CHAPTER 9

BENTHIC STANDING STOCK IN THE ESTUARY

9.1. INTRODUCTION

Organisms depend on one another for their survival. Measurement of standing stocks of ecosystem components is essential to understand ecological energetics. The significance of benthos in various trophic levels is well documented (Coull, 1990). Between the primary production and the fish production, the role of benthic organisms, first as a feeder of plant material and detritus and in turn forming food of higher forms is now well understood. Estimation of benthic standing stock is essential for the assessment of demersal fishery resources, as benthos form an important source of food for demersal fishes (Damodaran, 1973; Parulekar et al., 1982). For the better understanding of benthic productivity and benthic food chains, simultaneous measurement of standing stock of meiobenthos and macro benthos is imperative.

9.2. RESULTS

9.2.1. Numerical abundance of meiofauna

At station 1 the population density/10cm² ranged from 42 (November 2003) to 1068 (January 2003) individuals. In station 2 it varied from 114 (January 2003) to 2466 (November 2003) individuals/10cm². As far as station 3 is concerned population density ranged between 273 (August 2002) to 2931 (July 2003) individuals/10cm². Coming to station 4 the population density/10cm² ranged from 79 (November 2002) to 569 (October 2002) individuals. At station 5 it varied from 105 (November
2002) to 837 (October 2002) individuals /10cm². At station 6 the maximum density observed was 121 (March 2003) individuals /10cm² and this station was devoid of fauna in a number of sampling. The average density of meiofauna at stations 1 to 6 were 319, 977, 1034, 278, 387 and 18 individuals /10cm² respectively (Refer table: 6.1.1-6.1.6).

At station 1 the density of nematodes/10cm² ranged from 30 (November 2003) to 965 (January 2003) individuals. In station 2 it varied from 108 (January 2003) to 2440 (November 2003) individuals /10cm². As far as station 3 is concerned the density ranged between 253 (August 2002) to 1575 (February, 2003) individuals /10cm². Coming to station 4 the density/10cm² ranged from 33 (November, 2002) to 447 (July, 2002) individuals. At station 5 it varied from 81 (November, 2002) to 775 (October 2002) individuals /10cm². With respect to station 6 the maximum density observed was 12 (May 2003) individuals /10cm² and this station was devoid of fauna in a number of sampling. The average densities of nematodes at stations 1 to 6 were 250, 974, 810, 215, 316 and 5 individuals /10cm² respectively.

Polychaetes were occasionally absent at stations 1, 2, 4, 5 and 6. At station 1 the maximum polychaete density observed was 216 (October 2002) /10cm² individuals. In station 2 it was 10 individuals (February 2003) /10cm². As far as station 3 is concerned their density ranged between 2 (August 2002) to 59 (September 2002) individuals /10cm². Coming to station 4 the maximum density /10cm² was 190 (October 2002) individuals. At station 5 it was 34 (October 2002) individuals /10cm². At station 6 the maximum density observed was 12 (March 2003) individuals /10cm². The average density of polychaetes at stations 1 to 6 were 35, 3, 16, 22, 10 and 1 individuals /10cm² respectively.

At station 1 the population density of copepods/10cm² ranged from 0 (December 2002) to 41 (April 2003) individuals. In station 2 it varied from 0 (September 2002 and January 2003) to 22 (February 2003) individuals /10cm². As far
as station 3 is concerned the density ranged between 0 (April 2003 and June 2003) to 33 (May 2004) individuals /10cm². Coming to station 4 the density/10cm² ranged from 2 (May 2003) to 65 (March 2003) individuals. At station 5 it varied from 0 (November 2002) to 202 (May 2004) individuals /10cm². At station 6 the maximum density observed was 102 (March 2003) individuals /10 cm² and this station was devoid of copepods in a number of sampling. The average density of copepods at stations 1 to 6 were 12, 7, 7, 13, 48 and 9 individuals /10 cm² respectively.

At station 1 the maximum density of foraminifera observed was 78 individuals (December 2002) /10cm². In station 2 it was 8 individuals (March 2003) /10cm². As far as station 3 is concerned population density ranged between 6 (August 2002) to 1735 (July 2003) individuals /10cm². At station 4 it was 55 (March 2003) individuals/10cm². At station 5 it was 34 (October 2002) individuals/10cm². Occasional absence of foraminifera was reported from station 4 and 5. However, station 6 was devoid of foraminifera during the sampling period. The average density of foraminifera at stations 1 to 5 was 10, 2, 189, 9, and 4 individuals/10cm² respectively.

The group 'others' had an average concentration of 4 individuals /10cm² at station 1, 16 individuals /10cm² at station 2, 15 individuals /10cm² at station 3, 18 individuals /10cm² at station 4, 9 individuals /10cm² at station 5 and 3 individuals /10cm² at station 6.

9.2.2. Biomass of meiofauna

Nematodes and polychaetes were the major contributors towards meiofaunal biomass. The average biomass at station 1 to 6 were 0.637 mg/10cm², 1.054 mg/10cm², 1.056 mg/10cm², 0.532 mg/10cm², 0.403 mg/10cm² and 0.073 mg/10cm² respectively (Table 9.1.1-9.1.6).

At station 1, polychaetes contributed 0.277mg/10cm² which form 43.5% of biomass; nematodes, copepods and the group others contributed 38.6%, 9.73% and
8.32% respectively. With respect to station 2, nematodes contributed 0.954mg/10cm² which form 90.5% of biomass. The copepods, the group others and polychaetes contributed share of 3.62, 3.33 and 2.57 % respectively. When we consider station 3, nematodes contributed 0.841 mg/10cm² which form 79.64%; polychaetes, copepods and group others donated 11.93%, 3.41% and 5.02% respectively. Coming to station 4, nematodes contributed 0.211mg/10cm² which form 39.66%; polychaeta, copepoda and the group others contributed 32.71%, 12.97% and 14.66% respectively. At station 5, copepodes supplied a major share towards biomass (0.197mg/10cm²) which form 48.88%. Nematodes having 42.18% shares came next. Polychaetes and group others supplied 5.46% and 3.226% respectively. With respect to station 6 copepods contributed 0.044mg/10cm²; which form 60.27%. Nematodes, polychaetes and the group others contributed 23.29, 10.96 and 4.11% respectively.

9.2.3. Numerical abundance of macrofauna

At station 1 the population density of polychaetes /0.1m² ranged from 126 (February 2003) to 2896 (November 2002) individuals. In station 2 it varied from 28 (August 2002) to 220 (November 2002) individuals /0.1m². As far as station 3 is considered population density ranged between 74 (July 2003) to 1218 (October 2002) individuals /0.1m². Coming to station 4 the total population density/0.1m² ranged from 26 (July 2003) to 7404 (October 2002) individuals. At station 5 it varied from 74 (July 2003) to 1380 (October 2002) individuals /0.1m². At station 6 it ranged from 0 (August 2002, November 2002 and May 2004) to 66 (March 2002) individuals /0.1m². The average density of polychaetes at stations 1 to 6 was 472,121,277,606,347 and 13/0.1m² respectively.

At station 1 the population density of crustaceans /0.1m² ranged from 4 (February 2003) to 74 (May 2003) individuals. In station 2 it varied from 0 (September 2002) 16 (June 2003 and July 2003) individuals /0.1m². As far as station 3 is considered population density ranged between 4 (April 2003 and June 2003) to 822
Coming to station 4 the density/0.1 m² ranged from 0 (August 2002 and June 2003) to 72 (October 2002) individuals. At station 5 it varied from 0 (September 2002) to 40 (January 2003) individuals/0.1 m². At station 6 the maximum density observed was 8 (January 2003 and February 2003) individuals/0.1 m² and this station was devoid of fauna in a number of sampling. The average density of crustaceans at stations 1 to 6 was 31, 11, 137, 17, 17 and 4 individuals/0.1 m² correspondingly.

The molluscs were sporadic in occurrence at stations 1, 2, 3, 4 and 5. They were found to be absent at station 6. The highest density reported for molluscs at stations 1, 2, 3, 4 and 5 were 30 (March 2003), 26 (July 2003), 82 (April 2003), 290 (April 2003) and 10 (February 2003)/0.1 m² respectively. The average densities of molluscs at stations 1 to 5 were 6, 40, 22, 39 and 4/0.1 m² respectively. The average density of pisces at stations 1 to 5 were 1, 1, 3, 2 and 1/0.1 m² respectively. The group 'others' had an average concentration of 6/0.1 m² at station 1, 12/0.1 m² at station 2, 50/0.1 m² at station 3, 20/0.1 m² at station 4, 20/0.1 m² at station 5 and 20/0.1 m² at station 6 (Ref: Table: 8.1.1-8.1.6.)

9.2.4. Biomass of macrofauna

Molluscs were the major contributors towards biomass in the study area (Table: 9.2.1-9.2.6). They were highly significant at stations 2, 3 and 4. Polychaetes were the second dominant contributor dominated mainly at stations 1, 4 and 5. Crustaceans gave considerable contribution at stations 1, 3 and 4. The contribution of the group others to the biomass is comparatively less at all stations.

The average biomass recorded from stations 1 to 6 were 32.41 g/m², 8.7 g/m², 82 g/m², 88.67 g/m², 11.54 g/m² and 0.139 g/m². At station 1 polychaetes contributed 17.54 g/m² which form 54.59%. Molluscs, crustaceances and others contributed 26.77, 18.54 and 0.09 % respectively towards the average biomass. When we consider station 2, molluscs contributed 4.51 g/m², which form 53.68%.
remaining groups polychates, crustaceances and the group others supplied 35.95, 8.45 and 1.94 % respectively. As far as station 3 is considered, the molluscs alone contributed 68.21 g/m² which form 86.46%. The rest of the fauna polychaetes, crustaceans and others contributed 9.01, 4.25, and 0.27% respectively towards average biomass. With regard to station 4, molluscs supplied 74.03 g/m², which is 83.71% of the average biomass. Polychates, crustaceans and the other groups supplied 14.33, 1.95 and 0.02% respectively. Coming to station 5 the polychaetes contributed 10.14 g/m² which form 89.81%. Crustaceans, molluscs and other groups contributed 6.64, 3.3 and 0.3% respectively. As far as station 6 is considered average biomass was only 0.18 g/m². Of which polychaetes contributed 0.09 g/m² which form 50 %. The crustaceans and other groups contributed 27.3 and 22.28% respectively.

9.3. DISCUSSION

Nematodes were consistent and constituted the bulk of meiofauna at all stations. In meiofauna samples, 90-95 % of individuals and 50-90% of biomass are usually contributed by this group. The meiofauna of the Cochin backwaters showed considerable fluctuation in the total density during the study period, which coincided with parallel changes in some environmental parameters. Similar changes have been reported by earlier investigators (Kondalarao and Murty, 1988; Ansari et al., 2001) from Indian coast. The maximum density observed in the present study was similar to those reported from other shallow regions of the Indian coast (Ansari and Parulekar 1993; Ansari et al., 2001). Jayasree, 1971 reported a maximum value of 1229/10 cm² for meiofauna of Cochin backwaters. However an increment to 2931/10 cm² was observed in the current survey.

Biomass of benthos varied significantly among habitat. Meiofaunal biomass generally paralleled the abundance value. According to Pfannkuche (1985) the
Measurement of biomass can often be more meaningful than the enumeration of densities to assess the standing stock.

Corresponding to the population count the biomass displayed spatial and temporal variation. However, for macrobenthos biomass had no direct relationship with the numerical abundance of fauna, but it depends on the size of the animal. The seasonality in the standing stock is synchronised well with the seasonal occurrence of individual organism. This is in agreement with the observations of Harkandra (1975) in Kali estuary.

Meiofaunal biomass in different stations decreased in the following order: Station 3 > Station 2 > Station 1 > Station 4 > Station 5 > Station 6. Whereas that of macrofauna decreased in the following order: Station 4 > Station 3 > Station 1 > Station 5 > Station 2 > Station 1 > Station 6. The benthic densities and biomass show perceptible differences between areas with different primary productivity in surface layers (Soltwedel, 2000). The average meiofaunal and macrofaunal biomass of Cochin backwater were 0.626 g/m² and 37.257 g/m² respectively (Table: 9.3). Macrofaunal biomasses of Krisna, Godavari, Mahanadi and Hoogly estuary were 0.11 g/m², 3.64 g/m², 16.04 g/m² and 2.48 g/m² respectively (Ansari et al., 1982).

In the current survey the ratio between population density of meiofauna and macrofauna of Cochin backwater was 140:1, while the biomass ratio was 1:60 (Table: 9.3). Rodrigues et al. (1982) reported that in the sublittoral zone (<20m) population ratio of meiofauna is to macrofauna was 80:1, while the biomass ratio was 1:9. However, Gerlach (1971) reported that the total meiobenthic biomass was 15% greater than macrobenthos in marine sediments. In the Karwar region the ratio between population density of Meiofauna: macrofauna was 314:1 while the ratio between the biomass was 1:18 (Anzari, 1978). The density of meiofauna and macrofauna at Krisna, Godavari, Mahanadi and Hoogly estuary were in the ratio 2193:1, 94:1, 417:1 and 1531:1 and the biomass of meiofauna and macrofauna of
these estuaries were in the ratio 2.7:1, 1:2, 1:3 and 1.7:1 (Ansari et al., 1982). The quantitative differences seen in different estuaries mainly depend on the environmental factors, trophic relationship, reproduction and recruitment processes.

The meiobenthos and macrobenthos together contributed a biomass of 37883 kg wet wt/km² in the Cochin backwater. The average macrobenthic biomass along Cochin backwaters was found to be 37257 kg wet wt/ km². Using the conversion factors developed by Parulekar et al. (1980) the dry weight obtained is 3299.8 kg/ km². Since 34.5% of the dry weight is made up of carbon the above value can be expressed as 1138.4 kg C/ km². Macrobenthos has a production of about twice the standing crop (Sanders, 1956). Based on this the macrobenthic production is 2276.8 kg C/ km²/yr. This will call for a demand of 2276 kg C/ km²/yr for macrobenthoic production considering the ecological transfer energy of 10%.

The average meiobenthic biomass along Cochin backwaters was 626 kg wet weight/ km². Using the conversion factors developed by Wieser (1960) and Gerlach (1971) the dry weight obtained was 156.45 kg/ km². Since carbon content is found to be 34.5%, the above value can be expressed as 53.98 kg C/ km². Most species of meiobenthos has a life span of three months, the annual meiobenthic production in the Cochin backwater is calculated as 215.9 kg C/ km²/yr. This will call for a demand of 2159 kg C/ km²/yr for meiobenthic production. For the production of meiobenthos and macrobenthos 24927 kg C/ km²/yr is demanded. According to Shoji et al. (2008) the primary production of Cochin backwaters is 2.1-608.0 μg C/ L/ d. As the degree of dependence between primary and secondary production was extremely weak, sources other than the planktonic compartment need to be explored to understand the Carbon cycling in this estuary (Shoji et al., 2008). The present study also substantiates this view.
CHAPTER 10

LONG-TERM CHANGES IN THE COMMUNITY STRUCTURE OF MACROBENTHOS

10.1. INTRODUCTION

The quest of man to conquer the nature has led to ever increasing degradation of the environment than envisaged. The greatest threat that haunt Kerala, the Gods own country, is the near crisis situation owing to degradation and destruction of unique habitats, topography and biodiversity. It is most unfortunate that the strength of natural endowments and biodiversity, unique to this land has not received due appreciation and valuation. Cochin backwaters, the life line of central Kerala, are subject to development pressures, such as harbour development, land reclamation, recreational projects and other anthropogenic inputs. Biological variables are important components in water quality assessment because they may uncover problems undetected in the measurements of different physicochemical parameters or under estimated by other methods (Dauer, 1993). Benthic fauna are considered as important indicators of water quality and are used in a variety of monitoring programmes to assess overall estuarine health and to follow long-term trends in estuarine communities related to anthropogenic impacts around the world.

An individual assessment at a site provides a snapshot of current conditions, whereas the sequential assessments allow analysis of environmental degradation or remediation. So an attempt has been undertaken to give information on the degree to
which baseline data can be used to identify constancy or a change of benthos of Cochin backwaters. Historical data for the study area is available from Pillai (1978), Batcha (1984), Sarala (1986) and Sheeba (2000) during the periods 1974-76, 1977-78, 1981 and 1996-97 respectively. These studies are important basis for the analysis of temporal changes in the benthos of Cochin backwaters. The present investigation was a resurvey of five selected stations of Cochin backwaters with an eye to trace the biodiversity change that might have occurred over the period 1974-2004. For Station 1 (Thevara) baseline data was available from Pillai (1978), Batcha (1984) and Sheeba (2000); and for station 2 (Mattancherry) from Pillai (1978) and Batcha (1984). The Station 3 (Barmouth) was surveyed by all the four investigators. For Station 4 (Bolghatty) and Station 5 (Varapuzha) baseline data are available only from Sarala (1986) and Sheeba (2000).

10.2. RESULTS

10.2.1. Long-term changes in the species composition of benthos

Comparison of the data of current survey with that of previous studies revealed striking differences in the community structure of benthos (Table: 10.1.1-10.1.5). Based on the abundance (Average) the different species were differentiated into Rare-R (Population density=1/m²); Less common-LC (Population density=2-5/m²); Common-C (Population density=6-10/m²); Very Common-VC (Population density=11-50/m²); Abundant-A (Population density=51-100/m²) and Highly abundant - HA (Population density ≥ 101/m²).

10.2.1.1. Polychaetes

Polychaetes had the highest population density in the estuary for the past thirty years. When we consider station 1, during the period 1974-1976, Lumbriconereis sp, Nephthys oligobranchiata, Prionospio polybranchiata and
**Paraheteromastus tenuis** were the dominating species. Where as the period 1977-78 witnessed the preponderance of **Ancistroyllis constricta**, **Nephthys oligobranchiata**, **Nephthys polybranchiata** and **Prionospio pinnata**. During the year 1996 **Ancistroyllis constricta**, **Notomastus** sp and **Prionospio polybranchiata** contributed a major share towards the total density of polychates. However during the period 2002-04, **Prionospio cirrifera** and **Heteromastus bifidus** were exceedingly abundant. Coming to station 2, during 1974-76 period **Nephthys oligobranchiata** and **Prionospio polybranchiata** were the dominating species. During 1977-78 period **Ancistroyllis constricta** and **Diopatra neapolitana** proliferated remarkably. The period 2002-04 was characterized by the abundance of **Prionospio polybranchiata** and **Paraheteromastus tenuis**. At station 3, during 1974-75 period **Ancistroyllis constricta**, **Prionospio cirrifera**, **P.pinnata** and **P.polybranchiata** showed dominance over other species. During the period 1977-1978 **Ancistroyllis constricta** and **Diopatra neapolitana** were the common species. In the year 1981 **Diopatra neapolitana**, **Heteromastus bifidus**, **Lumbriconereis simplex**, **Pistia** sp and **Prionospio polybranchiata** were widespread. Again during the period 1996-1997 **Ancistroyllis constricta** and **Diopatra neapolitana** were contributed considerably to total density. The period 2002-2004 was characterized by the dominance of **Prionospio cirrifera** and **Paraheteromastus tenuis**. When we consider station 4, during the year 1981 **Heteromastus bifidus** dominated in the sample followed by **Aphrodita** sp, **Dendronereis estuarina**, **Lycastis indica** and **Prionospio polybranchiata**. During the period 1996-1997 the area was dominated by **Notomastus latericeus**. However **Diopatra neapolitana** and **Prionospio polybranchiata** also gave considerable numerical density. The period 2002-2004 witnessed the abundance of **Heteromastus bifidus**, **Paraheteromastus tenuis**, **Prionospio cirrifera** and **P.polybranchiata**. As far as station 5, is concerned the representation of macrofauna was rather poor in the base line survey itself. In the year 1981 **Dendronereis estuarina** was the dominating group. During 1996-97 period
dominance of a particular group was not reported from this station. *Prionospio cirrifera* has comparatively better representation at this station during 2002-04.

From the table 10.1.1.-10.1.5 is clear that 23 polychaete species, which, were reported once from Cochin backwaters, were absent in the present survey. At present these species may be either disappeared or severely decreased in abundance. The species like *Aphrodita* sp, *Disoma* sp, *Eulalia viridis*, *Eunice tubifex*, *Fabricis* sp, *Glycera alba*, *Glycera convoluta*, *Glycera longipinnis*, *Goniada emerita*, *Heteromastus similis*, *Heteromastus filiformis*, *Lepidontus* sp, *Lumbriconereis heteropoda*, *Mesochaetopterus* sp, *Mercierella elongata*, *Odonto syllis*, *Owenia* sp, *Perinereis cavitrons*, *Phylodoce gracilis*, *Pistia* sp, *Polycirrus*, *Sabellidae* and *Serpula* sp were not encountered in the current study. In addition to this members of *Amphinomidae* also disappeared. Compared to earlier survey the abundance of *Paraheteromastus tenuis*, *Prionospio cirrifera*, *P.polybranchiata* and *Polydora kempi* were increased. However the distribution of *Prionospio pinnata* appeared to be more limited.

The following species, of current survey like *Exogone* sp, *Glycera trydactyla*, *Glycinde bonhourei*, *Ophelia* sp were not reported in the base line surveys. In the earlier survey *Maldane* sp, *Scyphoproctus djiboutiensis* and *Syllis spongicola* were reported from some other parts of the estuary but not from their present location. So they are also new to the concerned stations. In short the species composition of polychates in the study area had been changed in each survey.

### 10.2.1.2. Crustaceans

In the baseline surveys itself majority of the crustacean species were sporadic in occurrence. When we consider station 1 *Grandidierella* sp was the dominating group during 1974-76. During 1977-78, *Corophium triaenonyx* was the dominant variety. During 1996-97 dominance of a particular group was not seen. *Grandidierella* sp was the dominating group during the period 2002-04. Coming to station 2 during
1974-76 period there was the dominance of Apseudes chilkensis. During 1977-78 Alpheus sp, Corophium triaenonyx and Grandidierella sp contributed major share towards the population density. By 2002-04 density of all these species declined sharply. At station 3 dominance of a particular group was not reported during 1974-76 period. But during 1976-77 period Alpheus sp and Corophium triaenonyx contributed a notable share. In the year 1981 Corophium triaenonyx, Cirrolinea fluviatilis, Grandidierella and Quadrivisio bengalensis were extremely dominating in the estuary. During the period 1996-97 in addition to the dominant species of 1981, Eriopisa chilkensis also gave considerable contribution towards total density. In 2002-04 Corophium triaenonyx and Grandidierella sp supplied a major share. As far as station 4 is concerned, in 1981 Corophium triaenonyx, Quadrivisio bengalensis and Grandidierella sp were flourished in this station. In 1996-97 periods Corophium triaenonyx was the dominant species. In 2002-04 dominance of a particular group was not reported. At station 5 the representation of crustaceans was rather poor in baseline study itself and by the period of current survey the station became devoid of crustaceans. The density of following species like Alpheus euphrosyne, A.fabricius, A.malabaricus, and A.paludicola, Acetes sp, Penaeus indicus, Rhynchoplax sp, Ampelisca zamboanga, Balanus sp, Eriphia smithii, Litocheira sp, Melita sp, Metapenaeus sp, Quadrivisio bengalensis, Squilla nepa, Scylla serrata, Synidotea variegata and Viaderiana sp were found to be considerably decreased. The exotic crabs Neorhynchoplax sp and Xenophthalmodus moebii were new invaders in to the system.

10.2.1.3. Molluscs

In the baseline surveys most of the molluscs were sporadic in occurrence. For the past three decades dominance of a particular species was never reported from station 1. However at station 2 there was the dominance of Modiolus undulatus during the period 1977-78. At station 3 during the phase 1974-76 and 1977-78 Modiolus
*undulatus* gave considerable number towards total population density. In 1981 substantial contribution was from *Modiolus striatulus*. In 2004 *Musculista senhousia* was the flourishing organism at this station. The dominance of a particular group was never reported from station 4. At station 5 *Littorina* sp was common in 1981. The following 18 species of molluscs may be disappeared from the estuary which include *Arca bistrigata*, *Balbonia* sp, *Bithina* sp, *Dendorophylax* sp, *Dentalium* sp, *Dosinia* sp, *Littorina* sp, *Leiochrides africanus*, *Meritrix casta*, *Modiolus metacalfei*, *M. striatulus*, *M. undulatus*, *Naculana* sp, *Solen* sp, *Standella* sp, *Sunetta scripta*, *Tellina* sp, and *Villorita* sp. The bivalve *Musculista senhousia*, which is a new invader to the system, became the prevailing species. Its byssus threads, which were forming a thick mat over the estuarine bottom, prevent the growth of other benthos. The other exotic mollusc having occasional occurrence includes *Katalysia* sp and *Thais* sp.

As shown in the table the diversity of minor groups also declined.

**10.2.2. Numerical abundance**

Table: 10.2 gives a picture about variation in the numerical density of benthos from 1974 to 2004 period. The base line data selected for southern region is from the investigations of Pillai (1978) and that for northern region is from the survey of Sarala (1986). It is clear that the density of polychaetes increased considerably at stations 1 to 4. Yet its density decreased at station 5. The abundance of crustaceans decreased at stations 1, 2, 4 and 5; still it was increased at station 3. Density of molluscs decreased noticeably at stations 3, 4 and 5. However at stations 1 and 2 molluscan density increased recently due to the preponderance of the exotic mollusc *Musculista senhousia*. 
10.2.3. Biomass

Table 10.3 explains variation of benthic biomass over the period 1974-2004. The base line data was available only for southern sector (stations 1, 2 and 3). It is understood that the biomass of polychaetes and molluscs considerably increased at all stations. The biomass of crustacea increased at stations 1 and 3; however it was decreased at station 2.

10.2.4. Diversity indices

In order to get a comparable data the diversity indices for previous years were recalculated using the computer programme PRIMER v.5 (Table 10.4, Fig: 10.1). The diversity indices for the study area were considerably fluctuated during different periods with in the last three decades. When we consider station 1, Margalef index varied from 6.7 (2002-04) to 10.64 (1974-76) and Pielous evenness index ranged from 0.5 (2002-04) to 0.8(1977-78). Shannon index oscillated from 1.88 (2002-04) to 2.9 (1977-78). Simpson index fluctuated from 0.71(2002-04) to 0.93 (1977-78). Coming to station 2 Margalef index varied from 7.1 (1977-78) to 9.4 (1974-76) and Pielous evenness index ranged from 0.46 (1977-78) to 0.64 (2002-2004). Shannon index oscillated from 1.8 (1977-78) to 2.4 (2002-2004). Simpson index fluctuated from 0.68 (1974-1976) to 0.84 (2002-2004).

At station 3 Margalef index varied from 3.73 (1996-97) to 11.17 (1974-76) and Pielous evenness index ranged from 0.16 (1981) to 0.61(1974-76). Shannon index oscillated from 0.63 (1981) to 2.48 (1974-76). Simpson index fluctuated from 0.27 (1981) to 0.83 (2002-2004). As far as station 4 is concerned, Margalef index varied from 5.95 (2002-2004) to 8.83(1996-97) Pielous evenness index ranged from 0.57 (1981) to 0.83 (1996-1997). Shannon index oscillated from 1.94 (2002-04) to 2.95 (1996-97). Simpson index fluctuated from 0.77 (2002-04) to 0.94 (1996-97). When we consider station 5, Margalef index varied from 4.04 (2002-2004) to 4.6 (1981) and Pielous evenness index ranged from 0.59 (1981) to 0.79 (1996-97). Shannon index
oscillated from 1.77 (2002-04) to 1.97 (1996-97) and the Simpson index fluctuated from 0.77 (2002-04) to 0.88 (1997-98).

10.2.5. Cluster analysis.

In the cluster analysis same stations of different years never form a group. If the communities were stable during different periods each single group in the dendrogram should consists of same stations, however the analysis showed each group consisted of different stations of different time interval. This suggested that the communities recorded in different periods were evidently quite distinct among themselves. The station 5 of all surveys was linked together to form a group. These results advocate that the community in the survey area has under gone a long-term change in composition during the period 1976-2004 (Fig: 10.2).

10.2.6. MDS

In the MDS plot the overlapping of same stations during different time interval was limited. It very much revealed the trend with regard to grouping of stations observed in cluster analysis. At station 2 the drift was less pronounced during successive sampling. In all other stations the assemblages were progressively diverge from the initial stage during successive sampling (Fig: 10.3).

10.2.7. ABC – plot / k- dominance curve

The data pertaining to species abundance and biomass were allowed as inputs to ABC-curve to see whether they are subjected to any form of disturbances or not. The results were shown graphically (Fig.10.4). The W values for the periods 1974-76 and 2002-04 were 0.371 and -0.182 respectively.
10.3. DISCUSSION

Cochin is the industrial capital of Kerala. Many scholars have produced clear evidences to indicate the nature of evolving resource crisis and environmental degradation in Cochin backwaters. The sewage treatment system is inadequate and untreated organic and inorganic waste material is being discharged into the backwaters (KSPCB, 1981). Retting of coconut husk is another major source of organic pollution in the backwaters. The alarmed mining activity at River Periyar also may cause drastic change in the ecology of estuary. Dredging operations associated with shipping traffic cause a variety of physical and chemical disturbances. Large areas of mangrove in the backwater have been lost by human deeds. The regional decrease of mangrove causes destabilization of sediments. Cochin backwaters have fallen prey to illegal reclamation. Acres of estuarine areas are lost every year as a result of reclamation (Menon et al., 2000). Deposition of plastics in the estuary is another severe problem. Plastics have a long half life and its persistence in the marine environment poses a threat. The organisms may ingest or become entangled in the plastic waste. One of the recent estimates shows that in spite of receiving $42.4 \times 10^3 \text{ mol.d}^{-1}$ of inorganic phosphate and $37.6 \times 10^3 \text{ mol.d}^{-1}$ of inorganic nitrate from Periyar side of the estuary, the export to the coastal waters is only $28.2 \times 10^3 \text{ mol.d}^{-1}$ of inorganic phosphate and $24 \times 10^3 \text{ mol.d}^{-1}$ inorganic nitrates (Hema Naik, 2000). The estuary acts as a sink for the nutrients, flushing out only a portion of the pollution load that it receives. The enhancement with these nutrients can lead to light deprivation by phytoplankton blooms. The death and decay of planktons result in oxygen depletion of the system. The reduced oxygenation of the sediment has the potential to reduce the capacity of the denitrification process. Fundamental ecological changes triggered by nutrient enrichment related phytoplankton bloom are now evident in large coastal systems (Johansson and Sroeijs, 2002). Devassi and Bhattathiri, 1974; Remani, 1979 and Sarala, 1986 confirmed that Cochin backwater was subjected to a gradual change in different physicochemical parameters. The
Sampling and sample analysis techniques were different among researchers, which prevent a meaningful comparison of results of various investigations. However it is clear that the estuary is moving towards anoxic condition resulting from organic enrichment. The anoxia caused by organic enrichment or eutrophication is now common in the marine environment (Diaz and Rosenberg, 1995).

In the shallow water, the benthos dynamics are tightly related to the process occurring in the overlying water column. Benthos in the study area responds to above mentioned deteriorous effects by different ways. 23 species of polychaetes, 18 species of crustaceans and 18 species of molluscs which were once the inhabitant of the estuary have not sampled during present survey. The perceived loss of these organisms may be a result of poor settlement and recolonization due to altered physical condition. Otherwise the loss could be an artifact of fortuitous sampling of a small patch of these species in earlier surveys.

A complex interplay between species richness, biomass and abundance of polychaetes was observed in this survey. A sharp decrease in species richness and increase in abundance of some polychaetes was noticed. However some species were quite permanent. But the amplitude and the frequency of these changes were different among the stations. The modification was most abrupt at stations 4 (Bolghatty) and 5 (Varapuza) and it was least at station 2 (Mattancherry). The sharp increase in the population density of the euryhaline opportunist polychaete species like Heteromastus bifidus, Paraheteromastus tenuis, Prionospio cirrifera and P.polybranchiata suggest that they have got inherent ability to quickly colonize and dominate in disturbed areas. Most researchers from different parts of the world do agree that spionids and capitellids are indicators of stressed environment (Gaston and Young 1992; Weisberg et al., 1993; Carlo Heip, 1995). Compared to the baseline survey, the number of suspension feeders declined and deposit feeders increased in the present survey. This may be related to the nature of the food available in the
environment. In a gradient of organic matter enrichment in the sediments, the macrobenthos change from a fauna dominated by suspension feeders to deposit feeders along with some carnivore (Pearson and Rosenberg, 1978). Eutrophication may result in removal of filter feeders (Lenithan, 1999).

Dwindling the species richness and density of crustaceans and molluscs was another striking observation. Long and Chapman (1985) agreed that certain crustaceans are generally more sensitive to environmental degradation and are usually associated with less degraded areas. Decreasing the abundance of molluscs and crustaceans may be linked to nutrient loading (James, 2001). The present findings are in affirmative with these views. In addition to the aforesaid deleterious effects, construction and operation of the water-controlled structures like 'Thannermukham bund' also have influence on the declination of taxonomic richness and abundance of crustaceans and molluscs. Since this act as a barrier between the fresh water and saline water habitats the estuary may no longer serve as nursery grounds for the larvae of crustaceans and molluscs, as it did earlier. This is in agreement with Arun, 2005.

As mentioned earlier 4 species of polychaetes, 2 species of crabs and 3 species of bivalves of present survey were new invaders to the Cochin backwaters. Out of which the mussel *Musculista senhousia*, settles in aggregates and dominate itself in the benthic community. In the southern limb of the estuary it potentially excludes native species by suppressing the growth of other benthos in the same habitat. Its success in the estuary is probably due the absence of predators and its high adaptability in the disturbed environment. Vast volumes of ballast water are discharged into the estuary by overseas shipping. Different organisms can be transferred around the world in ballast water (Willan 1985). In many estuaries the exotic organisms are known to be brought as fouling on barges, drilling platforms and other structures (Foster and Wilan, 1979).
In the southern sector of the estuary the average standing stock of major taxa (Polychate, Crustaceans and Mollusc) was calculated to be 18.25\text{g/m}^2 in 1974-76 period and 39.8 \text{g/m}^2 in 2002-04 periods. This boot is supplied by spionids, cappitellids and *Musculista senhousia*. Since a comparable standing stock data is not available for the northern sector study was limited to southern sector of the estuary.

Cluster analysis illustrated that the macrofaunal community at the same stations during different time interval were highly variable and were linked at only a low level of similarity. Multivariate analysis has proven a useful technique to identify disturbed and undisturbed site (Growns et al., 1995). MDS plot displays irregular drift of stations and showed more confused pattern. In the MDS, the distance between the successive sampling years of the same station do not indicate a progressive return to their original state; which indicate variation in faunal composition at each sampling. All sampling stations came very close by the year 2004, which gives an idea that the heterogeneous system is moving to a homogeneous condition due the reduction in species diversity.

The ABC curve is helpful in finding out the disturbance to the biota. This method, as originally described by Warwick (1986) involves the plotting of separate \(k\)-dominance curves for species abundances and species biomasses on the same graph and making a comparison of these curves. Under stable conditions, the dominants in macrobenthic communities are \(k\) - selected species having less numerical abundance, large body size and long life span. In undisturbed communities the \(k\)-dominance curve for biomass lies above the curve for abundance for its entire length. When the disturbance perturbs in a community, smaller \(r\)-selected or opportunistic species with a short life span often become the biomass dominants as well as the numerical dominants. As disturbance perturbs the abundance curve lies above the biomass curve throughout its length.
The comparison of the ABC curves during different periods showed that in 1974-76 curves for biomass lies above the curve for abundance for its entire length, confirming that the backwater was unstressed. But during 2002-04 periods the curve for abundance lies above the curve for biomass for its entire length, substantiating that the backwater is stressed. The positive value of W for 1974-76 again confirmed an unstressed condition. The negative value of W for 2002-04 periods underlined the stressed condition. Warwick and Ruswahyuni (1987) and Warwick and Clarke (1991) made a comparative study in the community structure of macrobenthic communities in some tropical and temperate waters employing this technique and detected disturbance.

This study underlined that the threats are many; increasing in magnitude and the estuary is moving towards degradation. We cannot predict which community will replace the estuary in future. Since pollution has reached in an alarming level, it raises doubt whether this backwater will become a desert in future? If this happens these are gone forever. Present investigation also highlights the need to collect benthos samples for a regional assessment of environmental health and to use this benthic knowledge for impact assessment, pollution control, and resource conservation etc. Considering the ecological importance of estuary it is our duty to introduce conservation measures to save this ecosystem. There is no shortage of guidelines, codes of practice and information on how to manage ecosystem but there is still a notable lack of commitment to implement them. Genuine effort should be made by man to introduce control measures such as construction of sewage treating facilities, controlling industrial wastes going in to the estuaries by imposing stricter standards, prohibiting the destruction of mangroves and indiscriminate land reclamation etc. The construction industry must respect environmental principals and ensure that, pollution and sedimentation are minimal. There have been isolated protests against degradation and now there is a need for an integrated approach. It has been recognized that wise management of biodiversity is likely to be critical to
the very survival of humanity. We should convince ourselves that Kerala is not just another land, but the biological park of India. Every inch of this land is home to myriad, diverse and unique life forms. This invaluable biodiversity should be preserved and protected for our posterity.