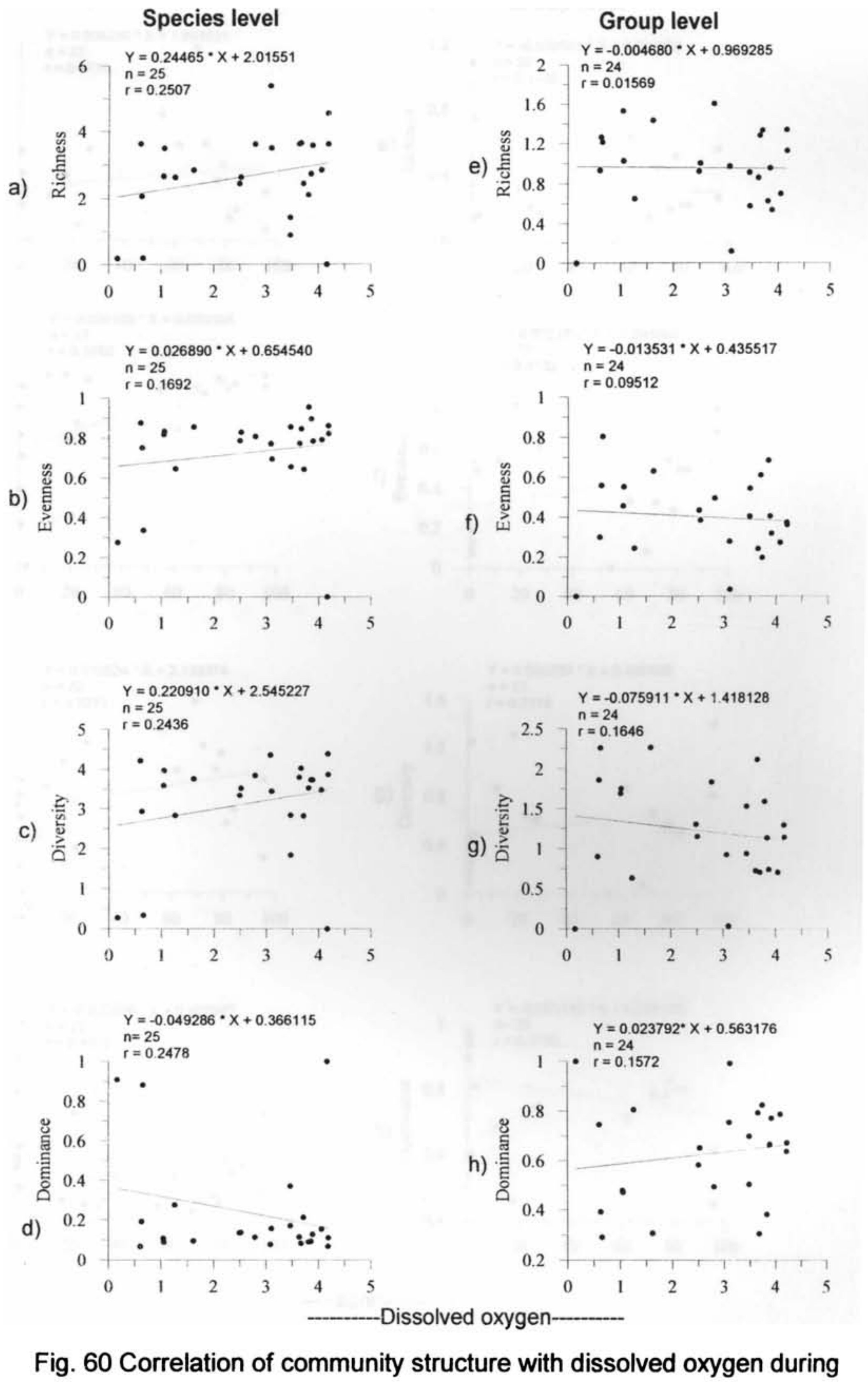

Fig. 60 Correlation of community structure with dissolved oxygen during pre-monsoon season

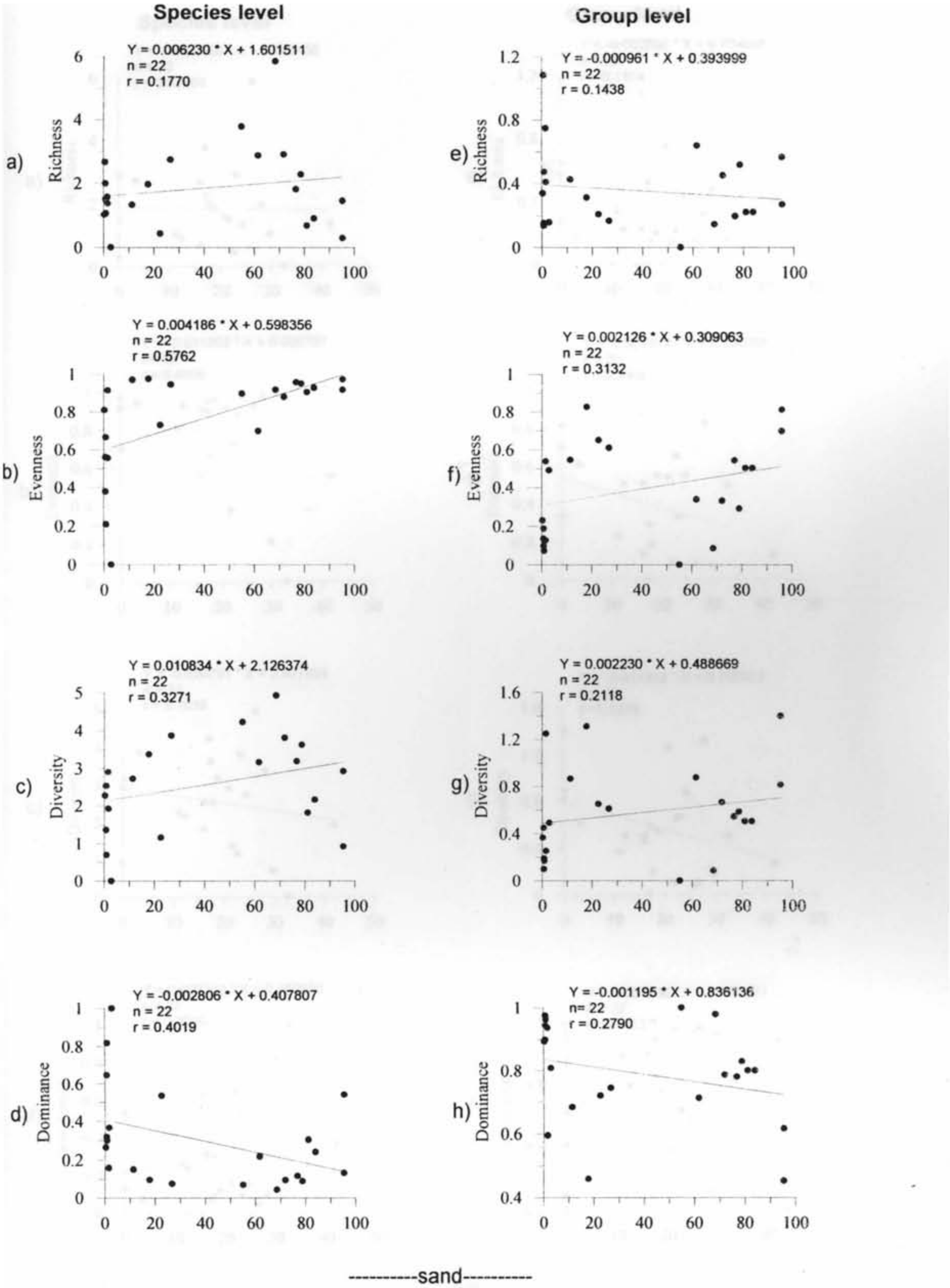

Fig. 61 Correlation of community structure with sand during post monsoon season

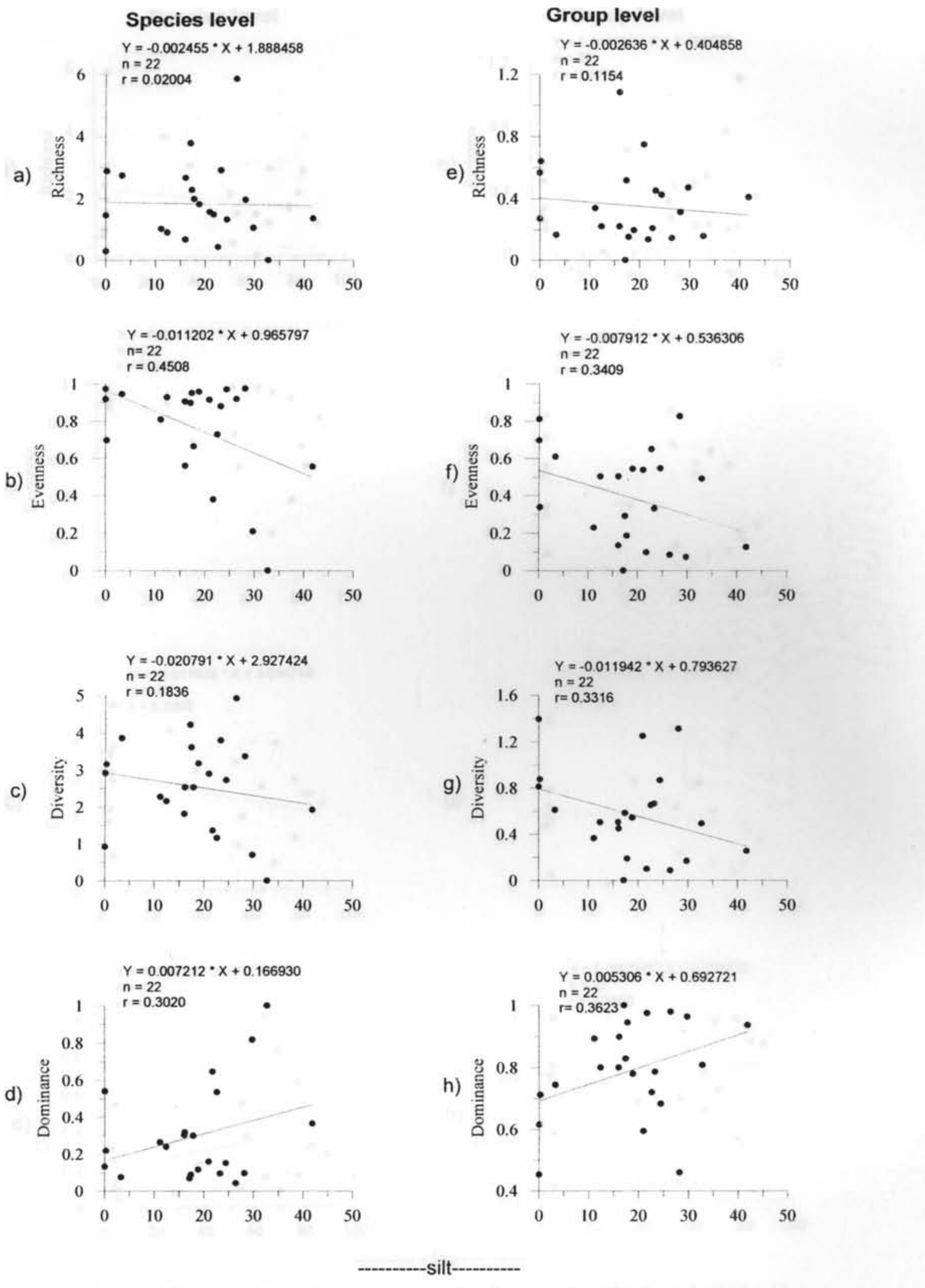

Fig. 62 Correlation of community structure with silt during post monsoon season

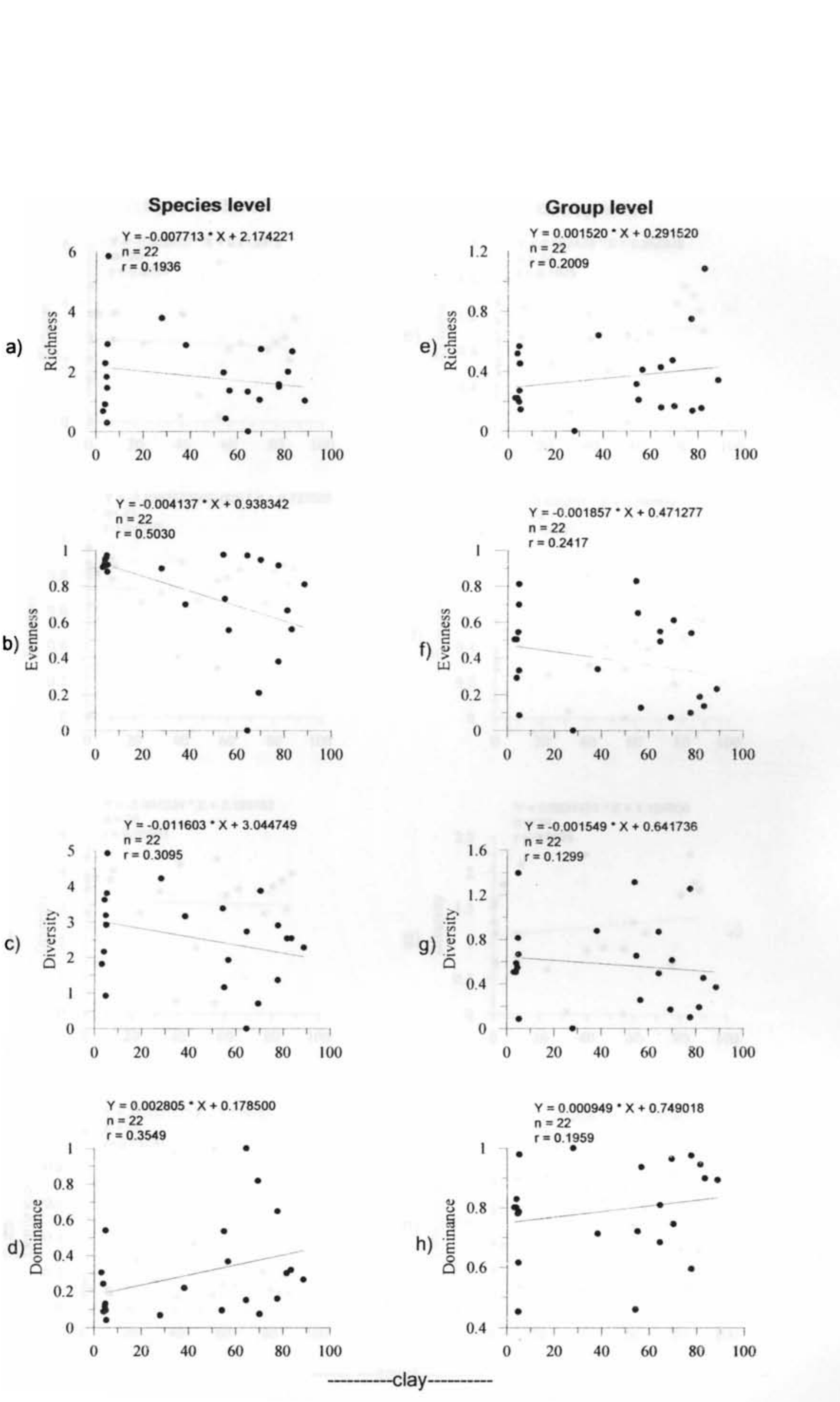

Fig. 63 Correlation of community structure with clay during post monsoon season

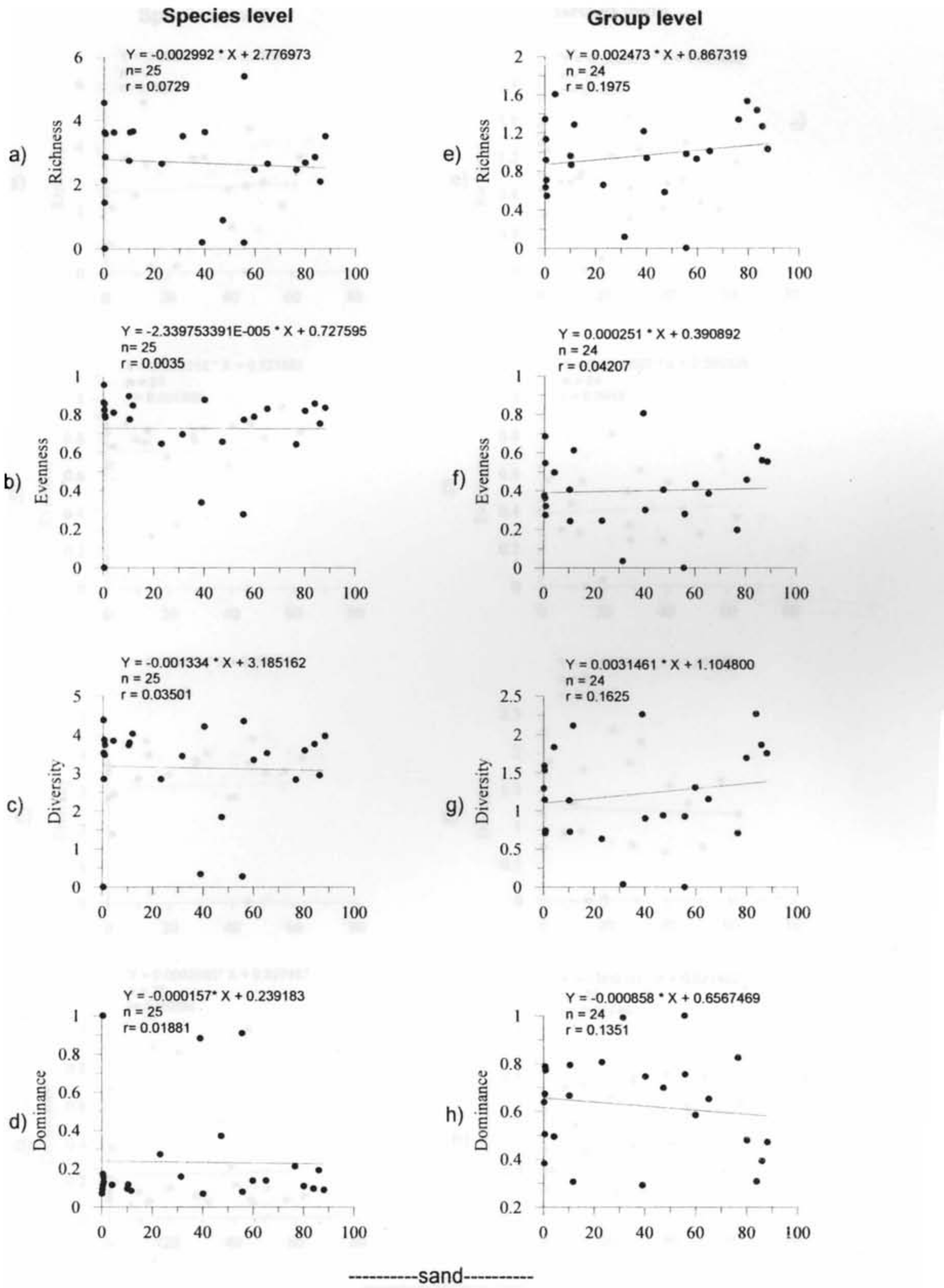

Fig. 64 Correlation of community structure with sand during pre-monsoon season

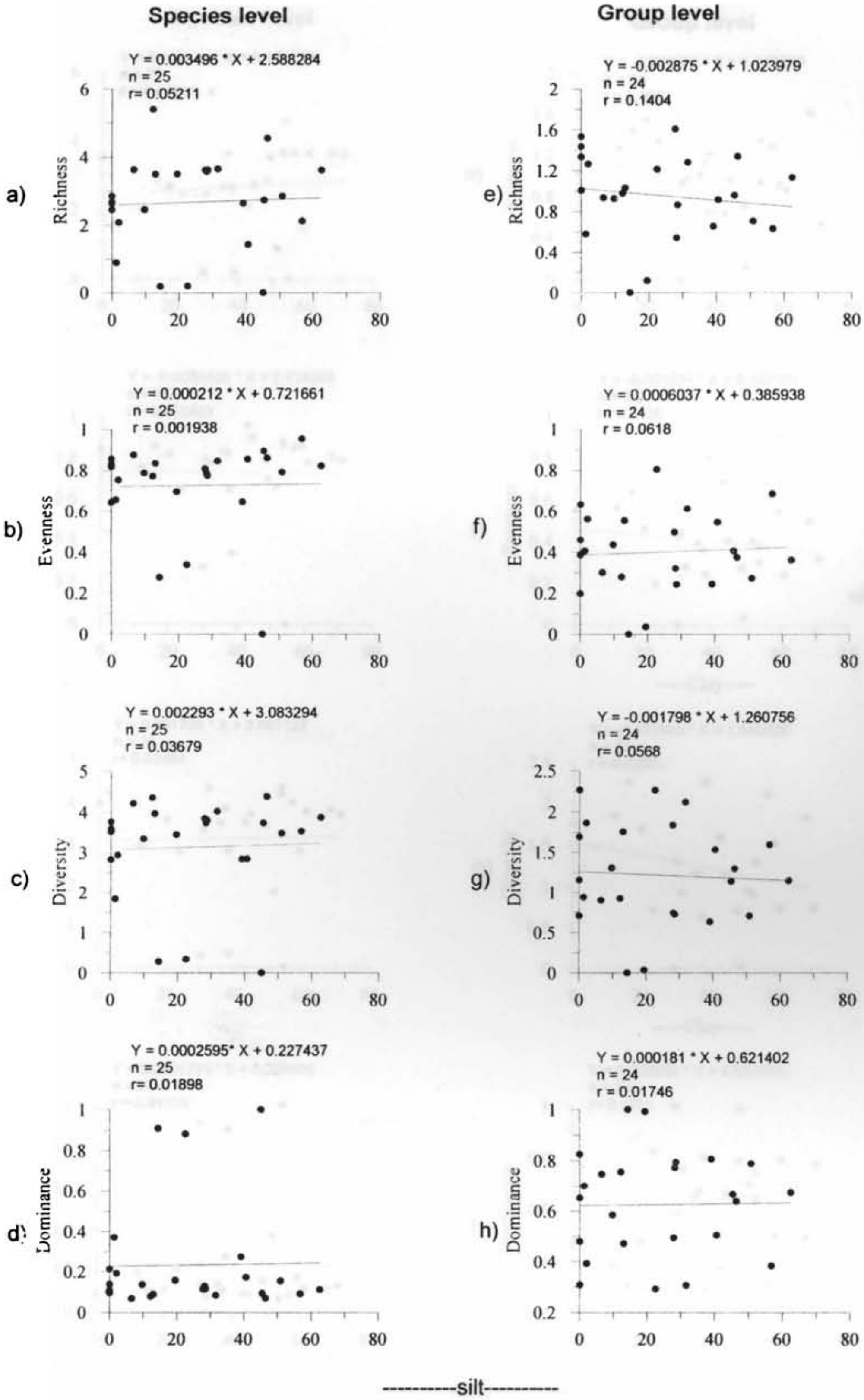

Fig. 65 Correlation of community structure with silt during pre-monsoon season

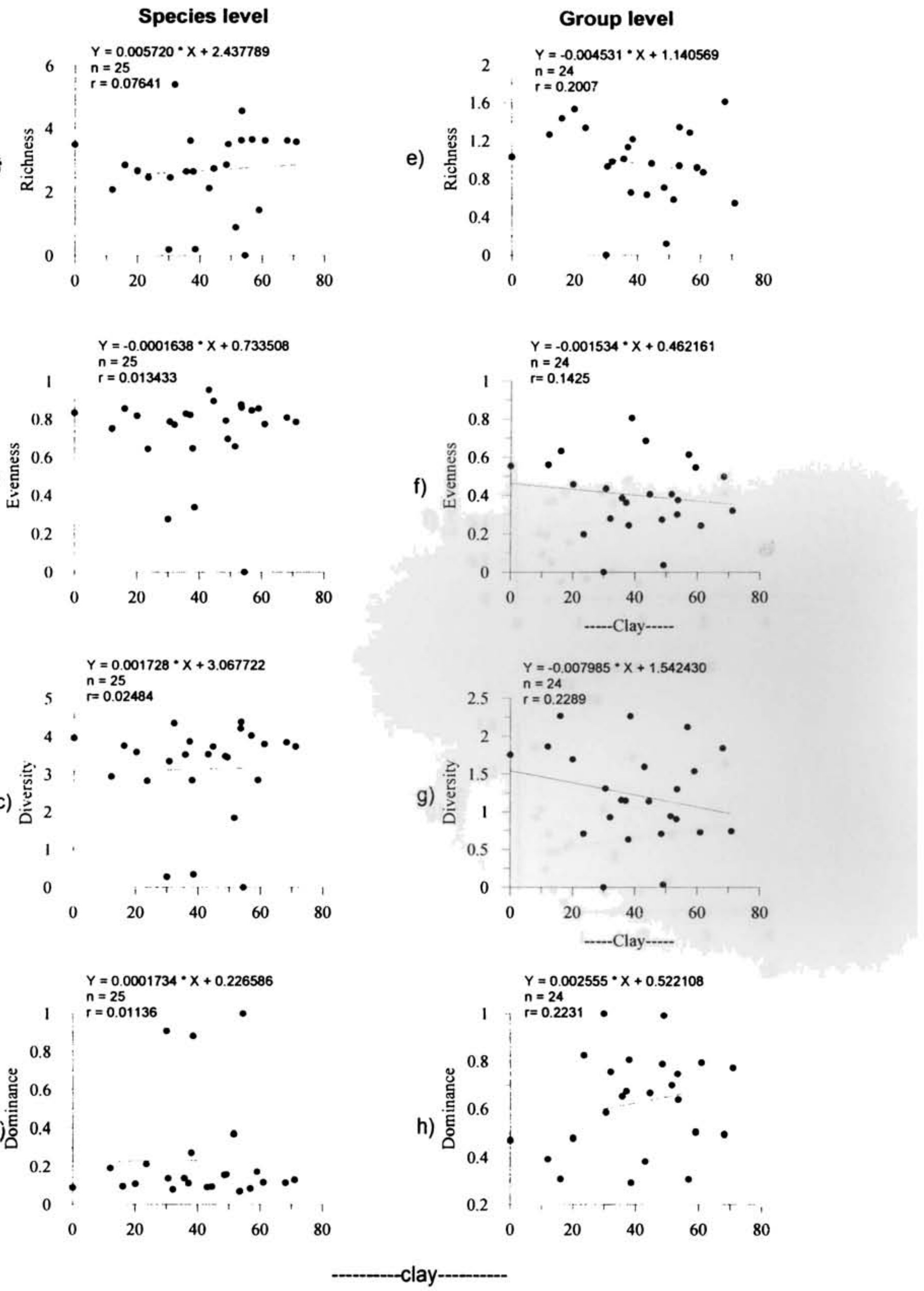

Fig. 66 Correlation of community structure with clay during pre-monsoon season

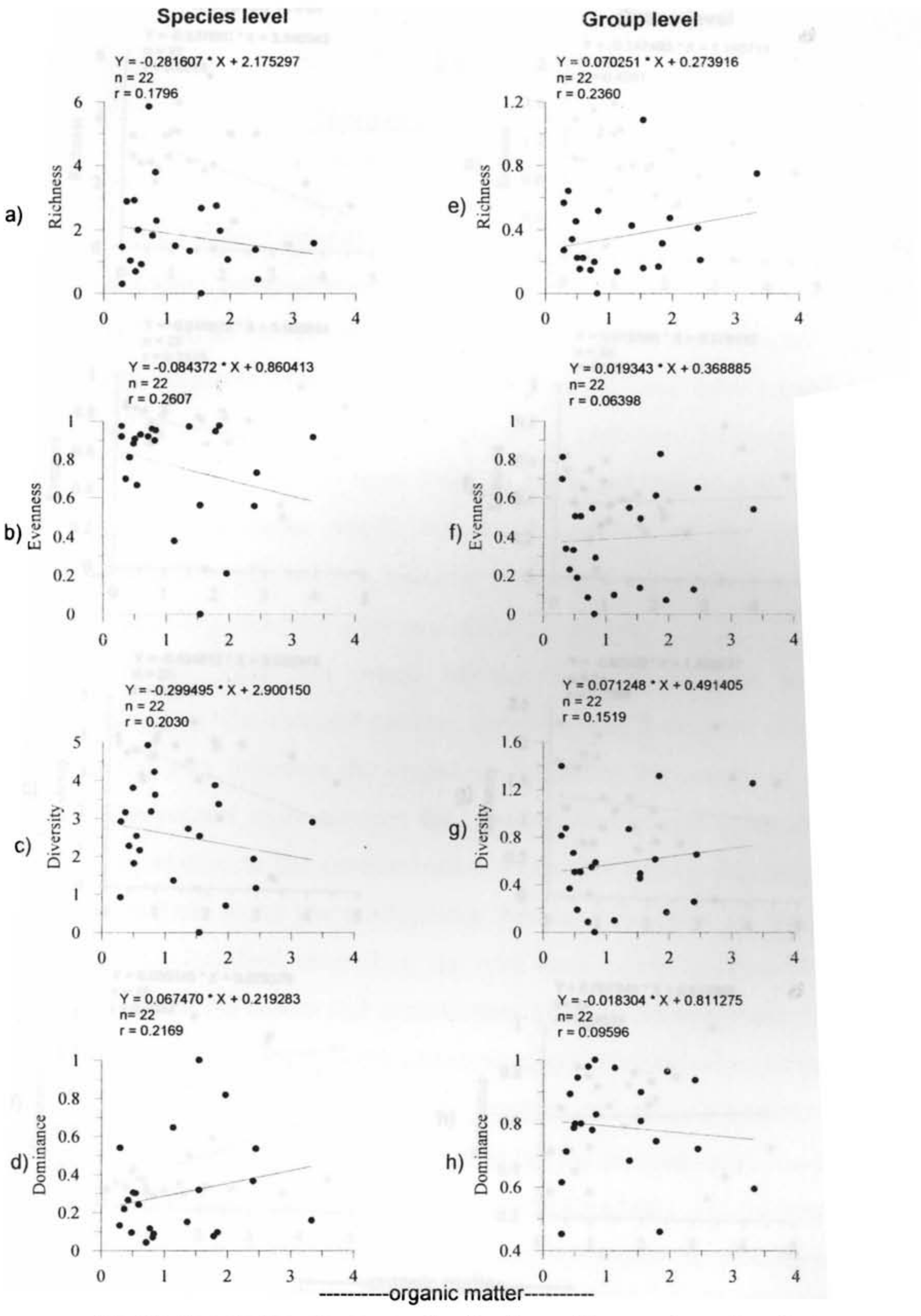

Fig. 67 Correlation of community structure with organic matter during post monsoon season

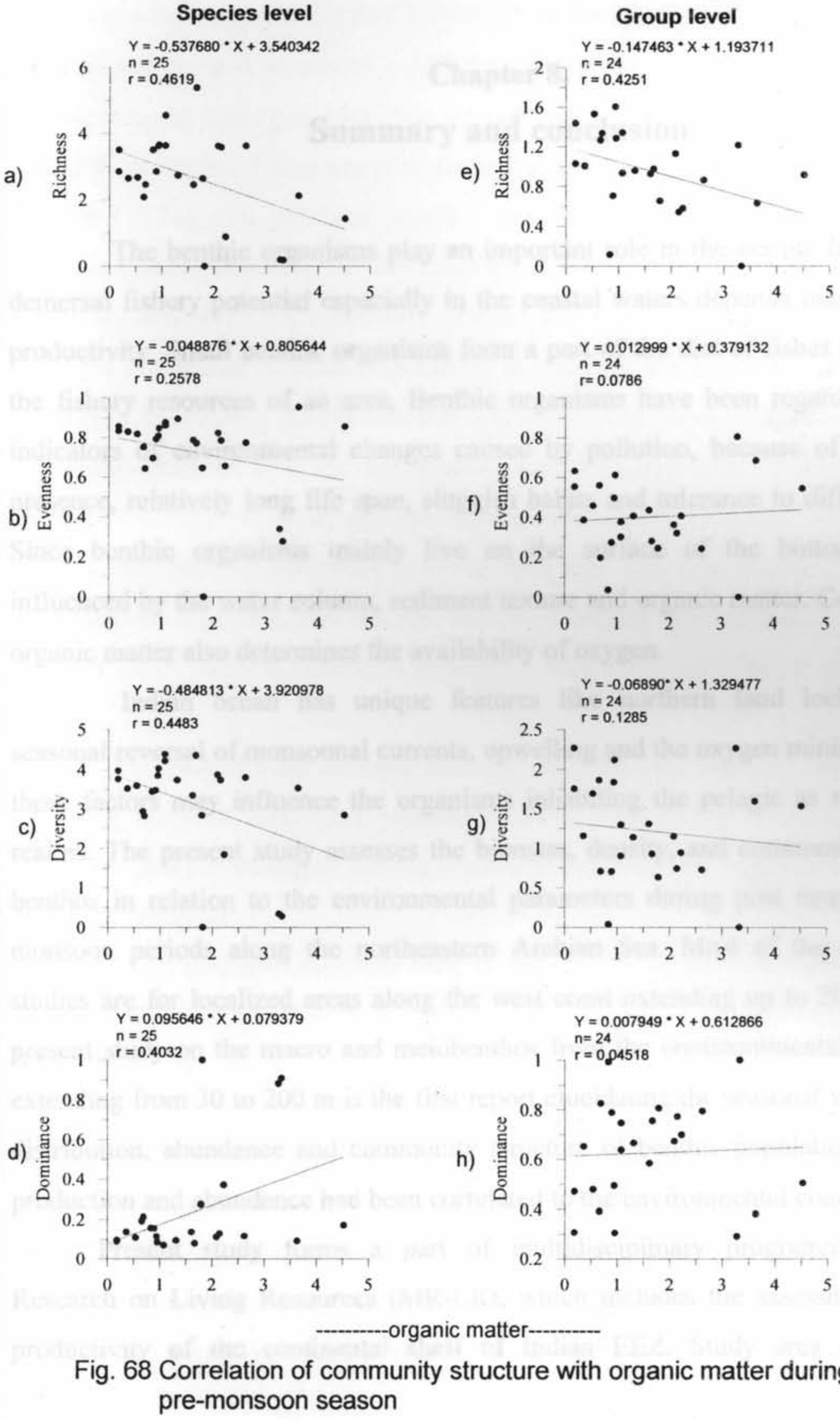

Fig. 68 Correlation of community structure with organic matter during pre-monsoon season

Chapter 8.

Summary and conclusion

The benthic organisms play an important role in the marine food chain. The demersal fishery potential especially in the coastal waters depends mainly on benthic productivity. Small benthic organisms form a part of the diet of fishes thus regulating the fishery resources of an area. Benthic organisms have been regarded as the best indicators of environmental changes caused by pollution, because of their constant presence, relatively long life span, sluggish habits and tolerance to differening stress. Since benthic organisms mainly live on the surface of the bottom terrain, are influenced by the water column, sediment texture and organic matter. Concentration of organic matter also determines the availability of oxygen.

Indian ocean has unique features like northern land locked boundary, seasonal reversal of monsoonal currents, upwelling and the oxygen minimum layer. All these factors may influence the organisms inhabiting the pelagic as well as benthic realms. The present study assesses the biomass, density, and community structure of benthos in relation to the environmental parameters during post monsoon and pre-monsoon periods along the northeastern Arabian Sea. Most of the earlier benthic studies are for localized areas along the west coast extending up to 20 m depth. The present study on the macro and meiobenthos from the conticontinental shelf of India extending from 30 to 200 m is the first report elucidating the seasonal variations in the distribution, abundance and community structure of benthic population. The benthic production and abundance had been correlated to the environmental conditions.

Present study forms a part of multidisciplinary programme, on Marine Research on Living Resources (MR-LR), which includes the assessment of benthic productivity of the continental shelf of Indian EEZ. Study area extended from

Marmagoa to Porbandar located between latitude 14° to 22° N and longitude 68° to 74.5° E and covered an area of ~ 55000 sq. km. Samples were collected from transects off Marmagoa, Ratnagiri, Mumbai, Veraval and Porbander from 30, 50, 75, 100, 150 and 200 m depths. Water samples for hydrographic parameters were collected using Sea-Bird CTD, and sediment samples were collected using Smith-McIntyre Grab. Statistical interprettation for community structure was done using PRIMER v 5 software, and student's *t* test was worked out for finding the seasonal difference. Multiple regression analysis was carried out to find the important ecological factors predicting the benthic dictribution and abundance. The fishery potential of the area was calculated from the biomass data obtained and compared with the available literature. Relationship between macro and meiobenthos was also worked out.

The thesis is presented in seven chapters. The first chapter gives a general introduction regarding the marine environment, its classification, definition, and importance of benthos, review of previous works, scope and objectives of the present study.

The second chapter deals with the materials and methods, which covers the sampling methods, analytical procedures for the estimation of various parameters, collection and processing of benthic organisms and their identification and methods for statistical inference.

The third chapter describes with the general hydrographic features of northeastern Arabian Sea. The distribution of environmental features like temperature, salinity and dissolved oxygen. During

Third chapter is on the hydrographic features of the study area and salient features are as follows. During post-monsoon, temperature decreased from shallow to deeper depths and transect wise analysis showed a general increase towards northern stations. During pre-monsoon, temperature initially increased from 30 m to 75 m depths and then decreased to deeper stations. It also showed a decrease towards northern latitudes. For salinity no consistent depth wise trend was observed during post-monsoon. During pre-monsoon salinity was low in the shallow stations and high in deeper stations especially in the southern transects. Transect wise distribution showed that salinity showed a general northward increase during both seasons. DO was high in the shallow stations and decreased towards deeper depth stations during both the seasons. Transect wise pattern showed a general increase to north in shallow depths and beyond 100 m it decreased towards north. Seasonal vatiations were conspicuous for temperature and DO. For salinity, significant variation was absent between the two seasons.

The fourth chapter discusses the sediment characteristics during post and pre-monsoon season. Shallow stations had dominance of fine sediment with high percentage of clay in both seasons. High percentage of sand was noticed at deeper stations. Latitudinally southern transects dominated with coarser sediments and northern transects with fine sediments during both the seasons. In general, high OM was observed in shallow stations and low in 75 to100 m during both seasons. During post-monsoon, OM decreased towards north below 75 m zone and beyond 75 m zone it increased towards north but no regular pattern in the OM distribution was observed during pre-monsoon. Significant seasonal variation in OM distribution was observed only in the 30 m depth.

Depth wise and transect wise variations of benthic (both macro and meio) biomass and density in both seasons are described in chapter 5. Macrobenthic biomass and density were mainly contributed by polychaetes (>80%) during both seasons. During post-monsoon, contribution of molluscs to the total biomass increased while that of crustaceans decreased. During pre-monsoon, crustaceans and molluscs were equally contributed to total biomass. Miscellaneous groups together showed a much higher representation during pre-monsoon than post-monsoon season. During post-monsoon, biomass and density decreased to deeper stations. Generally no transect wise trend was observed in biomass, however average value was relatively high in the northern transects. Density was high in the southern transects in most of the depth zones. Low biomass and density observed at 30 m contour is a peculiarity observed during pre-monsoon season. During this season, biomass and density increased from 30 m to 75 m and then decreased to deeper stations. Biomass was more in the north but for density, no general transect wise pattern was observed; however high average density was observed in southern transects. Both seasons recorded more or less similar biomass with a slight increase during pre-monsoon. Comparatively high density was observed during pre-monsoon. Statistical analysis showed no seasonal difference in biomass and density between the two seasons.

Meiobenthic biomass and density decreased to deeper depths. Transect wise biomass was more in the northern transect, whereas density showed no regular pattern. Nematodes contributed significantly to the total biomass and desity.

The faunal composition, and the community structure of benthos are presented in chapter 6. Four groups viz, polychaetes, crustaceans, molluscs and miscellaneous groups were identified from the study area. In polychaetes twenty-four families were encountered during post-monsoon and 34 families during pre-monsoon. In both seasons sedentarians contributed more than errantia. In errantia, family Pilargidae and Eunicidae were the dominant ones during both seasons. In sedentaria, family Spionidae and Magelonidae were the major ones during post-monsoon while during pre-monsooon family Cirratulidae and Spionidae dominated. Altogether 166 polychaete species were observed from the study area. Seventy-six species were present during post-monsoon, which included 25 errantia species and 51 sedentaria species. During pre-monsoon, 133 species were encountered of which errantia consisted of 43 species and sedentaria 90 species. During post-monsoon *Prionospio pinnata* was the only abundant species at all depth zones while during pre-monsoon, *Ancystrosillis constricta* and *Prionospio pinnata* were the abundant species.

Among non-polychaete taxa, crustaceans were the dominant group mainly constituted by decapods during post-monsoon and by amphipods during pre-monsoon. In molluscs, pelecypods were more frequent during post-monsoon as against gastropods during pre- monsoon. In miscellaneous groups, sipunculids were comparatively high in number during post-monsoon, and during pre- monsoon sipunculids and nematods were the major taxa encounterd. Statistical analysis showed that species richness was low during post-monsoon. Richness and diversity of polychaetes were high in the shallow depths while that of crustaceans and molluscs were high in deeper depths in both seasons.

Trophic relationships showed that primary production was adequate enough in the surface layers and was not limiting the benthic production. Estimated fishery potential showed that about 21% of the tertiary production could be supported by benthic community (macro and meiobenthos) and rest of which contributed by microfauna, epifauna and benthos below 30 m depth.

Benthic biomass and its relation to the environmental parameters like temperature, salinity, DO, sediment texture and OM are discussed in chapter 7. In general, benthic biomass was positively related with temperature, salinity and DO. Sediment texture was another important factor and polychates and miscellaneous groups prefer fine sediment, whereas crustaceans and molluscs prefer sand dominated substratum. OM in the range of 1-2% is conducive for benthos beyond 3% it adversely affects the organisms. Multiple regression analysis revealed that a combined effect of three or more environmental factors affect the biomass and density distribution of most of the benthic fauna. But for the density molluscs and miscellaneous groups during post- monsoon a minimum of two parameters (viz, sand and temperature for molluscs; DO and depth for miscellaneous groups) showed higher influence. Thus it can be stated that no single factor could be considered as an ecological master factor as observed by Harkantra and Parulekar (1991). Trophic relationships showed that estimated annual macrobenthic production for the study area is about 311 kgC/km^2/yr and meiobenthic production amounts to 994 kgC/km^2/yr (since meiofauna have an average life span of 3 months, total annual production will be more than that of macrobenthos) and the total annual benthic production (both macro and meio) in the study area will be 1.09 million tonnes.

Average macrobenthic biomass in the study area was 4.16 g/m^2 and for meiobenthos it was 2.88 mg/m^2. Benthic biomass and density was generally high in the shallow depths compared to the deeper zone. Average biomass for the shallow depths (30 and 50 m) was 6.73 g/m^2 and in deeper depths (150 m and beyond 150 m) it was 1.5 g/m^2. On av average basis, population density for shallow depths and deeper depths were 1971ind/m^2 and 790ind/m^2 respectively. Thus a three-fold decrease in the benthic biomas and more than one fold decrease in density from shallow to deeper depths were observed in the study area. Seasonal difference was not observed for biomass as well as density. Latitudinal variation was not well defined, however, relatively high biomass was recorded in the northern area while density was more in the southern area. Polychaetes were rich and diverse in the shallow depths and decreased with depth. in deeper zones, members of family Spionidae, Cirratulidae and Cossuridae were predominant suggesting their ability to withstand low oxygen conditions. But richness and diversity for crustaceans and molluscs were high in deeper depths. Similar to the macrobenthos, total biomass and density of meiobenthos were high in shallow depths and low in deeper depths. Nematods were the dominant group at all depths and their distribution pattern was comparable to that of total biomass and density. Copepods and miscellaneous groups were low in shallow depths and high at deeper area.

Temperature and DO showed significant variations between the seasons but significant difference in sediment charecteristics was observed only in the shallow depths (30 and 50 m). Benthic biomass and density did not show any significant difference for the two seasons. Community structure showed significant changes in the two seasons except few depths especially beyond 100 m. Ecological relationship showed that combined effects of temperature, DO, salinity and sediment charecteristics were mainly steering the benthic production, distribution and seasonal changes in the community structure. Effect of OM conducive to organism is up to 3% and more than this it is detrimental.

It can be concluded that seasonal difference in the benthic community was observed in lower depths and absent in deeper depths. Increased richness and diversity during pre-monsoon may be related to the increased primary prioduction which inturn influenced by the incresed nutrient input due to winter convection. No single ecological factor could be considered as a master factor. In gerneral the area supports moderately high benthic production and diversifiedd community. This study provides a valuable baseline data for future ecological assessment and monitoring of coastal marine ecosystem along the northwest coast of India.