CHAPTER 7
SUMMARY

Benthic productivity is of importance in assessing the biological production potential of any aquatic environment. It is well recognized that the distribution and abundance of benthic animals of a region are directly linked to the fishery of that particular area. Benthos, being an important source of food for demersal fishes, can serve as a reliable index of the fish stocks. Benthic population is also considered as an essential tool for pollution monitoring, since benthic fauna reflect the integrated effect of stress more effectively due to their sedentary habits. Because of the relative abundance of food and the shallowness of the estuaries benthic production in estuaries is quite high compared to other aquatic habitats.

For traditional fishing and aquaculture in the coastal areas, maintenance of water quality is very important. A proper understanding of the environmental parameters and their effects on biota is hence a pre-requisite for the management of any ecosystem. Benthic fauna has a direct relationship with the type of the bottom and the physical nature of the substratum, which also acts as a controlling factor to a considerable extent. Benthos, therefore, may be treated as sensitive indicators of pollution and shows the extent of accumulation of organic matter in sediments.

Considering the importance of benthos, an attempt has been made to study the composition, distribution, abundance and diversity of the components in relation to the environmental parameters in three different environments. Before this only one attempt has been made to study the overall effects of industrial pollution on benthos and water quality. That study aforesaid was undertaken in 1981 and covered the northern limb of Cochin backwaters, which forms a part of the present area. The data obtained during 1996 – 1997 is examined against the backdrop of this available information and applied to evaluate the changes over a period of 15 years on benthic communities in a system subjected to ongoing stress from industrial effluents. The environments selected were (1) the industrial and sewage effluent discharge sites of Cochin backwaters, (2) the mangrove ecosystem of Puduvypin and (3) the dredging and disposal site of Cochin Port Trust area. The data generated will be helpful in
assessing the present status of benthic productivity of this vital ecosystem and can be utilized for ecological monitoring and future evaluations.

The thesis is presented in 7 chapters. The first chapter gives a general introduction to the topic and describes the different types of benthos, their adaptations, food and feeding, benthic productivity, economic importance, pollution stress and also highlights the scope and purpose of the present study.

The second chapter is on the materials and methods, which covers the methodology adopted for the collection and analysis of benthic fauna, water and sediment samples from the three different environments and also the methods for statistical interpretation.

The third chapter comprises of the study of these environments in the Cochin backwaters for a period of one year (June 1996 to May 1997). Fourteen stations along the northern and southern limbs of Cochin backwaters up to a distance of 25km upstream were selected. The stations 1, 2, 11 and 13 are located near the discharge sites of industrial effluents in the southern and northern limbs respectively and stations 6 and 7 are at the sewage discharge site. Barmouth (station 14) is treated as a reference station.

The results of the physico-chemical parameters highlight the effects of pollution. The physico-chemical aspects deal with the spatial and temporal variations of the 16 environmental parameters studied (Temperature, Salinity, pH, dissolved oxygen, BODs, nitrite, nitrate, ammonia, phosphate, chlorophyll 'a', particulate organic carbon, suspended load, attenuation coefficient, sediment characteristics, organic carbon and energy content). The results of the study indicated the changes due to the large-scale movements of the estuarine water under the influence of tide, monsoon and land runoff coupled with its heterogenous nature owing to the effluent discharge from the industries.

The vertical gradient in temperature and salinity was very less for the entire area and this is due to the shallow nature of the estuary as also reported by earlier
workers. The general drop in salinity to near freshwater conditions observed during monsoon is due to the dilution by large amount of freshwater influx while the differences in the surface and bottom salinity is caused by the tidal influence creating a two-layered flow. Variations in the pH due to chemical and other industrial discharges render a stream unsuitable not only for recreational purposes but also for the rearing of fish and other aquatic life. The observed wide variation in pH in the northern and southern limbs can be attributed to the intermittent discharge of effluents from the chemical factories. The fairly steady pH values at stations 5 to 7 and 14 are governed by the influence of seawater intrusion.

In general high dissolved oxygen values were noticed during the study and the results are comparable with the results reported earlier for the estuarine and coastal waters. The low BOD₃ values noted in the area may be due to the efficient breakdown of organic matter in presence of high oxygen content, tidal dilution and significant contribution from inorganic sources to the total waste load discharged.

The high values of nitrite are to be seen against higher values of ammonia at the effluent discharge sites of the southern limb and the phytoplankton abundance during the preceding months. Nitrate concentration with abnormally high value indicates the external addition of some effluents rich in nitrogenous compounds into the estuary, by the agricultural runoff and municipal sewage. The maximum concentration of ammonia (167.56 μmol/l) at station 1 was observed in the southern limb, which decreased towards downstream. The northern limb registered a maximum (116.06μmol/l) at station 12. In the sewage discharge site and barmouth, the values were <25μmol/l. The high concentration of ammonia at stations located near the effluent discharge point may be due to the oxidation of ammonia, which is reported to be slow in relatively polluted waters. Phosphate concentration was high in the southern limb (1.36 to 150.70μmol/l) compared to other stations. The low values noticed during monsoon period can be explained by the combined effect of dilution of estuarine water by riverine freshwater containing low phosphate and removal by adsorption caused by the influx of silt laden freshwater. The high values in the southern limb may be attributed by the influence of industrial effluents from the plants producing phosphate fertilizers. High concentration of phosphate was
followed by an abundance of phytoplankton and the subsequent decrease in the concentration of phosphate may presumably be due to its utilization by phytoplankton.

Stations in the southern limb showed high chlorophyll 'a' values compared to other areas. Maximum value of 151.83 mg/m$^3$ was noticed at station 2. The phytoplankton abundance noticed in the southern limb may be due to the effect of nitrogenous effluents discharged near the area. No definite pattern was observed in the temporal and spatial distribution of particulate organic carbon and the values were comparatively high in the southern limb.

The increased turbulence during monsoon and high particulate matter associated with the land run off results in the substantial increase in the suspended load and the values exceeding 200mg/l were commonly observed. Generally high attenuation coefficient ('K' value) was noticed in the monsoon months (1.5 to 15.0 in July) and rest of the months showed values <5. High 'K' values were noticed during the study compared to earlier reports and this may be due to the ongoing changes in the system.

The substratum of the study area exhibited a varied textural type with a mixture of sand, silt and clay combinations. The concentration of organic matter at different stations depended upon the sediment texture and the values increased with proportion of finer fractions. The observed peak value in the monsoon month could be attributed to the influx of land run off containing considerable amounts of terrigenous matter and the deposits of planktonic matter, which sink to the bottom. Energy content of the study area varied from 12.96 to 2286.79 J/g, which is lower than the reported values for retting yards of Cochin backwaters and Ashtamudi estuary, receiving high organic loads.

In general water quality of the study area revealed fluctuating values for all the parameters possibly due to the intermittent release of the effluents from the industries located upstream in both limbs of Cochin backwater and the prevailing natural flow of dilution water throughout the investigation period.
The distribution pattern of bottom fauna exhibited considerable variations both quantitatively and qualitatively at different stations of the study area. The results revealed a progressive reduction in number of taxa/species from the mouth of the estuary to upstream stations. The difference in biomass and density in estuaries is often attributed to seasonal variations, migration, food availability, reproduction, recruitment etc. The existence of “alternative pathways for utilization of excess basic food material available in Cochin backwaters” propounded and quoted in previous studies by various authors is valid in the present context also.

Benthic productivity in terms of density and biomass was very low in the upstream stations, located near the industrial complex. Maximum number of 1020064 specimens with a biomass of 462771.17g was collected from station 3 during the investigation. This was contributed by a single species of gastropod. Second peak in density (831558) was observed at barmouth with a variety of faunal groups.

No definite pattern of variation was observed between seasons at the different stations. Seasonal averages showed high values during pre-monsoon at stns. 3 & 4. Stations 5 to 9 recorded high numbers during monsoon and stns. 12 and 14 showed high numbers during post-monsoon. Organisms were absent at station 1 during monsoon, stn. 2 during pre-monsoon and post-monsoon, stn. 10 during post-monsoon, station 11 during pre-monsoon and monsoon and station 13 during pre-monsoon.

A total of 14 groups were encountered during the study and the number of groups at different stations varied from 1 (station 1) to 11 (stations 9 & 4). The number of groups encountered at other stations were 2 groups at stations 2, 11,12 and 13; 4 groups at station 10; 6 groups at stations 3. 8 groups at stations 6 & 8; 9 groups at stations 5 & 7 and 10 groups at station 4.

A total of 91 species / genus / families belonging to 14 groups were encountered during the study. Polychaetes formed the dominant and common group.
constituted by 54 species from 19 families. Second dominant group amphipods contributed 7 species. Only 2 species, each were noticed under tanaidaceans and isopods. Three species were recorded under decapods, one species under mysids and one species under cumaceans. Gastropods and bivalves were represented by 5 and 8 species and insects were represented by 4 species. Rare occurrence of juvenile fishes and flat worms were also noticed.

Polychaetes dominated at all stations except at stns. 3 & 14, where gastropods and amphipods dominated respectively. Station 6 recorded maximum number (29) of polychaete species followed by station 7 and 8 (27). Stations 5, 4 and 9 showed 20 to 23 species, barmouth registered 18 species and 9 species were recorded from stn.13. In rest of the stations the number of species was less varying from 1 to 6.

Low diversity and higher population density of a few organisms denote stress condition, which practically eliminate many species but promote survival of a few. Contrary to this high diversity and lesser relative dominance of individual species characterise areas of relative environmental stability. Low diversity and lower number of fauna at the upstream stations during the study indicate stress conditions and the effect were reduced slowly towards downstream because of dilution and hence the increased diversity was observed.

The faunal composition exhibited a different picture in the sewage discharge area in having high benthic faunal density and diversity. The increasing dominance of polychaetes in this region suggests that the environment is receiving higher organic load by sewage discharge. Of the nine groups encountered from this area, polychaetes, represented by 29 species, dominated and contributed to more than 75% of the bottom fauna. A total of 53 species belonging to different groups were recorded from the sewage area.

The presence of large numbers of gastropod sp. at station 3 and the commercially important bivalve species, *Villorita cyprinoides* at station 4
contributed to the high biomass noticed at these stations. The spatial distribution of bivalves suggests that an increase in salinity is more conducive than the substratum.

Temporal and spatial variations in the different environmental parameters noticed here are thus reflected in the qualitative and quantitative distribution of the bottom fauna.

In general the study revealed stress and localised impact of industrial waste on the biota, predominance of stress tolerant species and low diversity in the vicinity of the effluent discharge point. These studies on impact of environmental parameters on the distribution of macrobenthos thus indicate the quantum of endurance warranted by the infauna to tide over the wide range of environmental stress. Low diversity and lower number of benthic fauna near discharge site can be attributed to the stress caused by cumulative toxic effects of effluents.

Species diversity was least at station 1 showing the presence of a single species. At station 2 only 3 species occurred showing low richness of 2.39. In the other stations the index varied from 0.67 (station 4) to 12.47 (station 7). The seasonal average richness of the 14 stations varied from 1.65 (station 3) to 7.60 (station 6). At station 4 to 9, the range for richness index was between 5.19 (station 5) and 7.60 (station 9). Species concentration factor measured by Simpson's index was very low at station 3. In other stations it varied from 0.16 (station 4) to 0.89 (station 6). The average distribution of the concentration factor was least (0.61) at station 4 and highest (0.80) at station 6. Species diversity index was < 1 at stations 3 and 14. In other stations it ranged between 0.50 (station 8) and 4.85 (station 7). The temporal distributional variability of diversity was higher at stations 4 to 9. Seasonal average of species diversity was least (2.04) at station 4 and maximum (2.85) at station 6. Species dominance index recorded a wide range (0.06 to 5.48) at stations 1 to 14. The temporal average distribution of species dominance in the effluent discharge area varied between 0.67 (station 5) and 0.88 (station 6). Species dominance index was distributed with high values at station 4 and station 6 and reduced with a small gradient from stations 6 to 9. On comparing the various seasons for species evenness index high values were observed at stations 5, 6, 8 and 14. At station 8, high
venness in distribution was observed in early post-monsoon. The statistical distribution of Heip's equitability coefficient showed a steady increase from station 3 (0.07) to station 6 (1.92), thereafter decreased to 1.06 at station 7. At station 14 there was a clear-cut change in the environmental conditions as indicated by low uniformity during June to October and nearly 4 times uniformity during November to May.

At station 1, *Capitella capitata* has moderate correlation with sand (r = 0.40) with a niche breadth of 3.54. At station 2, this species showed very low niche breadth and high correlation with organic matter and moderate correlation with clay. *Branchiocapitella singularis* and *Littorina littorea* have a niche breadth of 1.91 and 1.16, and were controlled by the same parameters. Station 3 with 14 species had maximum niche breadth (6.32) for *Lycastis indica* and was moderately controlled by suspended load and for *Prionospio polybranchiata* the niche breadth was 6.16 having high correlation with salinity and temperature had only low niche breadth (3.83). *Villosa cyprinoides* having very low correlation with ammonia and niche breadth of 2.64 indicated that at this station higher niche breadth was followed by lower abundance and low variability. Of the 40 species at station 4 the niche breadth varied between 1.18 (*Nucula* sp.) and 7.33 (*Villosa cyprinoides*) and these species were highly correlated with dissolved oxygen, nutrients, suspended load and silt.

Of the 37 species at station 5, 4 were moderately abundant and showed a niche breadth between 1.41 (*Diopatra neapolitana*) and 8.05 (*Ancistroyllis constricta*) and was highly correlated with nitrate dissolved oxygen and organic matter. Station 6, with 44 species, the niche breadth ranged between 1.52 (*Scolelepis indica*) and 8.04 (*Ancistroyllis constricta*) and they were moderately related to most of the parameters.

Of the 40 species recorded from station 7, the niche breadth ranged between 1.69 (*Oligochaete sp.*) and 6.98 (*Ancistroyllis constricta*) and they were controlled by salinity, temperature, nitrite, suspended load, sand and silt. The niche breadth of the 44 species at station 8 ranged between 1.34 (*Prionospio cirrobranchiata*) and 6.55 (*Prionospio polybranchiata*) and was highly correlated with nutrients,
temperature, sand, and particulate organic carbon. Among the 40 species at station 9, *Prionospio polybranchiata, Pendora flexosa Quadrivisio bengalensis, Dendronereis aestuarina Notomastus aberans and Heteromastides bifidus* were abundant and their niche breadth were 4.05, 2.06, 2.22, 8.09, 1.26 and 6.34 respectively and were highly correlated with ammonia and sand, with nitrite, with salinity, with ammonia and clay, with nitrite and suspended load and silt respectively.

At station 11 with 4 species, all rare had low niche breadth for *Dendronereis aestuarina* and *Prionospio polybranchiata* both having high correlation with salinity and organic matter. Station 14, showed 37 species of which the *Grandidierella gilesi, Quadrivisio bengalensis* and *Eriopisa chilkensis* were controlled by clay and *Corophium triaenonyx, Apseudes gymnophobium* and *Cirrolinia fluviatilis* were controlled by suspended load. In this station niche breadth varied between 1.09 (Mysid sp) and 5.62 (*Diopatra neapolitana*). All abundant species have very low niche breadth indicating an inverse relation between species abundance and niche breadth.

In the effluent discharge area the 14 stations were classified into 6 groups depending on the distance from the discharge sites on both limbs. The 6 groups were (1) stations 1, 2 and 3 (2) stations 4 and 5 (3) stations 6 and 7 (4) stations 8 and 9 (5) stations 10, 11, 12 and 13 and (6) station 14.

At stations 1, 2, and 3 the most important parameter combinations were nitrite, phosphate, silt and clay. Eight parameters viz., temperature, nitrite, ammonia, phosphate, organic matter, sand, silt and clay; predict the benthic density of these stations with 69.01% explained variability. All the model parameters, particularly the first three were highly significant (P = < 0.05) and the last one was statistically insignificant and hence need not be considered in the future prediction for benthic density in this area. At stations 4 and 5, the best set of parameters obtained was salinity, phosphate, ammonia, organic matter, sand and suspended load. The model parameters were ranked according to the relative importance. For predicting the benthic density at stations 6 and 7, the parameters temperature, nitrite, ammonia, organic matter particulate organic carbon, sand and clay were selected depending on
the comparatively high correlation of these parameters with total benthic density. This model could explain about 93.4% of the spatial as well as temporal variation in the benthic density distribution and all the parameters are significant (P<0.05) in predicting the benthic production. At stations 8 and 9 depending on the linear correlation between total density and parameters, like temperature salinity, phosphate, nitrate, organic matter, silt and clay were selected for the model and explained 94.44% of the spatial and temporal variations in the benthic density. At stations 10 to 13 depending on the benthic density and parameter correlation, the factors – temperature, salinity, dissolved oxygen, nitrite, nitrate, ammonia, organic matter, particulate organic carbon, and clay were selected for the model. The parameters considered at this station were nitrite, ammonia, sand and clay for the best prediction model using standardised values of the total benthic density. The individual effects and their first order interaction effects could predict the density using this model. At station 3, > 90% similarity was observed between June and other months and also between February and other months. Based on presence/absence of species June to November showed < 50% similarity.

At station 4 high similarities was obtained between months August to December and January to May (70 to 90%). Depending on the presence/absence of species, only April and February showed about 63% similarity. At station 5 high similarity was observed between the months, June to December and March to May (> 70%). Maximum similarity was observed between May and June to December (> 90%). Station 6 high similarity was observed between months (> 90%) between March and April (54%) and March and May (51%). Based on the presence/absence of common species January and February showed the least similarity with other months of the study period (< 10%).

At station 7, based on abundance of species, with May and April having highest similarity with other months of the year (> 70%). The highly dissimilar periods were September and January (< 60%). But based on the presence/absence of species it showed a similarity < 40% between months except that of August with September (64%). Station 8 showed high season wise similarity (> 75%) between months except that between September and December (< 62%). But the chance for
common occurrence of species was very poor during September and October with other months (< 24%). Station 9 showed high similarity for abundance of common species between January and other months, from June to December (> 95%). But December showed less similarity with from February to May (< 68%). But the presence of common species was very low (< 10%) between January and other months of the year.

The highly abundant species at station 10 *Dendronereis aestuarina* and *Pendora flexosa* showed high variation and were highly correlated with nitrite, nitrate, temperature and salinity whereas at station 11 this species was controlled by salinity, temperature, organic matter and silt content. The species *Capitella capitata* which were abundant at stations 12 and 13 were highly correlated with clay at station 12 and controlled by nitrate and particulate organic carbon at station 13. Except station 12 high similarity (> 98%) was observed between all the months.

Station 14 showed high seasonal similarity (> 98%) based on abundance of common species except June and July (< 20%) and April and May (< 60%). Based on presence/absence of common species a value (< 30%) was obtained except that between August and September (~ 69%) and October and November (59%).

Q-mode factor analysis was applied only to stations 3, 5, 6, 7, 8, 9, 12 and 14 because in other stations either low number of species were observed or species were obtained only in few months.

In station 3, the months except August and November were grouped in factor 1 which had high even value and formed the differential factor groups explaining 53.41% of the variation in the seasonal variation in benthic density. In station 5, 4 factor groups, containing the months, January, March, May in the factor 1, November and December in the factor 2, July to September in the factor 3 and June in the factor 4, explaining about 74.88% of the seasonal variation in the benthic density. High positive loading was obtained for factors 1 and 2 while high negative loading for factor 3. In station 6, four-factor groups having all positive loadings except the first one, which had wider range with negative loadings were obtained.
At station 7, four factor groups obtained with high negative factor loading. At station 8 out of the 5 factor groups obtained only the first four were statistically significant. At station 9 Q-mode analysis presented 4 statistically significant factor groups and provided only 47.85% of the seasonal variation in its distribution. At station 12 a unique characteristic for the benthic distribution was observed and explained 79.99% of the over all seasonal distribution. At station 14, three factor groups were obtained and explained about 57.35% of the seasonal variability.

The fourth chapter deals with the mangrove environment of Puduvypin. This environment is a shallow salt marsh with a depth of about 1 to 1.5m and has a width ranging from 40 to 50m. Six stations were sampled from this area for 10 months (June 1993 to April 1994).

The various environmental parameters indicated well-defined differences, the variability to a certain extent being imposed by the monsoonal regime. Monsoonal discharges directly affect the concentration of nutrients, salinity and suspended load. The overall picture of water quality of Puduvypin mangrove area revealed little fluctuation between stations. The spatial variation in salinity and temperature was not pronounced since the stations are very close. Freshwater condition prevailed during monsoon. Well-oxygenated condition existed in the study area throughout the observation period and all the values were above 2 ml/l. BOD₅ values were low (<5 mg/l).

Among nutrients ammonia and phosphate showed high values (12.40 to 32.20 µmol/l). The relatively high values of the above nutrients in this area may be attributed to the heavy freshwater discharge during this period in addition to the non-point sources.

Comparatively high values of chlorophyll 'a' (4.87 to 37.65 mg/m³) and particulate organic carbon (3.95 to 12.81) was noticed during monsoon period. High suspended load was noticed throughout the observation (47.39 to 76.37 mg/l). In general phosphate, Chlorophyll 'a', particulate organic carbon and suspended load showed an inter-relationship. High values of nitrite, nitrate and phosphate might have
contributed to the high phytoplankton growth and thereby high pigment content. The shallow nature of the area and the litter fall from the mangrove trees contributed substantially to the suspended load and thereby increase in particulate organic carbon content.

The substratum of the mangrove area was dominated by clayey silt with rich organic matter content. The organic matter showed good relationship with fine grained material and the values varied from 1.25 to 7.11% (av. 4.36%).

The total number of specimens of bottom fauna recorded from this area varied from 6698 (station P4) to 53343 (station P6). The average density and biomass for the different stations varied from 670 to 5334/m² and 10.11 to 25.74g/m² respectively. Though a total of 11 groups were encountered from this area the number and percentage composition of different groups varied from station to station. A total of 28 species belonging to different groups were encountered from this area. Ten groups were observed at station P1, 9 groups at station P2, 8 groups at station P3, 10 groups at station P4, 6 groups at station P5 and 7 groups at station P6. Maximum number of groups was noticed at P4 (10) and minimum number of groups at P5 (6). Species composition of the different stations in the mangrove area showed that tanaidaceans, the dominant and common group was represented by two species viz. *Apseudes chilkensis* and *A. Gymnophobium*. The second dominant group amphipod was represented by *Melita zeylanica*, *Quadrivirusio bengalensis* and *Grandidierella gilesi*. The third dominant and common group was polychaete represented by 8 species belonging to 5 families. Among decapod penaeid prawn was collected from all stations and crab was noticed at stations P3 and P5 only. Mysid and isopod occurred rarely. Gastropods and bivalves were also noticed at one or two stations only. The insect chironomid and water beetle were observed at P1 and P4. Juvenile fishes were collected from all stations.

Mangrove enclaves being an important component of estuarine ecosystems have been identified as producers and exporters of organic matter. The ground litter on the substratum produced by trees, shrubs and herbaceous plants contribute substantial amount of organic matter to the complex estuarine food webs and energy
transfer, consequently, litter production in the mangrove ecosystem has been used as a measure of productivity in view of the importance of litter to detritivorous organisms.

Clay and silt with high organic matter content (av. 4.36%) dominated the substratum in the mangrove ecosystem of Puduypin, which favoured the group of detritivorous organisms like tanaidaceans and amphipods.

Species richness index ranged between 0.71 (station P5) and 7.76 (station P4). The average temporal distribution ranged between 2.55 (station P6) and 3.71 (station P2). Seasonal distribution showed a normal pattern for temporal variation increasing from station P1 with a peak value at station P2 and values decreased in other stations. Species concentration index ranged between 0.10 (station P1) and 2.26 (station P4). Average species concentration index was more or less same in the study area. The temporal variability was least (12.90%) at station P5 and highest (38.65%) at stations P1 and P4. Species diversity index varied between 0.35 (station P1) and 3.83 (station P4). Average distribution of diversity was maximum (1.87) at station P1 and least (1.40) at station P4 with maximum (41.54%) temporal variation.

Species dominance index ranged between 0.31 (station P1) and 2.25 (station P4). Average distribution of dominance index showed that temporally maximum (1.48) dominance was obtained at station P4 and least (0.62) at station P3. The temporal variability showed the same pattern as that observed for species diversity index. Species evenness index which invariably related to dominance showed comparatively higher value at station P1 and least value at station P5. The evenness index ranged between 0.21 and 2.13 both, at station P1. The average temporal distribution showed peak value (1.25) at station P4 and low value (0.87) at station P5.

In mangrove area the niche breadth was dependent on the temporal variation. The range in number of species was 13 (station P5) to 18 (station P6) and the range for niche breadth was between 1.09 (Littorina littorea) and high correlation with dissolved oxygen and 4.52 (Juvenile fish and Lycastis indica) highly correlated with
nitrate. At station 2 niche breadth varied between 2.35 (*Lycastis indica*) and 5.43 (*Prionospio polybranchiata*). These species were controlled by chlorophyll a, nitrate and clay. At station 3, 83.33% of the species, the niche breadth ranged between 2.03 (*Capitella capitata*) and 7.78 (*Melita zeylanica*), both were highly correlated with organic matter and silt. For the remaining species niche breadth was very low (< 1.95). At station 4, (*Melita zeylanica*) showed a niche breadth ranging between 2.01 and highly correlated with phosphate, organic matter and salinity. Juvenile fish showed a high niche breadth of 4.92 and controlled by organic matter. At station 5, the maximum niche breadth (6.55) was for *Melita zeylanica* and it was highly dependent on organic matter and minimum niche breadth was (2.35) for *Grandidierella gilesi* and highly controlled by salinity. The trend observed here was higher abundance, lower seasonal variation, higher is the niche breadth. The niche breadth at station 6 ranged between 2.69 (Penaeid prawn) and 8.57 (*Melita zeylanica*) and highly correlated with chlorophyll ‘a’, suspended load and silt.

In the mangrove area, total benthic density was related to the parameters such as dissolved oxygen, phosphate, nitrite, ammonia, organic matter, particulate organic matter, BOD<sub>s</sub>, suspended load and silt. It was found that the standardised original values of the parameters, dissolved oxygen, phosphate, nitrite, ammonia, organic matter, particulate organic matter, suspended load and silt and their first order interaction effects could predict total benthic density.

This model was highly significant (P = < 0.05) and it explained about 90.81% of seasonal and spatial variation in the total benthic density. The individual as well as the interaction effects of the water quality and sediment characteristics were graded along with their significance standard error and confidence interval. This indicated that in the mangrove area the interaction effects were more significant than the individual factor effects.

The seasonal similarity was studied using Bray Curtis and community coefficient methods. At station 1, April showed invariably high similarity with other months of the year. The common occurrence of the species was observed more in January. At station 2, between months of the monsoon season high similarity for
abundance was observed. Using presence/absence, 32.60% similarity could be observed between June to September and November to January. At station 3, different picture was observed for between months similarity. June showed high similarity (>90%) with other months of the year. Based on the presence/absence of species August to November showed 50 to 85% similarity. At station 4 unlike the other study area throughout the study period 80 to 100% similarity was observed except during June and November (<70%) and during August and February (<60%) based on the abundance of the species. At station 5, June to November showed >70% similarity in the abundance of common species except August and September (51%) and August and November (56%). Based on presence/absence of species it has been observed that higher similarity in common species was only between June and August, November and April (71%). In all other months only <60% similarity could be observed. At station 6, a strange pattern for similarity between months has been observed. It showed a striking difference when compared to other 5 stations. All combinations of months, other than with September (>70%), showed <50% similarity in the abundance of the common occurrence of species. Similarity, based on presence/absence of species a strange difference was observed in this station in all the months (<33%). Common species occurred but in different abundance as indicated by Bray Curtis similarity index.

The fifth chapter discusses the environmental impact on bottom fauna of the dredging and dumping sites of Cochin Port during pre-monsoon and monsoon seasons. Thirty six stations located in and around the Cochin harbour, covering an area of 130 km² of the estuarine and nearshore areas were selected for the collection of sediment and benthic samples. Of these eight stations were sampled over complete tidal cycles for water quality parameters with stations 1 to 4 in the estuarine region, 5 & 6 in the outer channel and 7 & 8 at the dredge spoil dumping grounds.

The environment in and around Cochin harbour which has been under sustained and varying degrees of stress due to dredging over the last 5 decades has not shown any sign of serious environmental impairment as can be seen from the present study and documented data.
The present data and the data collected earlier indicate that there is build up of various nutrients in the harbour region and close to the coast. A comparison of the data collected over the years indicate that since 1965 there has been more than two fold increase in the general levels of inorganic phosphate of the river mouth (1.23 to 3.3 μmol/l). Similarly, the average nitrate values have also increased from 7.72 to 19.7 μmol/l in the backwater system. This is due to the effect of the effluents discharged from the fertilizer factory in the upstream. Earlier studies from this region have shown the release of nutrients and metals to the overlying water during dredging. But these nutrients come to normal levels within 20 minutes after dredging. So the long-term impact to the environment due to dredging is negligible.

Dissolved oxygen saturation in the surface and bottom waters varied in general, from 60 to 80 % and BOD₅ was within in the permissible limits. Particulate matter and sediment also did not indicate high levels. So, long term impact to the environment due to dredging is negligible.

The silty clay and sandy clay substratum predominated the study area except for one or two stations. Compared to monsoon, organic matter was low during pre-monsoon, the average organic matter in the areas 1, 2 and 3 ranged from 4.07 to 5.27% during monsoon and 3.71 to 4.27% during pre-monsoon. In the dredging channel the value were 3.40% during pre-monsoon and 3.51% during monsoon. In the disposal area the average organic matter content was 4.51 and 4.00% during pre-monsoon and monsoon periods respectively. On either side of the dredging channel the organic matter content values varied from 3.83 to 4.53 % and 3.61 to 4.34% during monsoon and pre-monsoon respectively. The average organic matter of this area varied ~ from 3 to 5%. High organic matter content in the region can be ascribed to high productivity of the overlying waters. Sewage and municipal discharge and clayey nature of the sediment may also be responsible for high organic matter.

The sediment characteristics and bottom topographic features will be restored after a period of intermittent dredging. The tidal flushing characteristics and river
discharge plus material inputs help the dredged site to return to its initial status as reported by earlier researchers.

The quantitative and qualitative study of benthos in the area showed a wide variation in their distribution, abundance and composition. This may be probably due to various biological and physico-chemical environmental factors. Wide fluctuations in salinity and nature of substratum and organic enrichment in the sediment are the important factors restricting the abundance of benthos. A sufficient quantity of sediment will be removed as a result of dredging. The fauna will be exposed to a new substratum.

Benthic fauna in the study area was comprised of polychaetes, oligochaetes, amphipods, tanaidaceans, isopods, decapods, mysids, cumaceans, sergestids, alpheids, barnacles, molluscs, fishes and rare groups like amphioxus, foraminifera, sea anemone, nematodes and echinoderms. Of these, polychaetes were the common and dominant group. Twenty one species were recorded during monsoon and 19 species during pre-monsoon. Fifteen species were common to both seasons. The damage caused to the bottom community by dumping the spoil was minimal and was well reflected in the data. Therefore it has been deduced that an increase in the quantum of dredge material and its disposal at selected site was unlikely to cause any serious damage to the bottom community. The impacts were essentially short term. The behaviour of organisms in the reference area was similar to that in the disposal area and no definite impact could finally be established. It was not perceptible since the species composition of benthos was observed to be similar with that in the neighbouring areas over the years. The absence of accumulation of dead shells in this area during the study period suggests that there was no indication of mortality due to impact of dredging and dredge spoil disposal. High species density and diversity were noted at the nondredged location compared to dredged area and under favourable condition the recolonization is possible in this dynamic environment.

During pre-monsoon species richness was high in areas 1 and 2 compared to other areas. Not much variation in the richness of the species was observed during monsoon. Species concentration factor showed the same trend during both season
having high values at stations of areas 1 and 2. The highest average diversity was in area 2 with lesser variability and least average diversity was in area 3 during pre-monsoon. During monsoon the diversity index showed a decreasing trend from area 1 to area 7. Based on the average distribution, species dominance index was highest in area 5 followed by area 2 and area 1. Least dominance was obtained in area 4, 6 and 7. During monsoon dominance index was less in areas 1 to 3 but not much significant difference at areas 4 to 7 during monsoon compared to pre-monsoon. Species evenness in distribution showed high values in area 1 and area 4. The disparity in community structure observed may be attributed to the dredging effect.

Of the 28 species encountered during pre-monsoon from Area 1, *Prionospio pinnata* showed high niche breadth (>3.1). All other species had a niche breadth <2. In area 2, the niche breadth varied from 1.07 (*Corophium triaenonyx*) and 5.19 (*Nephthys dibranchis*). In area 3, of the nine species encountered *Nephthys dibranchis* and *Prionospio polybranchiata* showed high niche breadth (2.2). In area 4, out of the 18 species, *Prionospio pinnata* showed a maximum niche breadth 2.87 and moderately depend on organic matter content. *Lumbrinereis simplex* was highly correlated with sand and this indicated that sediment characteristics to a moderate extent could control the niche breadth. Of the 10 species encountered from area 5, Gastropod sp. showed a niche breadth of 1.08 and *Cossura coasta* 2.05, both were controlled by organic matter. As in area 4, *Lumbrinereis simplex* was highly correlated with sand content with niche breadth of 1.85. In area 6, the niche breadth varied between 1.11 (*Scyphoproctus djiboutiensis*) and 2.75 (*Cossura coasta*). In area 7, Gastropod sp. showed the highest niche breadth of 3.16 and was negatively correlated with sand and organic matter.

During monsoon 36 species were encountered from area 1. *Paraheteromastus tenuis* and *Apseudes gymnophobium* showed high niche breadth of 6.34 and 7.88 respectively and these species were moderately correlated with silt content. In area 2, of the 21 species, *Scyphoproctus djiboutiensis* showed the maximum niche breadth (4.52) and was highly correlated with clay content. In area 3 with 17 species the niche breadth distribution was more consistent with lower values ranging between 1.00 (gastropod sp.) and 3.11 (*Auncistroyllis constricta*). In area 4, of the 11 species,
maximum niche breadth (3.56) was for *Prionospio pinnata* and was highly controlled by organic matter. In area 5 the highest niche breadth (2.73) was for *Lumbrinereis simplex* and it was moderately correlated with sand. *Perinereis cavifrons* and *Heteromastides bifidus* were highly dependent on organic matter. In these areas the relation between niche breadth, abundance and spatial variation was the same as in the other areas and same as that observed during pre-monsoon and higher niche breadth was correlated with high organic matter.

Benthic density and sediment characteristics studied during pre-monsoon showed that the log transformed standardised values of sand, silt and clay and organic matter content could predict the log standardised values of benthic density from the regression model applied. Relation between total benthic density and sediment characteristic during monsoon showed that sediment characteristic were not enough to predict the benthic density in the dredging area during this season.

Similarity between stations was obtained using parametric as well as non-parametric methods. In the parametric method, Bray Curtis coefficient of similarity based on actual counts of the species in the stations were used. In the non-parametric method community coefficient, which depends only on presence/absence of the species, was used. In area 1 during pre-monsoon >90% similarity was observed between stations 1 to 3 and 8 to 10. Similarity based on presence/absence was very low between stations. In monsoon more or less the same pattern of similarity was obtained between stations. On the whole a marginal increase in commonness was observed during this season. In area 2 during pre-monsoon highest similarity was observed between station 13 and other stations. During monsoon a slight reshuffling was observed in the number of common species in station 13 keeping a lower level of similarity in the rest of the stations, even though the trend was almost the same. Regarding the presence/absence of species not much significant difference could be observed for the pattern of station wise similarity during the two seasons. In area 3 the five stations studied did not present much difference in the station wise similarity based on the abundance of species during the 2 seasons while the presence of common species was more during monsoon than during pre-monsoon. In area 4 the abundance of species showed almost the same
pattern in both seasons. In areas 5 and 6 higher similarity was observed between stations during monsoon and premonsoon where as in area 7 it was in reverse order.

The Q-mode factor analysis applied to dredging areas 1, 3 and 4 during premonsoon showed that 4, 3 and 3 significant factor groups. During monsoon season Q mode factor analysis has been carried out only areas 1, 2 and 3. In area 1 only 3 statistically significant groups were obtained. In area 2, the 2 factor groups were important whereas in area 3 all the 4 factor groups were ecologically important.

The sixth chapter highlights the benthic productivity and fishery potential of the three different areas studied. Primary producers occupy the base of the ecological pyramids, which produce organic matter with the help of nutrients and sunlight. Productivity of benthos is also related to the primary productivity of the overlying water column. The herbivorous and carnivorous plankton and some of the benthic forms together occupy the second stage in the ecological pyramid. They in turn form the food of higher carnivores including fishes, which are the tertiary producers. Thus, it is evident that the benthos is a very important link in the food chain and any reduction in benthic productivity may adversely affect the demersal fishery.

The fishery potential of the three environments was estimated based on the benthic productivity to evaluate the change in the production potential of the area.

The maximum benthic production and potential were observed in the southern limb and this may be due to the high biomass obtained at station 3 and 4. At station 3 a large number of small gastropods were obtained and these were considered to be a potential contributor to the next trophic level. At station 4, the high biomass obtained was due to the presence of the bivalve sp., Villorita cyprinoides, which are considered to be subsistence fishery resource.

In the northern limb the high values obtained at station 8 were due to the presence of tube dwelling polychaetes and at station 12 it was due to the occurrence of polychaetes in large numbers. However, along the industrially polluted northern limb the fishery potential has reduced by a factor of 2 compared to the earlier report.
The fishery potential at barmouth during the previous and present investigations is comparable, probably due to lack of long term and persistent changes.

In the mangrove area the production was high compared to that of the estuarine and near shore regions. Along the dredging channel also the fishery potential was high and this could be attributed to the fresh recruits from adjacent area leading to recolonisation of a rich/healthy benthic community.