CHAPTER 6

Subtidal

Introduction

Materials and Methods

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Discussion

6.1 Introduction

Zooplankton are planktonic free-floating animals in fresh and marine aquatic systems, and are the major consumers of the organisms in the microbial food web. These organisms possess a wide range of feeding strategies, from the nematocysts (stinging cells) of cnidarians (e.g. jellyfish) to the complicated mouthparts of copepods.

Among the metazoan zooplankton, two major groups can be distinguished: the holoplankton, forms that spend their entire life cycle in the plankton; and the meroplankton, forms that spend only part of their life cycle in the plankton, usually larval forms of benthic or nektonic adults. Meroplankton is usually more abundant in coastal areas because of the near vicinity of the benthic realm.

Many benthic or intertidal organisms were represented as planktonic form of their life cycle during the study such as bivalve larvae, gastropod larvae, polycheate larvae, crustacean larvae, cladocerons etc. Hence the study of benthos of the same three stations was carried out to check the distribution of species of zooplankton diversity whose adult as well as younger stage available on those stations. Macrofauna play a critical role in trophic relationship by providing major sources of energy to economically and ecologically important fishes. Their diverse morphology and ability to adapt to various habitats make them important as food for large benthic community (Gerlach, 1978; Kardani et. al., 2011) and in recirculation of nutrients (Kristensen *et al.*, 1983). In this backdrop quantitative attempts were made to understand the potential role of macrofauna. However along the Indian coast, the study of macrofauna is rather recent. There exists a significant gap in the study of sub-tidal benthic fauna which was attributed to lack of interest in the subject in addition to few taxonomists

specializing in this aspect (Venkatraman and Wafar, 2005). Ecologically significant coastal habitats like Pulikat lake (Melluish, 1965; Krishnamurthy, 1971; Sunder Raj and Sanjeeva Raj, 1984; Thangavelu and Sanjeeva Raj, 1985a; Thangavelu and Sanjeeva Raj, 1985b; Thangavelu *et al.*, 1988b; Kalyani, 1988; Ramesh and Ramachandran, 2005), Chilika lake (Das, 1995; Misra, 1995; Sarkar, 1995; Subba Rao *et al.*, 1995; Sarma and Wilsanand, 1996) and general sub-tidal characteristics of Indian Ocean (Ansari and Parulekar, 2001) was studied and reviewed by many authors.

Species are the essential baseline for understanding diversity. Proper sampling and identification methods are very much essential to obtain reliable data to measure species richness and diversity. Natural communities of plants and animals generally comprise a large number of species. Communities may respond differently to a suite of differing environmental conditions and this generally determines changes in community structure. In an ecosystem, assessing patterns in community structure have several advantages over experimental periods. Benthic organisms are more suited in this context over pelagic forms since they are sedentary and therefore more feasible in assessing local effects (Warwick *et al.*, 1989). Clarke and Warwick (1994) while providing an agenda for studying changes in marine communities, proposed a number of possible analyses that vary from purely univariate techniques to complex multivariate procedures. Benthic realm monitoring is also a relatively sensitive, effective and reliable technique that can detect subtle changes that serve as an early indicator before more drastic environmental changes occur (Ajmal khan *et al.*, 2004). Benthic assemblages contain large number of species within a single sample. It requires a variety of techniques to be employed to simplify the resulting large data, involving various pre-processing of data before testing of

structure. Clarke and Green (1988) and Clarke and Warwick (1994) have summarized these steps, which fall under the five main headings:

1. Univariate methods
    a) Species Richness
    b) Shannon-Wiener's index
2. Graphical/distributional methods
    a) K-dominance curves
3. Multivariate methods
    a) Cluster Analysis
    b) MDS

All these techniques have been employed in analyzing the subtidal faunal communities in the three study areas in the present study. In the present study an attempt has been made to gain further information on the subtidal fauna of Gulf of Kachchh coastal forms. Present study consolidates the findings of the benthic macrofaunal composition, distribution and abundance carried out during June 2007 to May 2009 at three study area namely Mundra, Mandvi and Sanghi. Subtidal epibenthic communities were studied qualitatively and quantitatively in these three stations.

6.2. Materials and Methods

Triplicate samples using Peterson grab with a covering area of 0.625m^2 was employed in all the stations to collect subtidal samples. The faunal separation was done using a 0.5 mm mesh (McIntyre *et al.*, 1984). The benthic samples passed through sieve were fixed with 5% formaldehyde and stained with Rose

Bengal (Holme, 1964) in the field when collected. This facilitates further sorting and identification in the laboratory. The collected benthic fauna were identified and counted up to the group/Taxa/genus and if possible to the species level. To the gathered information the following statistical methods were applied to analyze different aspects of the subtidal communities in the three study sites.

Univariate methods:

These methods are used to extract the features of communities which are not the function of any specific taxa, i.e. these methods are species independent. Compared to multivariate methods, these are obtained more easily and are also as sensitive as multivariate methods (Warwick and Clarke, 1991) in terms of detecting changes. Most commonly used indices which are used in this study are mentioned here.

Shannon-Wiener index (H'):

The data were analyzed using the following formula of Shannon and Wiener (1949) known as the Shannon index of diversity (H').

$$H' = \sum_{i=1}^{s} Pi \log_2 Pi$$

Here P_i= ni /N for the i^{th} species, S = total number of species, (ni) = number of individuals of a species in sample, N = total number of individuals of all species in sample. Here the value of H' is dependent upon the number of species present, their relative proportions, sample size (N), and the logarithm base. The choice of the base of logarithm is arbitrary (Valiela, 1995) and here $\log^2$ has been used.

Species richness:

This is one of the oldest and most basic diversity measurements, based directly on the total number of species at a site; the term species richness is often preferred since the exact number of species in a community is rarely known. The most commonly used Margalef index (d) has been used presently.

Margalef index (d):

Margalef index is denoted by 'd' and was calculated using the following formula:

$$d = (S-1) / \log N,$$

where, S = total number of species and N = total number of individuals

Pielou's evenness index (J'):

The equitability (J') was computed using the following formula of Pielou (1966):

$$J' = H'/H'max,$$

where, H' is the observed species diversity and H'max is the logarithm of the total number of species (S) in the sample. For example, 2 species with 50 individuals each would represent complete equitability or evenness with a value of 1.Two species with one and 99 individuals each, would score only 0.08.

Graphical/distributional methods:

These techniques are intermediate between univariate summaries and full multivariate analysis of the species/samples matrix. Two widely used methods are employed here to compare biotic diversity.

k-dominance curve:

This curve representation has been developed by Lambshead *et al.*, (1983). k-Dominance curve results from plotting percentage cumulative abundance against species rank k on a logarithmic scale.

Multivariate methods:

In contrast to diversity indices, the multivariate methods preserve species identity and are generally regarded as more sensitive in detecting changing community patterns. Thus effects can be detected earlier (Gray *et al.*, 1990; Warwick and Clarke, 1991). Multivariate methods, however, also suffer from some shortcomings. They are considerably more complex than other methods, involving substantial pre-processing or editing of data, such as transformation, and presently there is no uniform or agreed procedure. The data matrix was reduced for data processing to remove rare species from analysis.

Cluster analysis:

Cluster analysis was done to find out the similarities between groups. The most commonly used clustering technique is the hierarchical agglomerative method. The results of this are represented by a dendrogram with the x- axis representing the full set of samples and the y-axis defining the similarity level at which the samples or groups are fused. Bray - Curtis coefficient (Bray and Curtis, 1957) was used to produce the dendrogram. The coefficient was calculated by the following formula.

$$S_{jk} = 100 \left\{ 1 - \frac{\sum_{i=1}^{p} |y_{ij} - y_{ik}|}{\sum_{i=1}^{p} (y_{ij} + y_{ik})} \right\}$$

$$= 100 \frac{\sum_{i=1}^{p} 2 \min(y_{ij}, y_{ik})}{\sum_{i=1}^{p} (y_{ij} + y_{ik})}$$

where, y_{ij} represents the entry in the i^{th} row and j^{th} column of the data matrix i.e. the abundance or biomass for the i^{th} species in the j^{th} sample; y_{ik} is the count for the i^{th} species in the k^{th} sample; | ... | represents the absolute value of the difference; 'min' stands for, the minimum of the two counts and Σ represents the overall rows in the matrix.

MDS (Non - Metric multi Dimensional Scaling) :

This method was proposed by Shepard (1962) and Kruskal (1964) and this was used to find out the similarities (or dissimilarities) between each pair of entities to produce a 'map', which would ideally show the inter relationships of all. Samples lying closer have more similarity in species composition and abundance while samples lying apart have more dissimilarity in species composition and abundance.

6.3. Results:

In the present study, organisms of the following 5 groups were recorded in the benthic sample collection having integrated relationship with zooplanktons recorded.

i. Polychaetes
ii. Gastropods
iii. Bivalves
iv. Crustaceans and
v. Miscellaneous

A total of 42 taxa of macrofauna in the subtidal realm were encountered during this two year study from all the 3 stations. Of the 42 species recorded, polychaetes were largest component in the collection with 13 species. Gastropods were found to be the next dominant group in the order of abundance with 11 species. The bivalves and crustaceans ranked third and fourth respectively with 10 and 6 species. The group miscellaneous came last in the order with 2 species.

Sanghi recorded a total of 34 species of macrofauna. Among them, there were 12 species of polychaetes, 7 species of gastropods, 7 species of bivalves, 6 species of crustaceans and 2 species of miscellaneous. Cirratulids, *Bursa granularis, Haminoea, Oliva gibbosa, Terebralia palustris* and *Cucullea cucullata* which were represented in other stations were absent throughout the study period in Sanghi creek. Inter-annual variation in species number was insignificant.

Similar to Sanghi, Mundra also recorded 34 species of macrofauna constituted by 12 species of polychaetes, 10 species of gastropods, 5 species of bivalves, 5 species of crustaceans and 2 species belonged to the miscellaneous . Maximum number of 28 species at this station was recorded during winter 2007 and monsoon 2008 while minimum of 22 species were recorded during Monsoon 2008.

Mandvi recorded the lowest of 31 species during this two year study which in turn is constituted by 11 species of polychaetes, 4 species of gastropods, 8 species of bivalves, 6 species of crustaceans and 2 species of others. Number of species recorded at Mandvi in all the seasons of both the years was comparatively lesser than the other two stations. Lowest number of 15 species was recorded during winter 2007 and 2008 and monsoon 2009 while the highest number of 22 was recorded during summer 2007.

Among polychaetes forms like Sabellids, *Nereis sp, Glycera sp,* terebellids were found to occur in most of months recording highest frequency of occurrence. Forms like Sabellarids, *Amantia leptocirrus, Amphitrite sp, Nephtys, Sigalion sp* recorded least frequency of occurrence. Among Gastropods, the dominant species were *Bursa granularis, Cerithidea cingulata., Dentalium sp., Nassarius pullus, N. dorsatus., Nasa* sp., *Oliva gibbosa., Terebralia palustris* and *Umbonium vestarium* were recorded in most of the months whereas forms like *Haminoea, Terebralia palustris* and *Nassa dorsatus* were recorded only in few months and their frequency of occurrence was least.

With respect to bivalves, the dominant species namely *Meretrix meretrix, M. casta, Catalysia* sp., *Cucullea cucullata., Donax cuneatus, Epitonium scalare, Paphia* sp., *Solen kempi* and *Solen lamarcki* and the crustaceans species such as *Tanaeus* sp., *Apseudes* sp. amphipods, isopods, nematodes and shrimp larvae showed their consistency in their distribution in all the transects. The group miscellaneous included some of the species of brittle stars and foraminiferans which were infrequent in their occurrence.

6.3.1. Season- wise occurrence of macrofauna at stations:

Seasonal occurrence of macrofauna in the three study stations for two years is given in Table 6.1. Numbers of groups were generally higher during summer and monsoon seasons in both the years whereas winter in all the stations recorded lower number of taxa. In Sanghi maximum of 9 taxa were recorded during winter 2007-08 while lowest group number of 6 was recorded during summer 2007-08. Subtidal faunal abundance in all seasons was lower during 2008-09 comparing 2007-08 in Sanghi. Throughout the study, Mundra recorded 34 taxa. In Mundra, monsoon of 2008 recorded higher faunal groups of 28 than

other seasons. At this station, summer recorded the lowest taxa in all the season. In Mandvi, summer 2007-08 and 2008-09 recorded higher groups of 22 and 16 whereas lowest group of 15 was recorded during winter and monsoon of 2008-09.

Summer, 2008

At Sanghi, there were 6 species of Polychaeta, 3 species of gastropods, 6 species of bivalves, 5 species of crustaceans and 2 species of miscellaneous .

With respect to Mundra, 8 species of Polychaeta, 6 species of gastropods, 4 species of bivalves, 5 species of crustaceans and 2 species of miscellaneous were recorded.

Mandvi registered 6 species of Polychaeta, 3 species of gastropods, 6 species of bivalves, 5 species of crustacean and 2 species of miscellaneous.

Monsoon, 2008

At Sanghi, 9 species belonging to Polychaeta, 6 species each to gastropods, bivalves and crustaceans and 2species of miscellaneous were recorded.

In Mundra, there were 10 species of Polychaeta, 7 species of gastropods, 5 species of bivalves, 4 species of crustaceans and 2 species of group miscellaneous.

With respect to Mandvi, Polychaeta consisted of 8 species, gastropods consisted of 2 species, and bivalves and crustaceans consisted of 4 species each. The group miscellaneous consisted of 1 species.

Winter, 2009

Sanghi registered 8 species of Polychaeta, 4 species of gastropods, 6 species of bivalves and 5 species of crustaceans. The group miscellaneous consisted of 1 species.

In Mundra, there were 8 species of Polychaeta, 6 species of gastropods, 4 species of bivalves and 5 species of crustaceans. The group miscellaneous consisted of 2 species

At Mandvi, Polychaeta consisted of 6 species, gastropods consisted of 3 species and Crustacean consisted of 4 species. Bivalves and group miscellaneous consisted of 1 species each.

Summer, 2009

At Sanghi, 7 species belonged to Polychaeta, 4 species to gastropods bivalves and crustaceans belonging to 6 species each. The group miscellaneous consisted of 2 species

In Mundra, Polychaeta consisted of 8 species, gastropods consisted of 5 species, bivalves consisted of 3 species and crustaceans consisted of 5 species. The group miscellaneous consisted of 2 species

Mandvi registered 4 species of Polychaeta, 2 species of gastropods, 3 species of bivalves, 5 species of crustacean and 2 species of miscellaneous.

Monsoon, 2009

At Sanghi, 7 species belonging to Polychaeta, 5 species each to gastropods, bivalves and crustaceans and 2species of miscellaneous were recorded.

In Mundra, there were 7 species of Polychaeta, 5 species of gastropods, 3 species of bivalves, 5 species of crustaceans and 2 species of group miscellaneous.

With respect to Mandvi, Polychaeta consisted of 4 species, gastropods consisted of 2 species. Bivalves and crustaceans consisted of 1and 5 species respectively. The group miscellaneous consisted of 2 species.

6.3.2. Population density of macro benthos:

Similar to first year, overall density showed dominance of crustaceans though it was represented by 6 groups only, crustacean group density was much higher for the overall study period accounting an average of 47866/10m^2(77.7%) whereas Polychaeta and bivalves with a richness of 13 and 11 groups showed an overall density of and 3396/10m^2 and 2986/10 m^2. The 'Other' groups recorded a density of 3145/10 m^2 though it had only two groups apparently due to higher density recorded for foraminiferans (Table 6.2, Table 6.4). Overall density in both first and second years was generally higher during winter whereas monsoon recorded lower densities (Annexure-1). Station-wise, overall density was higher at Sanghi followed by Mundra and Mandvi in both the years. Considering average individual group wise density, highest density was noticed in the crustacean group isopods (4356/10 m^2 and 3421/10 m^2) followed by amphipods (1987/10 m^2). These groups recorded highest density during the 2007-08 sampling as well. Overall individual lowest density of 1/10 m^2 was recorded for the taxa cirratulids during monsoon of 2007-2008. Among Polychaeta, one unidentified Polychaeta recorded the maximum density of 123/10 m^2. Among gastropods, *Nerita* sp recorded fairly higher density of 187/10 m^2. The lowest density of 4/10 m^2 and 5/10 m^2 was recorded for groups like *Bursa granularis* and *Nephtys capensis* (Table 4.2).

Station-wise, Sanghi recorded a density range of 3540 to 7,751 organism/10 m^2 with the maximum occurring during winter 2009 and minimum during summer 2008 (Fig. 6.1). Overall density was higher during the first year (2007-08) than the second year (2008-09). At Mundra, the density range of benthic macrofauna varied from 1457 to 2285/10 m^2 animals per square metre. The minimum density was recorded during monsoon 2009 and maximum in monsoon 2008. In Mandvi, the density of macrofauna per square meter fluctuated from 2068 to 4008 animals. The minimum was noticed during winter 2008 and maximum in summer 2009.

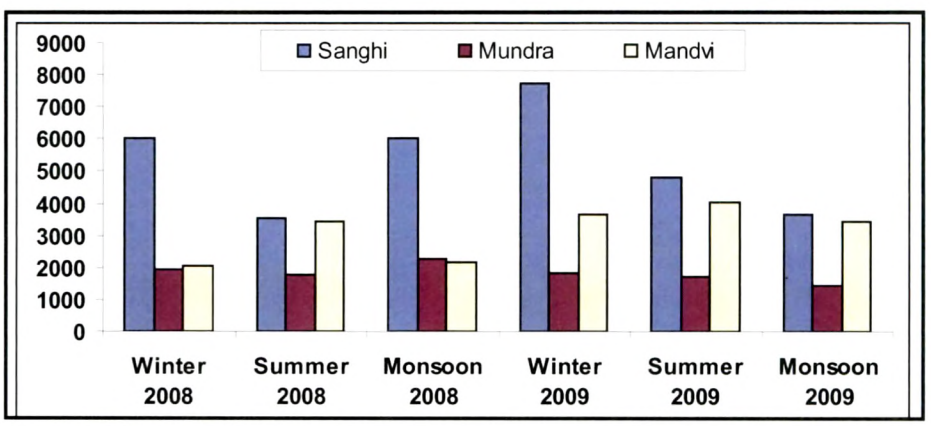


Fig. 6.1. Seasonal variations in population density of macrobenthos recorded in three stations

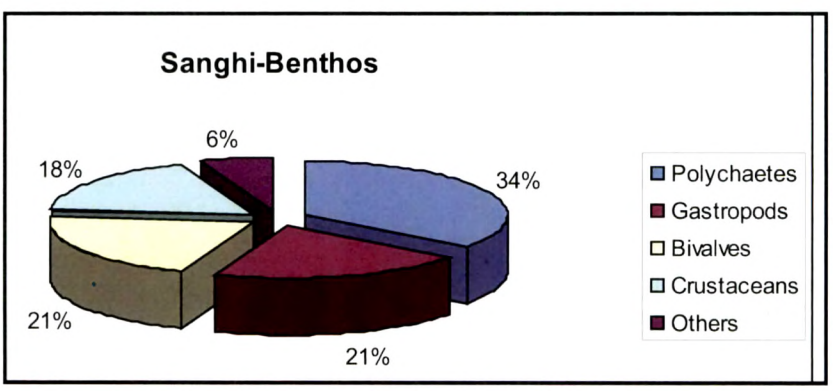
6.3.3. Percentage composition of macrofauna

The percentage composition of macrofauna is depicted in Fig. 6.2 for all the three stations (Sanghi, Mundra, Mandvi). In Sanghi, Polychaeta were found to be the dominant group constituting 34% of the total benthic organisms recorded. Gastropods formed the second dominant group with a percentage occurrence of 21%. Bivalves and crustaceans had a percentage contribution of 21% and 18%,

respectively. The group miscellaneous came last in the order of dominance with a meagre percentage of 6%.

Both at Sanghi and Mundra Polychaeta dominated with a percentage incidence of 35% of the total benthic organisms enumerated. Gastropods ranked second with a percentage of 29%. Bivalves and crustaceans contributed each 15% to the total benthic organisms collected. The contribution of group miscellaneous was 6%.

Similar to other two stations, Polychaeta were dominant contributing 36% to the total manual composition. The Bivalves were found to be the next best with a percentage contribution of 26%. Crustaceans and gastropods constituted 19% and 13% of the total benthic organisms collected at this station. The contribution of group miscellaneous was 6%.



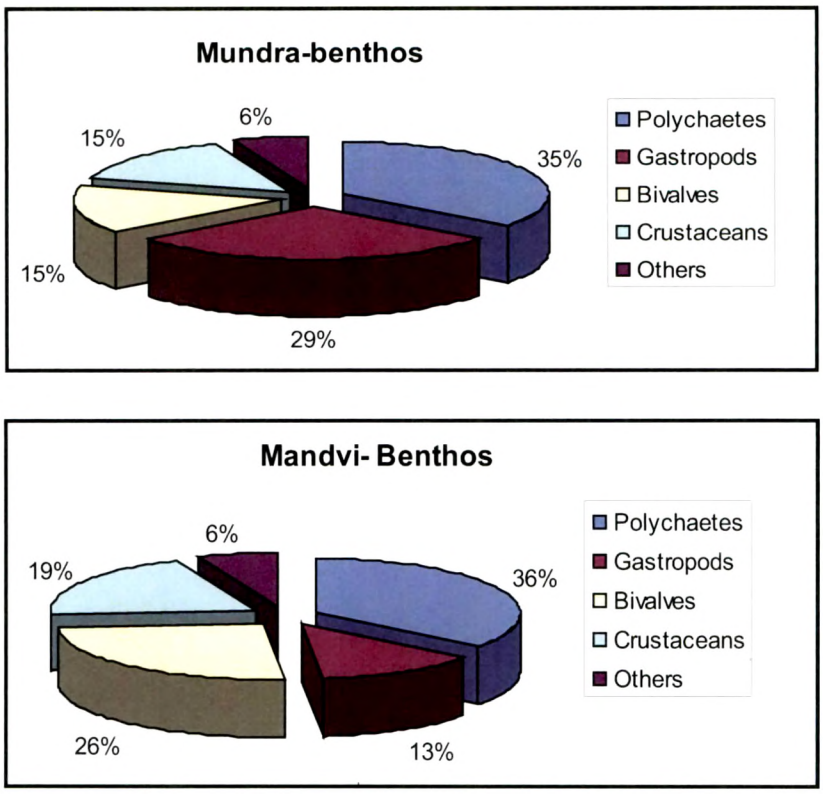


Fig.6.2. Percentage composition of macrobenthos in the Study Stations during the study period.

6.3.4. Species count versus number of organisms

Number species in each stations and their contribution to the total abundance was analyzed for each stations and the results are shown in Fig 6.3. and Fig 6.4. Group numbers were almost similar at Sanghi and Mundra whereas Mandvi recorded lower group numbers. Consistent with its high species richness highest numerical abundance was observed in Sanghi and the lowest was in Mundra (Fig 6.3). Though group richness was higher than Mandvi, Mundra contribution to faunal abundance was lower. In general, Sanghi with its highest group richness was highly abundant as well.

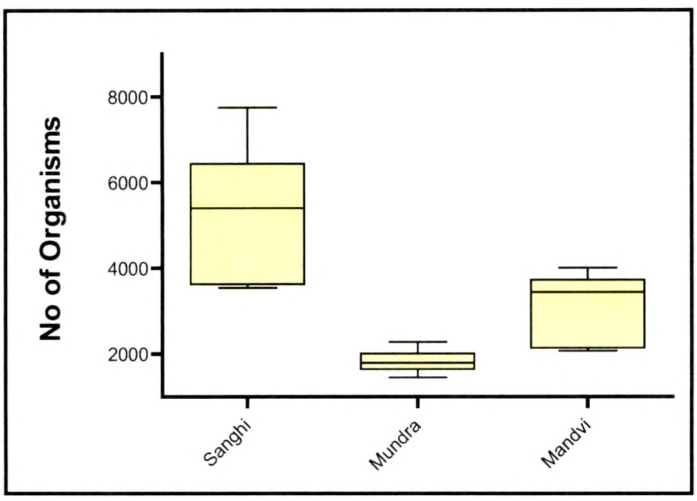


Fig 6.3 Species count at three stations

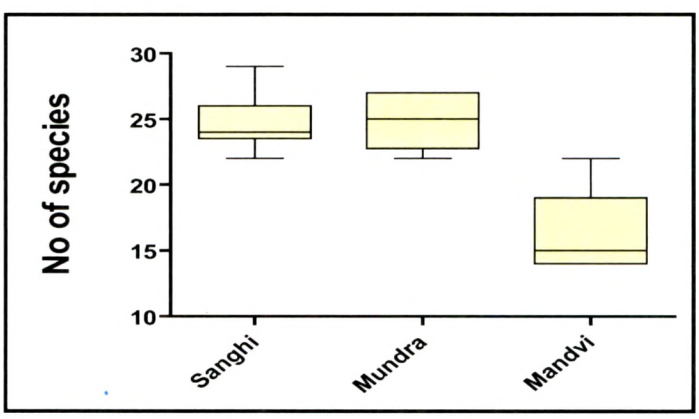


Fig. 6.4 Numerical abundance at three stations

Season-wise numerical abundance in relation to species count showed occurrence of highest numerical abundance during winter, 2009 and lowest in Monsoon, 2009 (Fig. 6.6). Lower species count was observed in Monsoon, 2009 and the highest species count was observed in Monsoon 2008 (Fig. 6.5). However, this positive relationship between higher group diversity and

numerical abundance was not observed in all seasons. For example, summer and monsoon 2008 which recorded higher group diversity registered only moderate abundance.

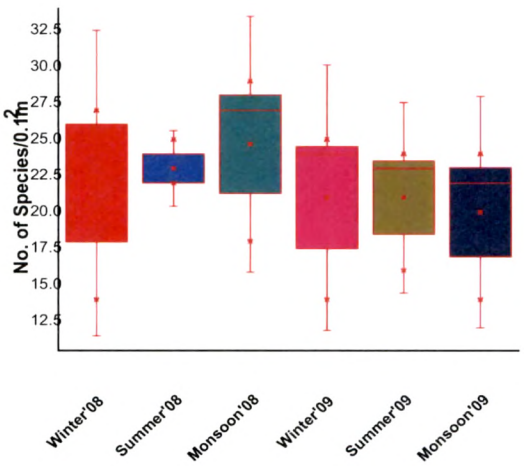


Fig 6.5 Species count during six seasons

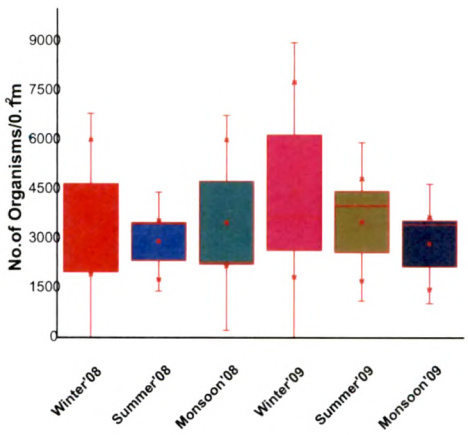


Fig. 6.6 Numerical abundance during six seasons

6.3.5. Univariate methods

6.3.5.1. Species diversity (Shannon-Wiener index)

The various diversity indices calculated in the three stations during all the seasons are given in Table 6.3.

The Shannon diversity index for the entire study (June 07-May 2009) varied between 2.153 (Mundra, winter 2008) and 3.066 (Mundra, winter 2009). In Sanghi, it ranged between 2.229 (winter 2008) and 3.022 (monsoon 2009) with a mean (±SD) of 2.65±0.36. Winter of 2007 and 2008 generally recorded lower values whereas it was high during summer and monsoon 2008. Similar to Sanghi diversity values during winter 2007 was lower in Mundra, but winter 2008 recorded higher values. Range of diversity values at Mundra was between 2.153 (Winter 2008) and 3.066 (Winter 2009) with a mean (±SD) of 2.70±0.35 and in Mandvi, it varied between 2.255 (Summer 2009) and 2.738 (Monsoon 2008) with a mean (±SD) of 2.40±0.19 (Fig. 6.7).

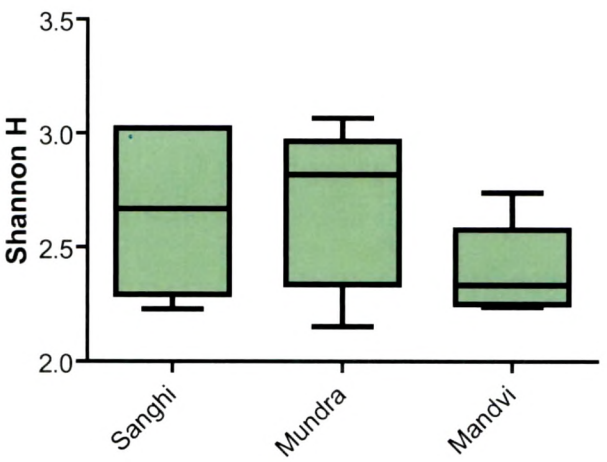


Fig. 6.7. Subtidal faunal diversity at three stations

Season-wise, Shanon diversity index during the whole study period varied between 2.153 (Mundra, Winter 2008) and 3.066 (Mundra, Winter 2009). During winter 2008, diversity values were lowest than all other seasons and it ranged between 2.153 (Mundra) and 2.331 (Mandvi) with a mean (±SD) of 2.24±0.09. During second year, summer and monsoon recorded lower values than winter. During summer 2008, it ranged between 2.337 (Mandvi) and 2.93 (Mundra) with a mean (±SD) of 2.58±0.31. During monsoon 2008, it varied between 2.398 (Mundra) and 2.878 (Sanghi) with a mean (±SD) of 2.67±0.25. During winter 2009, it ranged between 2.315 (Sanghi) and 3.066 (Mundra) with a mean (±SD) of 2.64±0.39. During summer 2009, it ranged between 2.255 (Mandvi) and 3.021 (Sanghi) with a mean (±SD) of 2.71±0.40. During monsoon 2009, it varied between 2.238 (Mandvi) and 3.022 (Sanghi) with a mean (±SD) of 2.68±0.40. (Fig. 6.8)

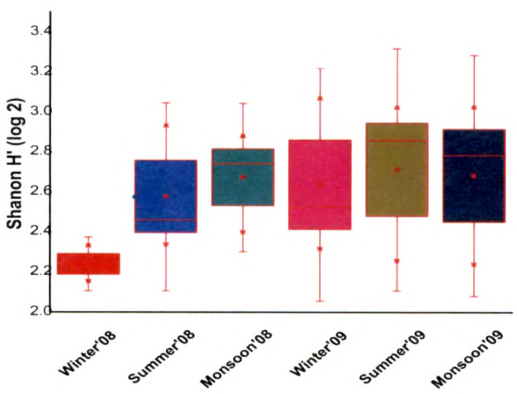


Fig. 6.8 Subtidal faunal diversity during six seasons

6.3.5.2. Species richness (Margalef's Index):

As in the species diversity, the means and 95% confidence intervals of richness values were calculated and graphed station-wise and season-wise. The species richness during the study period varied between 1.586 (Mandvi, Winter 2009) and 3.439 (Mundra, Winter 2008). Richness values were consistently higher at Mundra followed by Sanghi while Mandvi recorded comparatively lower richness values in all the seasons. In Sanghi, it ranged between 2.568 (Winter 2009) and 3.219 (Monsoon 2008) with a mean (±SD) of 2.77±0.24. In Mundra, it ranged between 2.883 (Monsoon 2009) and 3.439 (Winter 2008) with a mean (±SD) of 3.17±0.22 with first year (2007-08) recording higher values than the second year (2008-09). In Mandvi, it varied between 1.586 (Winter 2009) and 2.578 (Summer 2008) with a mean (±SD) of 1.91±0.40. (Fig. 6.9)

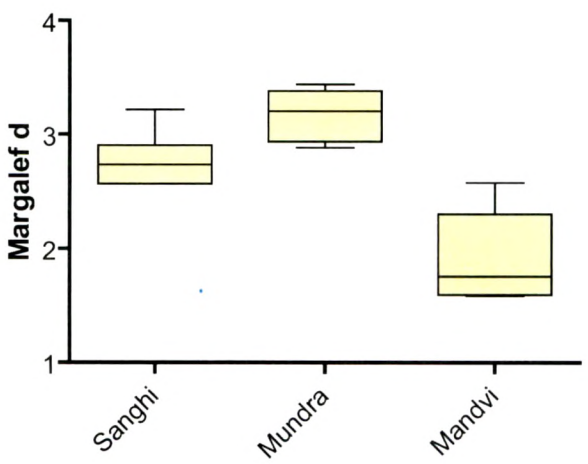


Fig.6.9 Species richness at three study stations for the entire study

Season-wise species richness of the study period varied between 1.586 (Mandvi, Winter 2009) and 3.439 (Mundra, Winter 2008). Seasonal richness values during

2007-08 was higher than the values of the second year (2008-09). During winter 2008, it ranged between 1.703 (Mandvi) and 3.439 (Mundra) with a mean (±SD) of 2.63±0.87. During summer 2008, it ranged between 2.57 (Sanghi) and 3.212 (Mundra) with a mean (±SD) of 2.79±0.37. During monsoon 2008, it varied between 2.213 (Mandvi) and 3.362 (Mundra)) with a mean (±SD) of 2.93±0.63. During winter 2009, it ranged between 1.586 (Mandvi) and 3.194 (Mundra) with a mean (±SD) of 2.45±0.81. During summer 2009, it ranged between 1.808 (Mandvi) and 2.953(Mundra) with a mean (±SD) of 2.49±0.60. During monsoon 2009, it varied between 1.597 (Mandvi) and 2.883 (Mundra) with a mean (±SD) of 2.43±0.72. (Fig. 6.10)

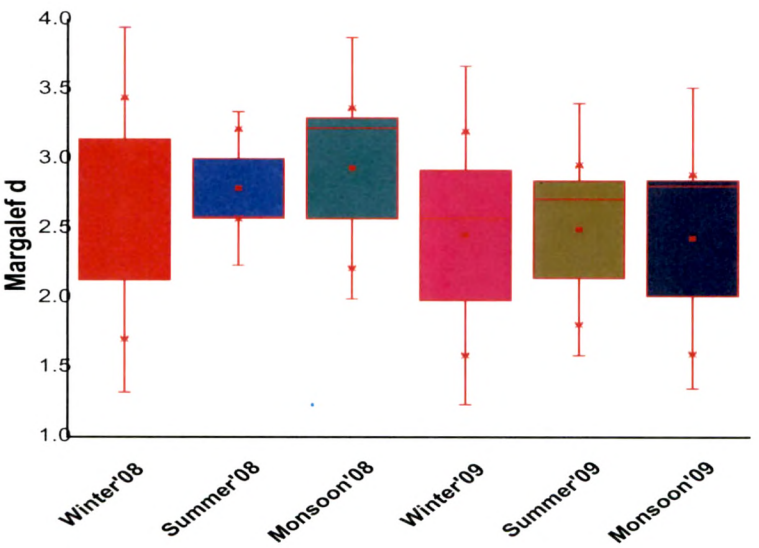


Fig. 6.10. Species richness during six seasons.

6.3.5.3. Species Evenness (Pielou's index)

As in the other indices, the means and 95% confidence intervals of station-wise and season-wise evenness values were computed. The species evenness during the study period varied between 0.45 (Mundra, winter 2008) and 0.66 (Mandvi during Monsoon 2008, winter 2009 and Sanghi during summer 2009 and monsoon 2009). In Sanghi, it ranged between 0.48 (winter 2008) and 0.66 (summer and monsoon 2009) with a mean (±SD) of 0.57±0.076. In Mundra, it ranged between 0.45 (Winter 2008) and 0.66 (Winter 2009) with a mean (±SD) of 0.58±0.084 and in Mandvi, it varied between 0.52 (Summer 2008) and 0.66 (Monsoon 2008 and winter 2009) with a mean (±SD) of 0.60±0.054. Evenness values at all the three stations were lower during the first year (2007-08) than the following year (2008-09). (Fig. 6.11)

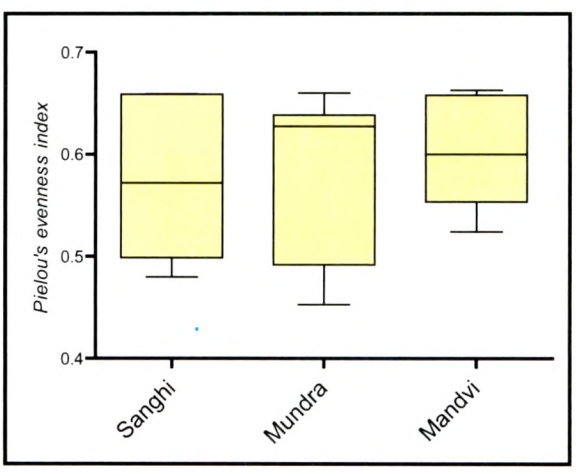


Fig.6.11. Species evenness at three stations

Season-wise species evenness during the study period varied between 0.45 (Mundra, Winter 2008) and 0.66 (Mandvi during Monsoon 2008, Winter 2009 and Sanghi during Summer 2009 and Monsoon 2009). Winter 2008 recorded the

lowest evenness value with a range between 0.45 (Mundra) and 0.61 (Mandvi) with a mean (±SD) of 0.52±0.085. Summer 09 and monsoon 09 recorded highest evenness values among all seasons. Generally values were lower during all the three seasons of 2007-08 whereas the subsequent year recorded higher values. (Fig. 6.12)

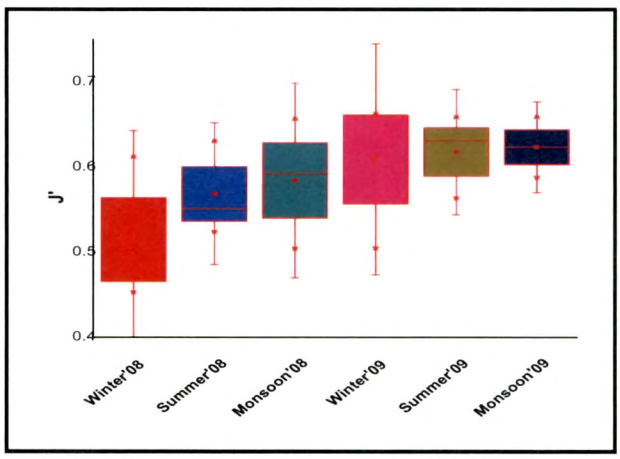


Fig. 6.12. Species evenness during six seasons.

6.3.6. Graphical or distributional techniques

6.3.6.1. K- Dominance curve

Multiple K-dominance plots were constructed for all the samples during both the years, through the application of PRIMER. Fig. 4.13 shows the observed findings for all samples collected during entire study period. It can be seen that the maximum macrofaunal population was 29 species in Sanghi, contributing 80% of the total macrofaunal numbers. The minimum species count (14) was recorded at Mandvi.(Fig. 6.13)

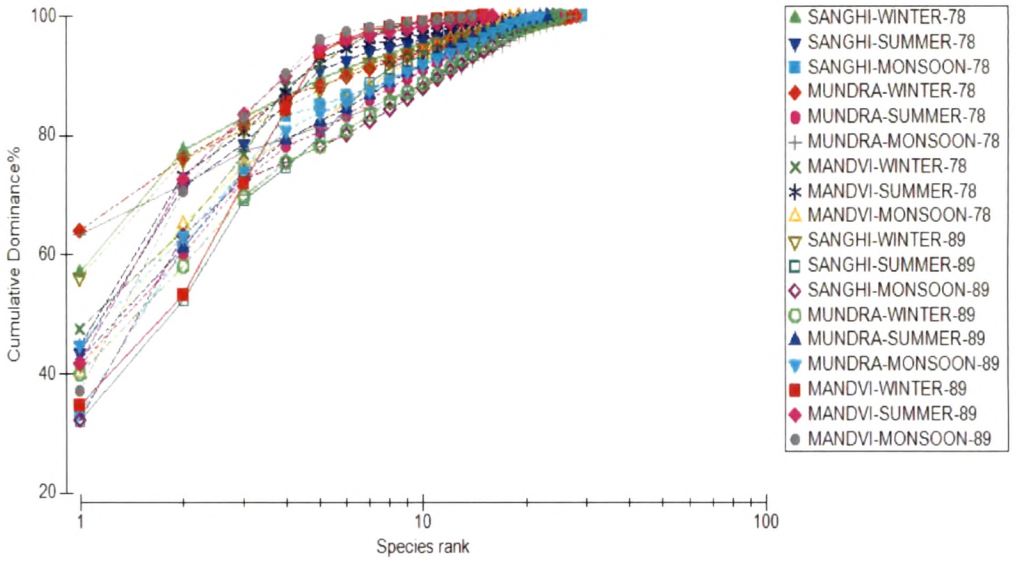


Fig. 6.13 Cumulative Dominance of Intertidal Fauna during the study period

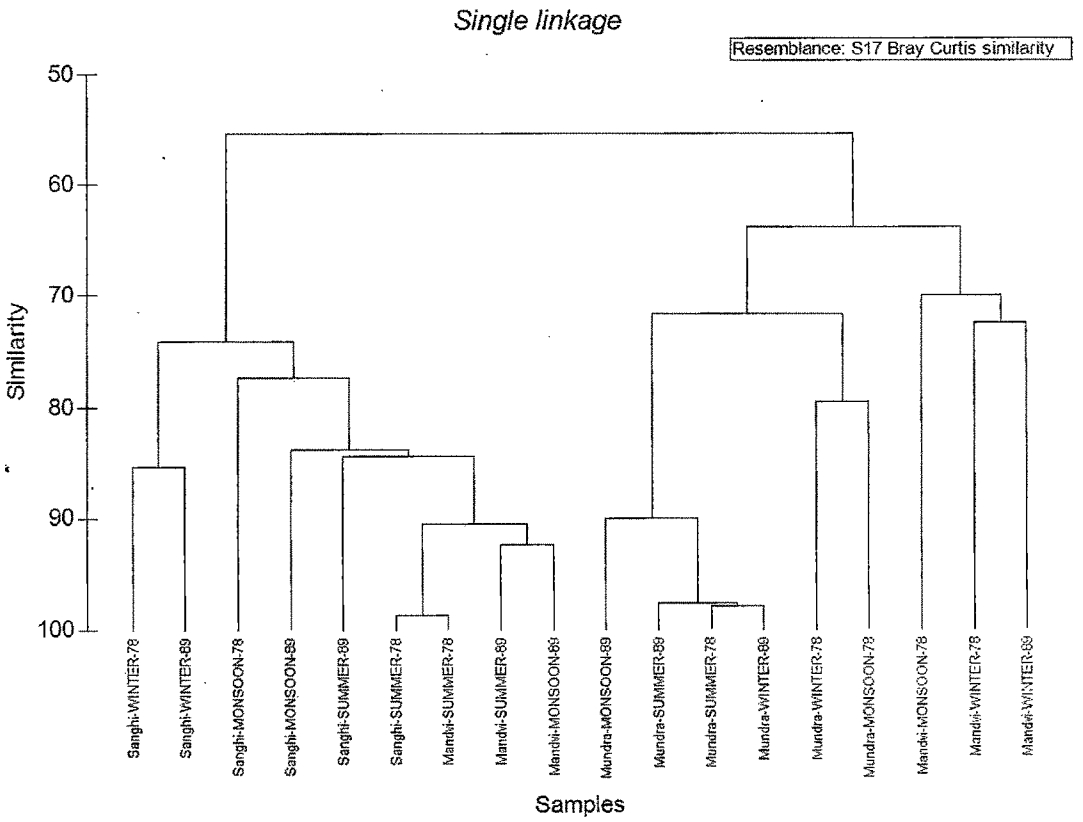
6.3.7. Multivariate methods

6.3.7.1. Cluster analysis (Bray- Curitis similarity) and multi-dimensional Scaling (MDS)

Cluster analysis is a technique in which entities are sequentially linked together according to their similarity (or dissimilarity) producing a two dimensional hierarchical structure (dendrogram). Figs.6.14. display the results of the hierarchical clustering, using the group average linking on the macrofauna species abundance data for the 3 stations during six seasons along the west coast of India. Bray-Curtis similarities were calculated on the 4th root transformed data (as implemented in PRIMER).

From the overall cluster analysis (Winter 2008 to Monsoon 2009), it was observed that maximum similarity (98.63%) was between Sanghi and Mandvi Summer 20008. Mandvi Summer and Monsoon 2009 (92.33%) joined with this group at

89.5%. Mundra Summer 2008 and Mundra Winter 2009 formed another group at 97.91%. Mundra Summer 2009 joined with this group at 96.75% and Mundra monsoon 2009 joined with this group at 89.13%, respectively. This two main group joined at 28.55%. This same trend was confirmed in MDS ordination. (Fig. 6.15)



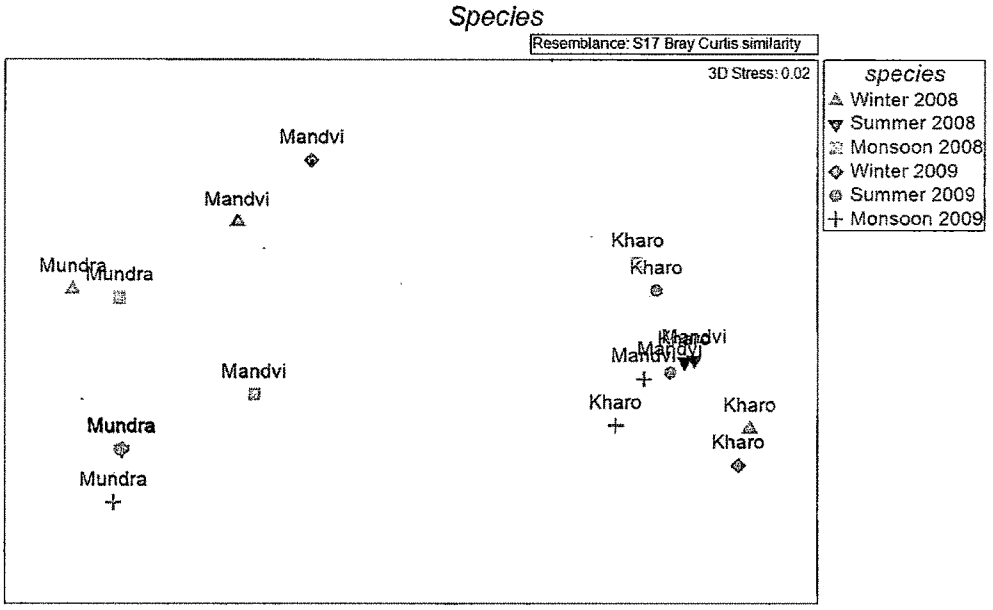


Fig. 6.14 and 6.15 Hierarchical clustering and biotic MDS of the seasons and stations showing subtidal species assemblages at various similarity levels.

6.4. Discussion

Investigations on benthos in the tidal waters are enormous. Most of these studies deal with only abundance of different groups and investigation on the qualitative aspect of these groups are quite inadequate. Macrofaunal composition in the present study included 5 major groups viz. Polychaetes, Gastropods, Bivalves, Crustacea, and miscellaneous. Of the 5 taxonomic groups, the most dominant and prevalent group was free-living Polychaetes followed by gastropods and then bivalves, crustaceans, and others. Dominance of polychaetes in subtidal waters were earlier reported by many workers like Ansari *et al.,* (1986), Mohammed (1995), Kumar (2001) and Kundu *et al.*,2009 all in east and west coast waters. In the present study, the macro-benthic faunal

density ranged from 1,457 to 7,751 animals/10 m^2 at all stations throughout the study period. Occurrence of highest abundance (7,751 animals/10 m^2) found at Sanghi during winter 2009. This could be due to low temperature and turbidity coupled with a stable environment during this season. In the present study, low population density (1,457/10 m^2) was recorded during monsoon 2009 at Mundra. Normally Mundra receives higher rainfall than other coastal stretches of Kachchh. Low population density recorded at Mundra could be due to this enhanced rainfall and subsequent decline in salinity reducing the density during monsoon months. Similar to this, Seshappa, (1953) reported a 'severe decline' in the shallow water macro-benthos during the southwest monsoon, and the decrease was attributed to lowered salinity. This density decline during monsoon months due to lowering salinity was also confirmed in the works of Kumar and Antony (1994) and Kumar (2001). Species diversity is a simple and useful measure of a biological system. Sanders (1968) and Redding and Cory (1975) found a high level of agreement between species diversity and the nature of the environment and, hence, regarded the measure of species diversity as an ecologically powerful tool. Moreover, Pearson and Rosenberg (1978) proposed that the use of diversity indices is advantageous for the description of faunas at different stages in the succession. Sanders (1968) postulated that the species diversity is mainly controlled by the fluctuations in the environment that lead to less diversity. Species diversity in the present study registered a fluctuation between 2.153 (Mundra, winter, 2008) and 3.066 (Mundra, winter, 2009) between stations and seasons. Salinity of the sediment and overlying water column seems to play a crucial role in determining density. The pattern of lower and higher species diversity during winter recorded in the study area is in conformity with the earlier observations made in Vellar (Chandran, 1987) and Coleroon estuaries

(Devi, 1994). Similarly, richness of benthic macro-fauna was maximum (3.439) during the winter 2008 at Mundra. Similar observation was reported by (Kumar , 1995) in Cochin backwaters. The low richness recorded in this study during monsoon (1.586) might be due to the freshwater flow which induced low saline conditions, which in turn affected the distribution of benthos, particularly, the polychaetes. Maximum diversity and richness recorded during winter at the study sites might be due to stable environmental factors, such as salinity, which play an important role in faunal distribution. During the present investigation many dead bivalve shells were collected in the benthic sampling in all the stations and seasons which might be due to the high organic contents in the fine sediments originating from the mangrove habitats nearby especially at Sanghi and Mundra site. High organic content clogs the respiratory apparatus of bivalves (Bloom *et al.*, 1972). In their subtidal faunal study at Thane creek, Venkatachalam and Kale (2002) recorded polychaetes as the dominant group in terms of abundance. Contrarily, in the present study, crustaceans though represented by only 6 groups were numerically dominant, though polychaetes were represented by the highest number of 13 groups. Crustaceans are generally known to tolerate higher levels of environmental parameters. Recorded numerical dominance of crustaceans is clearly attributable to their ability to tolerate higher environmental extremes.

Table 6.1. Seasonal Distribution of Major Groups (no. of species) during the study Period

Major Groups	Sanghi			Mundra			Mandvi			Sanghi			Mundra			Mandvi		
	2007-08									2008-09								
	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M
Polychaetes	7	6	9	9	8	10	6	6	8	8	7	7	8	8	7	6	4	4
Gastropods	4	3	6	9	6	7	3	3	2	4	4	5	6	5	5	3	2	2
Bivalves	7	6	6	4	4	5	1	6	4	6	6	5	4	3	3	1	3	2
Crustaceans	5	5	6	4	5	4	4	5	4	5	6	5	5	5	5	4	5	5
Other forms	2	2	2	2	2	2	1	2	1	1	2	2	2	2	2	1	2	2
Total	25	22	29	28	25	28	15	22	19	24	25	24	25	23	22	15	16	15

Table 6.2. Seasonal Distribution of Major Groups (no. of organisms) during the study Period

Major Groups	Sanghi			Mundra			Mandvi			Sanghi			Mundra			Mandvi		
	2007-08									2008-09								
	Win	Sum	Mon	Win	Sum	Mon	Win	Sum	Mon	Win	Sum	Mon	Win	Sum	Mon	Win	Sum	Mon
Polychaetes	250	106	463	157	200	301	48	88	219	345	182	358	224	174	105	62	69	45
Gastropods	488	336	229	114	100	124	95	327	110	487	484	239	118	115	100	105	310	298
Bivalves	292	246	187	39	33	48	56	228	242	517	294	232	45	24	36	59	216	192
Crustaceans	4867	2787	5031	1379	1095	1692	1830	2772	1542	6168	3640	2715	1110	1080	942	2959	3378	2879
Others	105	65	88	237	331	132	45	29	66	234	251	112	337	325	274	456	35	23
Total	6002	3540	5998	1926	1759	2297	2074	3444	2179	7751	4851	3656	1834	1718	1457	3641	4008	3437

Table 6.3. Subtidal Diversity, Richness and Evenness Indices of the Stations during the Study Period

Season	Station	Species Richness	Abundance	Mergalef Richness	Pielou's Evenness	Shannon Diversity
Winter 2008	Sanghi	25	6002	2.759	0.4799	2.229
	Mundra	28	1921	3.439	0.4529	2.153
	Mandvi	15	2068	1.703	0.6122	2.331
Summer 2008	Sanghi	22	2068	1.703	0.6122	2.331
	Mundra	25	1759	3.212	0.6308	2.93
	Mandvi	22	3444	2.578	0.524	2.337
Monsoon 2008	Sanghi	29	5998	3.219	0.5925	2.878
	Mundra	28	2285	3.362	0.5044	2.398
	Mandvi	19	2171	2.213	0.6566	2.738
Winter 2009	Sanghi	24	7751	2.568	0.5048	2.315
	Mundra	25	1834	3.194	0.6602	3.066
	Mandvi	15	3633	1.586	0.6629	2.524
Summer 2009	Sanghi	25	4815	2.712	0.6589	3.021
	Mundra	23	1718	2.953	0.6314	2.856
	Mandvi	16	4008	1.808	0.5636	2.255
Monsoon 2009	Sanghi	24	3656	2.803	0.6591	3.022
	Mundra	22	1457	2.883	0.6237	2.781
	Mandvi	14	3437	1.597	0.5879	2.238

Table: 6.4 Subtidal Macrofaunal Density during the Study Period in Mundra, Mandvi and Sanghi

	2008									2009								
	Sanghi			Mundra			Mandvi			Sanghi			Mundra			Mandvi		
Groups/Taxa	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**
Polychaetes																		
Armandia leptocirrus				5		12	6		8		36					8		
Amphitrite sp.					45	30				31			48	39	29			
Cirratulids				6	11	19	3		34				14	11	1	5		
Glycera sp		24	24	21	38		21	21	23	19	28	36	41	34	24	19	24	18
Glyceridae	45	16	64			36		13	29	59	24	76						
Nephtys capensis				5	4		4			29			7	5		11		
Nereis sp.	39	21	48	11	22	27	11	18	33		29	45	25	16	6	13		
Sabellarids	19		80									54						
Sabellids	12	15	23	86	45	44		12	56	25	19	35	48	38	28		15	9
Sigalion sp			12	3	26	24			12				29	22	12			
Spionids	23		34	8		34	3		24	36		46				6		
Terebellids	23	17	80		9	21		14		23	25	66	12	9	5		17	11
Unidentified Polychaete	89	13	98	12		54		10		123	21						13	7
Richness	**7**	**6**	**9**	**9**	**8**	**10**	**6**	**6**	**8**	**8**	**7**	**7**	**8**	**8**	**7**	**6**	**4**	**4**
Density- m^2	**250**	**106**	**463**	**157**	**200**	**301**	**48**	**88**	**219**	**345**	**182**	**358**	**224**	**174**	**105**	**62**	**69**	**45**
Gastropods																		
Bursa granularis				3	2	8	2						5			6		
Cerithidea cingulata	64	54	68	11	10	35		51		67	62	63	13	11	12		54	48

	2008									2009								
	Sanghi			Mundra			Mandvi			Sanghi			Mundra			Mandvi		
Groups/Taxa	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**
Dentalium sp.			12	24	21	18			15				24	17	13			
Haminoea				5														
N. dorsatus			6	5		14						9						
Nassa sp	32	26						23		66	34							
Nassarius pullus			12	19	18							12	21	32	22			
Nerita sp	336	256	64			24		253		287	264	76					256	250
Oliva gibbosa				5	4	4							7	4	12			
Terebralia palustris				6			15									18		
Umbonium vestarium	56		67	36	45	21	78		95	67	124	79	48	51	41	81		
Richness	**4**	**3**	**6**	**9**	**6**	**7**	**3**	**3**	**2**	**4**	**4**	**5**	**6**	**5**	**5**	**3**	**2**	**2**
Density	**488**	**336**	**229**	**114**	**100**	**124**	**95**	**327**	**110**	**487**	**484**	**239**	**118**	**115**	**100**	**105**	**310**	**298**
Bivalves																		
Bivalve Spat	208	198	97				56	195	214	378	206	109				59	198	192
Catalysia sp	12		9							34		21						
Cucullea cucullata				15	16	14			12				19	14	16			
Donax cuneatus	6	12	15	11	9	6		9	8	19	20		12	4	9		12	
Epitonium scalare				5	2	11			8				5					
Meretrix meretrix	8	5	11			5		2		21	13	23						
Paphia sp.	12	6						3		24	14						6	0
Pholas sp.	19	16	24					13			24	36						
Solen kempi	27	9	31					6		41	17	43						

	2008									2009								
	Sanghi			Mundra			Mandvi			Sanghi			Mundra			Mandvi		
Groups/Taxa	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**	**Win**	**Sum**	**Mon**
Solen lamarcki				8	6	12							9	6	11			
Richness	**7**	**6**	**6**	**4**	**4**	**5**	**1**	**6**	**4**	**6**	**6**	**5**	**4**	**3**	**3**	**1**	**3**	**2**
Density-No/10 m^2	**292**	**246**	**187**	**39**	**33**	**48**	**56**	**228**	**242**	**517**	**294**	**232**	**45**	**24**	**36**	**59**	**216**	**192**
Crustaceans																		
Amphipods	1234	987	1987	112	215	195	267	984	543	1543	995	1134	218	212	156	340	1234	1156
Nematodes	177	234	547	1234	732	1456	984	231	876	211	242	345	735	729	654	1263	432	426
Amphitrite sp.		15	12					12			23	24					15	9
Isopods	3421	1543	1678	3	21	20	345	1540	56	4356	1551	1178	24	18	14	678	1678	1275
Shrimp larvae	16	8	22		102			5		29	16	34	105	99	101		19	13
Tanaids	19		785	30	25	21	234		67	29	813		28	22	17	678		
Richness	**5**	**5**	**6**	**4**	**5**	**4**	**4**	**5**	**4**	**5**	**6**	**5**	**5**	**5**	**5**	**4**	**5**	**5**
Density-No/10 m^2	**4867**	**2787**	**5031**	**1379**	**1095**	**1692**	**1830**	**2772**	**1542**	**6168**	**3640**	**2715**	**1110**	**1080**	**942**	**2959**	**3378**	**2879**
Others																		
Brittle star	7	9	10	3	5	9		6			17	22	8	2	7		9	3
Foraminiferans	98	56	78	234	326	123	45	23	66	234	234	90	329	323	267	456	26	20
Count	2	2	2	2	2	2	1	2	1	1	2	2	2	2	2	1	2	2
	105	65	88	237	331	132	45	29	66	234	251	112	337	325	274	456	35	23
Total Richness	**25**	**22**	**29**	**28**	**25**	**28**	**15**	**22**	**19**	**24**	**25**	**24**	**25**	**23**	**22**	**15**	**16**	**15**
Total Density-No/10 m^2	**6002**	**3540**	**5998**	**1926**	**1759**	**2297**	**2074**	**3444**	**2179**	**7751**	**4851**	**3656**	**1834**	**1718**	**1457**	**3641**	**4008**	**3437**