BENTHIC ECOLOGY OF SELECTED PRAWN CULTURE FIELDS AND PONDS NEAR COCHIN

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Dedicated to My Parents

CERTIFICATE

This is to certify that the thesis entitled ***"BENTHIC ECOLOGY OF SELECTED PRAWN CULTURE FIELDS AND PONDS NEAR COCHIN"*** *is a bonafide record of the research work carried out by Kum.* ***PREETHA. K.*** *under my guidance and supervision under the Post-Graduate Education and Research Programme in Mariculture, at Central Marine Fisheries Research Institute, Cochin, and that no part thereof has been presented for the award of any other Degree.*

Cochin - 682 014
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DECLARATION

*I hereby declare that this thesis entitled "**BENTHIC ECOLOGY OF SELECTED PRAWN CULTURE FIELDS AND PONDS NEAR COCHIN**" is a record of original and bonafide research carried out by me under the supervision and guidance of **Dr. N. Gopalakrishna Pillai, Senior Scientist, Central Marine Fisheries Research Institute, Cochin** and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.*

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PREFACE

In the recent past, world-wide fishing effort has increased and the resources must be approaching or must have already surpassed the maximum sustainable yield. In this context, aquaculture assumes a significant role as the next alternative to enhance food production. During the year 1993-94, export of marine products from India recorded an all time high of 239918 Mt valued at Rs. 2252.80 crores, of which 60,000 t was contributed by prawns from lands under shrimp farming. The exploitation of this economically significant group has reached an optimum level in our waters. As a source of additional resource, aquaculture has been resorted to which has a long recorded history in India and has been traditionally practised in suitable low-lying areas.

The traditional prawn and fish culture systems are characterised by non-selective stocking by trapping the seeds brought into the culture fields during the high tide and allowing them to grow without supplementary feeding. Multiple harvesting is practised and the management of the culture fields is altogether poor. So, the young prawns and fish trapped in the fields depend on the natural productivity of the fields for their nutrition. To a great extent the quality and quantity of the benthos decide the productivity of the culture fields in the absence of supplementary feeding. Several biotic and abiotic factors influence the productivity of these benthic organisms. A knowledge of these factors and their interactions has become an essential pre-requisite for maintaining the balance of not only the benthic organisms but also the animals that prey upon them. Therefore, it is essential to understand the ecological features of these organisms in order to manage their enhancement and effective utilisation of the organic food naturally available in the environment for the culture practices.

The fauna and flora living at the bottom as well as the sub-bottom levels, technically termed benthos, form one of the important biological components of an ecosystem. The bottom fauna is represented by a wide spectra of animal groups and exhibit wide diversity. Most of the earlier works were chiefly related to the studies on the distribution and density of benthic animal communities in space and time. With the increasing knowledge on the complex relationships of different animal groups and the environment in which they live, studies on the ecology of animal communities received considerable attention as man started exploiting the living resources. Thus biology and ecology of benthic organisms assumes importance in the study of aquatic sciences.

Based on their size, the benthic organisms are divided into three categories viz., microbenthos, meiobenthos and macrobenthos. The term meiobenthos was coined by Mare (1942) to describe the organisms within the size range of 45 µm to 500 µm which often get excluded while sampling for macrobenthos (> 500 µm). In recent years, renewed interest has been aroused in understanding the dynamic nature of meiobenthos and their relationships with coexisting benthos and other associated demersal organisms.

Though there are several published accounts on the benthos and benthic ecology of the Cochin backwaters, very little information is available on the benthic communities and their interactions with the environment of the adjoining culture systems. The present study, on the benthic ecology of some prawn culture fields and ponds near Cochin was taken up with a view to provide information on the quantitative and qualitative distribution of benthos and their trophic relationship to prawn and fishes of the different culture ecosystems including the contiguous canals, and to the physico-chemical parameters influencing their production. The results of analyses of data based on a two-year observation period carried out in nine selected prawn culture sites at different parts of Cochin during December 1988 to November 1990 are presented in this thesis.

Investigations on hydrological and sedimentological characteristics of nine stations covering the different prawn culture systems were carried out for a period of 2 years. Seasonal variations in the physico-chemical parameters composition and abundance of benthic fauna, production of prawn and the relationships between the various parameters and benthic production were studied in three types of culture systems viz. perennial fields, seasonal fields and canals in between the coconut groves.

The thesis is presented in 4 Chapters. Chapter I presents an INTRODUCTION to the topic of study and a review of relevant works to bring an awareness to the present status of research in benthos and benthic ecology. Chapter II, MATERIALS AND METHODS, includes the techniques of sampling, preservation of samples and methods of analyses of various physico-chemical factors and benthos. A description of the area covered under the study is also given in this chapter. Chapter III, HYDROGRAPHY deals with the results of investigation and discussion on the physico-chemical parameters of water and Chapter IV, SEDIMENT covers the sedimentoloical characteristics of the different culture systems followed by a detailed discussion. Chapter V, BOTTOM FAUNA presents an account on the various aspects of benthos and benthic ecology and the details of prawn production. A discussion on the overall assessment of interrelations between abiotic and biotic factors is given in Chapter VI, DISCUSSION. A critical evaluation of the implication of benthic production on prawn production under culture conditions and trophic relationships are also included in this chapter. An executive SUMMARY of the observations made during this study is presented in the final section of the thesis which is followed by the BIBLIOGRAPHY of the references cited in the text.

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CONTENTS

CHAPTER I

INTRODUCTION

The world demand for fish and fishery products is increasing steadily, and it is generally accepted that it will not be possible to meet the heavy demand with resources exploited from the wild alone. The Indian Exclusive Economic Zone provides a sea surface area of about 2.02 million sq.km for fishing. Still the fishing activities are generally restricted upto the middleshelf waters due to several operational and economic reasons with the result the capture fishery production either remained static or some resources even exceeded the rational limits of yield. Therefore, inorder to increase marine fish production, it is accepted worldwide to resort to aquaculture of quality finfish/shellfish species.

Aquaculture, as a biological technique oriented towards production of desired aquatic organisms, is fast developing and it can claim an equal footing with agriculture and animal husbandry. In India aquaculture is of social and economic importance as it offers employment, food and income to a large number of people and foreign exchange to the nation.

During the last few years the fish production of India in general had been showing a stagnating trend. The marine fish production in India during 1993 was estimated around 2.2 million tonnes, which incidentally was also the projected potential and optimum yield from the presently exploited fishing zone. The marine fish production has reached a plateau because of the fishing being mainly concentrated in the 0-50 depth zone of the coastal belt. Today shrimps and lobsters have acquired an important place, especially as a commodity supporting the export trade of sizeable magnitude, and hence their production has to be augmented. The prawn fishery of India is supported by many species that coexist in the fishing grounds and it is characterised by wide seasonal and annual fluctuations. Besides, the prawns being smaller in size in the catch and the concomitant decrease in catch per unit effort, are indicative of a sign of overfishing. In recent years the exploitation has reached an optimum level in many parts of the country especially along the southwest coast. As a resource of additional food supply and to augment export market, culture of suitable prawn species under controlled conditions has to be carried out on a large scale. Further, capture fisheries is becoming more and more capital-intensive, especially with the spiralling cost of the construction of fishing vessels and fuel. Although culture can not replace capture fisheries, it would certainly supplement and augment the total fish and prawn production.

Prawn culture which has a long history is being practised in vast low-lying areas in a traditional way in India as well as in some of the Southeast Asian countries. The culture of prawns in impoundments adjoining the estuaries and backwaters of both central Kerala and West Bengal is well known. '_Gazni_' in coastal Karnataka and '_Kazans_' in Goa are also low-lying areas where traditional prawn culture is being practised.

In Kerala about 5117 ha of low-lying area are being utilised for prawn culture (Rao, 1980). Two types of traditional prawn culture are being practiced. One is the seasonal system or the 'Venal kettu' in which the culture operation is seasonal, during the summer (Venal) months i.e. from November to April. During the southwest monsoon period when the water becomes almost salt-free, a special variety of paddy (pokkali) which can tolerate salinity upto 8 ppt, is cultivated(Plate 2). The crop lasts for 90 to 100 days. Paddy stumps and straw left to decay after harvest, form a good manure in the soil. These seasonal systems, varying in size from 0.5 to 10 ha are confluent with the brackishwater either directly or by canals controlled by sluice gates. The yield is about 700 kg/ha in these fields (George and Suseelan 1983 and Nasser and Noble, 1991).

The second type of culture practice is being carried out in deeper brackishwater impoundments which are not suitable for paddy cultivation owing to their greater depth. They are used for culturing prawns throughout the year, and are called 'Varsha kettu' locally (Plate 1). These perennial fields vary in size from 2 to 75 ha and have an average yield of 838 kg/ha (George, 1974).

In addition to these two systems, the canals in the coconut groves (Plate 3) are also being used for prawn culture. These canals form an interlinking network in the coconut groves. With the help of sluice gates, water flow is controlled in these canals to convert them into an enclosed system for prawn culture.

In the conventional method, water from the backwater is allowed to enter the culture fields through sluice gates during high tide. The incoming water brings with it juveniles of prawns and fish into the fields. During the low tide, the sluice gate is closed using wooden frames with nylon netting to prevent the prawn and fish seed from going out. The harvest takes place 1 1/2 to 2 months after stocking, which is closely associated with lunar periodicity and lasts for about 6 to 7 days, spreading before and after the full/new moon days, the period is called 'Thakkom' locally. The harvesting is carried out during low tide by keeping a conical bagnet at the sluice gate and a lamp is used to attract the prawns towards the sluice. (Plate 1)

A common factor in all the three types of culture practices is the absence of any input towards selective stocking or supplementary feeding of prawns/fishes. The seed which enter these systems solely depend on the natural food available in the field which in turn, is influenced by a number of factors. Prawns being bottom feeders, their production depends mostly on the density of the benthic communities.

Indepth investigation on the benthic fauna are imperative for a proper understanding and management of any aquaculture system. Earlier works on benthos have shown the importance of the estimation of benthic biomass in evaluating its utilisation as food by the animals in the higher trophic levels. Trophic relation between fish and prawn and benthic organisms were studied as early as 1951 by Smidt. Hayne and Ball (1956), Bregnballe (1961), Paine (1966), Marshall (1970), Gerlach (1971), Sikora et al. (1975) and Gaston et al. (1988) have reported several fish species as consumers of bottom fauna. Damodaran (1973) studied the benthos of the mud banks of Kerala coast and opined that the meiobenthic populations be correlated to selected demersal species that support the local fishery. He also corroborated the food web drawn upon by Qasim (1970)for the same locality. A direct relationship was observed between the benthic biomass and exploited demersal fishery resources on the South West Coast of India (Harkantra et al., 1980) and Prabhu and Reddy (1987). According to Sikora et al. (1983) meiofauna serve as "packages" of microbial biomass making it available to other detritivores. Coull (1970) emphasized the importance of meiofauna as detritus degraders and their role in nutrient recycling. Alheit and Schiebel (1982), working on the trophic relationships of demersal fishes, showed that meiobenthic harpacticoids represent an excellent food source for the juveniles of several demersal fishes and reported that fish predation has a significant impact on both the number of benthic organisms and densities of certain macro invertebrate groups. Stephenson (1980) studied the relationships of the macrobenthos of Moreton Bay to catches of prawn. Flint and Rabalais (1981) developed a food web hypothesis for shrimp production from the Gulf of Mexico and suggested the existence of direct relationships between pelagic and benthic components. The role of higher trophic levels in a sublittoral benthic community was studied by Zajac (1985).

The benthic fauna and its distribution in many Indian estuaries and backwaters have been well documented. Desai and Krishnankutty (1967), Jayashree (1971), Kurian et al. (1975), Pillai (1977 and 1978), Batcha (1984), Singh (1987) and Ambika Devi (1988) have studied various aspects of the benthic fauna of different parts of Vembanad Lake.

Despite the awareness of the importance of aquaculture and the role of benthic organisms in the trophic relationships, studies on the bottom fauna of the culture systems are scanty. The benthic fauna of brackishwater ponds at Port Canning had been studied by Stebbing (1907, 1908a and 1908b). Pillai (1954) conducted an ecological study in the 'bheris' of West Bengal and enlisted the benthic organisms present. Ali and Lellak (1985) described the species diversity of benthic microalgae and bottom fauna of tropical fish ponds. Srinivasan (1982) and Sugunan (1983) carried out brief studies on the meiobenthos of culture ponds around Cochin.

Though there are several published accounts on the ecology of benthos in the open waters, that of culture ponds has remained scanty. The low-lying areas adjacent to the backwaters which support culture activities, have not been studied in detail for their macro- and meiofaunal constituents. As reported by the earlier workers, the benthos functions as direct food for other organisms at the higher strata of the food chain. In the paddy-cum-prawn culture systems of Kerala, where scientific management is very poor and no supplementary feeding is practised, the cultured organisms depend on the natural productivity of the fields for their nutrition. Under these circumstances, a thorough knowledge on the benthic communities and their interactions with the environment is necessary for understanding and assessing the organic food naturally present within the system. The present work has been carried out with a view to collect data and to provide information on the qualitative and quantitative distribution of macro- and meiobenthos and their relationships with the bottom feeding prawns of the selected perennial and seasonal culture fields and canal, in between the coconut groves around Cochin.

In the present study, a detailed sampling was conducted using a 'van Veen grab' to assess the qualitative and quantitative nature of benthos. All macro- and meiobenthic organisms contributing to the fauna were identified, and their pattern of distribution and seasonal abundance discussed. The density of macrofauna has also been assessed. The importance of different benthic forms and their contribution to the standing crop were studied in detail. Trophic relationships between benthos and bottom feeding commercially important prawns are given due consideration.

The physico-chemical aspects of the culture systems have been analysed in detail and their relation to the distribution and abundance of bottom fauna had been dealt with. Environmental parameters such as temperature, salinity, dissolved oxygen, pH, alkalinity, ammonia, nitrite, nitrate, silicate and phosphate in bottom waters were estimated. The physico-chemical nature of the sediment also was subjected to investigation. The influence of all these ecological parameters on the production and ecology of bottom fauna has also been discussed in the present study.

CHAPTER II

MATERIALS AND METHODS

2.1 AREA OF STUDY:

The Cochin backwater forms a part of the Vembanad lake, the largest backwater system in Kerala, which extends between latitudes 9° 28'E and 10° 10'N and longitudes 76° 13' and 76° 30'E. The two outlets of the lake into the Arabian sea are at Cochin and at Munambam, through which seawater enters into the backwater due to tidal influence. Cochin backwater is a positive type of estuary. The tides of this region are of mixed semi-diurnal type, and two successive high and low water appears each day with an average height of about 90 cm. The hydrographic profile is governed by tidal incursion, evaporation and the run-off from the rivers emptying into the backwater, which make it an extremely unstable ecological system.

The present investigation was carried out in the prawn culture systems situated on the low-lying areas adjacent to the Cochin backwater. These culture systems are connected to the backwater either directly or through canals, and receive water from the backwater during high tides. The changes in the hydrographical parameters of the culture systems are determined to a great extent by the water brought in by the tidal amplitude.

A pilot survey was conducted in November 1988 in the low-lying areas around Cochin, where prawn culture is being practised in a traditional way, to fix the sampling sites. Based on this survey nine sampling sites were randomly selected at Narakkal, Edavanakkad, Cherai, Chittoor, Vaduthala and Panangad (Fig. 1). They included 4 perennial ponds, 3 seasonal fields and 2 canals in the coconut groves. They are :

Perennial ponds

Stations	1	-	Edavanakkad
	2	-	Cherai
	3	-	Vaduthala
	4	-	Panangad

Seasonal fields

Stations	5	-	Narakkal
	6	-	Cherai
	7	-	Chittoor

Canals

Stations	8	-	Narakkal
	9	-	Edavanakkad

Station 1 at Edavanakkad has an area of 4 ha and a depth of 1 to 1.2m (Plate 1).Station 2, located at Cherai has an area of 4 ha and an average depth of 1m. The perennial pond at Vaduthala (Station 3), covers an area of 4 ha and the average depth is 1.2 m. The sluice opens directly into the backwaters. Hatchery raised seed were stocked in this pond. The station 4 is a perennial pond at Panangad, which is the farthest from the barmouth compared to all other sites selected for the

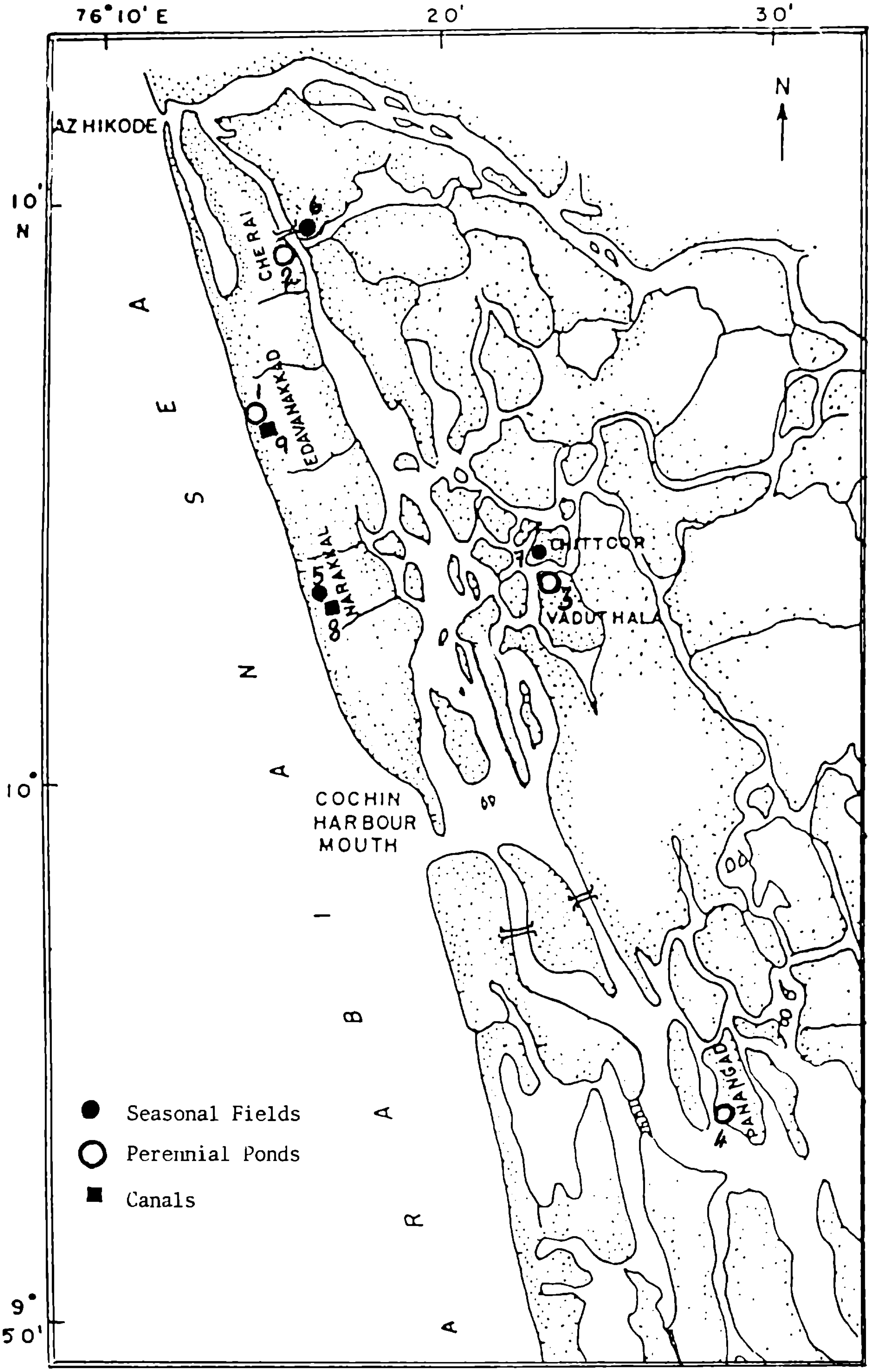

Fig. 1. Map of Cochin backwater showing the sampling stations.

Perennial pond at Edavanakkad with the sluice opening to the feeder canal.

Electric lamps attached to the sluice gate to attract prawns.

Seasonal field at Narakkal being prepared for prawn culture after the harvest of paddy.

Seasonal field at Chittoor during paddy cultivation period.

Coconut grove canal at Edavanakkad.
Sluice can be seen at the extreme end of the canal.

study. This is an extensive system and covers an area of 11.6 ha and the depth is 1.2 m. Manuring was done using ground nut oil cake, rice bran and cow dung in the ratio 1:1:25, twice a week in January and February in the first year of the study. Jelly fish were present in the pond in large numbers during the premonsoon months.

The seasonal field (station 5) is situated at Narakkal, a small fishing village in the Vyppin island. The area of this field is 2 ha and the average depth is 65 cm (Plate 2). Staion 6 is a seasonal field at Cherai , lying adjacent to the station 2 described above. These two culture systems are separated only by a bund of 3 m width. These systems receive water from the same feeder canal. Station 6 has an area of 2 ha and a depth of 60 cm. Station 7 is a seasonal field at Chittoor(Plate 2) and it opens directly into the backwater through the sluice. The area of this field is 1 ha and the depth is 50 cm. On one side of the field there is thick vegetation of Ipomea sp. During the postmonsoon months the entire water surface was covered by Salvinia molesta.

The coconut grove canal at Narakkal (Station 8) has a total length of 40 m, width of 2 m and an average depth of 50 cm. On either side of the canal there are rows of coconut trees shading the water almost throughout the day. The canal at Edavanakkad (Station 9) has a total length of 30 m and a width of 1.5 m, with an average depth of 55 cm. this canal also is overshadowed by coconut palms on both sides (Plate 3).

The materials for the present study were collected at fortnightly intervals from December 1988 to November 1990 from these stations.

2.2 HYDROGRAPHY

The physico-chemical parameters studied were temperature, salinity, dissolved oxygen, pH, alkalinity, ammonia, nitrite, nitrate, phosphate and silicate. Surface water samples were collected using a plastic bucket and a bottom sampler was used for the sub surface samples.

Winkler technique, modified by Carritt and Carpenter (1967) was followed for the estimation of dissolved oxygen. Mohr's titration method described by Strickland and Parsons (1968) was used for the determination of salinity. Total alkalinity was determined by the titration method as followed by Boyd (1982).

pH of the water samples was measured using a Toshnival make pH meter having a glass electrode and a calomel electrode as reference. Before taking the pH of the sample, the meter was calibrated with standard buffer solutions having pH 5, 7 and 9 at room temperature.

The air and water temperatures were measured in the field using a high precision thermometer (0 to 50 ^{o}C).

Ammonia content in the water was determined by phenol hypochlorite method of Solarzano (1969) as described by Strickland & Parsons (1968). The intensity of the blue colour developed as a result of the reaction was measured in a spectrophotometer at a wave length of 643 nm. A freshly prepared ammonia standard was used with each sample and the ammonia content was computed from the equation.

$$\frac{\text{Concentration of standard}}{\text{Concentration of sample}} = \frac{\text{OD of standard}}{\text{OD of sample}}$$

The ammonia content was calculated in µg at/I. The Nitrite-nitrogen and Nitrate-nitrogen were estimated by the Morris and Riley method as described by Strickland and Parsons (1968). The samples for nitrate were kept away from sunlight for 20 hours for reduction, after the addition of the buffer and the reducing agent. Later, to these samples and the samples for nitrite, acetone, sulphanilamide and NNED were added to get a pink colour. The optical density of the sample was measured at a wave length of 543 nm, spectrophotometrically. Standard solutions were used to prepare different concentrations and calibration graph was prepared.

The Mullin and Riley method, as described by Strickland and Parsons (1968) was followed for the estimation of silicate. The intensity of the blue colour developed owing to the addition of reagents was measured in the spectrophotometer at 810 nm. A calibration graph was prepared using different concentrations of the standard silicate solution.

The reactive phosphate was measured following the method suggested by Strickland and Parsons (1968). The optical density of the sample was measured at 885 nm wavelength and the concentration of phosphate was determined, by reference to a calibration graph prepared from known concentrations of standard phosphate solution.

2.3 SEDIMENT ANALYSIS

The sediment samples were taken from the van Veen grab haul. These samples were collected in polythene bags and in the laboratory each sample was dried in an oven at 60 ^{o}C and stored in a desicator for further analysis.

2.3.1 Grain size analysis

The grain size analysis was carried out during premonsoon, monsoon and post-monsoon periods for two years, in the upper layers of the sediments. The sieve and pipette analysis method of Krumbein and Pettijohn (1938) was followed to study the grain size.

2.3.2 Organic carbon

The organic carbon present in the sediment sample was determined by the Chromic acid method described by Walkely and Black (1934). From the seasonal fields after the paddy cultivation, a series of collections were made in addition to the regular sampling to note the increase in organic carbon content as a result of the biological decomposition of hay and paddy stumps. Two to three standardisation blanks were analysed along with the samples and the results were calculated from the equation.

$$\text{Percent C} = \frac{3.951}{9}\left(1 - \frac{T}{S}\right)$$

where C = the sample weight in gram

S = ml ferrous solution, standardisation blank titration.

T = ml ferrous solution, sample titration.

2.4 SAMPLING OF BENTHIC ORGANISMS

For the present study, quantitative samples of macro-and meiobenthos were collected using a van Veen grab with an effective sampling area of 0.04 m^2. As the depth was low at the sampling stations, the grab was operated by hand. As soon as the grab was hauled up, a subsample was taken from it, using a 10 cm long graduated glass correr with an inner diameter of 2.7 cm to study the meiobenthic organisms. This subsample was taken without disturbing the upper layers, by inserting the corer through the window at the top of the grab. After the subsample was taken, the contents of the grab were measured in a graduated plastic bucket, since this helped to assess the performance of the grab. Two grab samples were collected at each station and the average number of benthic organisms were tabulated. The animals were separated from the mud by hand sieving at the field, using a 500 um sieve. After a cursory examination, the organisms were collected in wide mouthed plastic bottles and preserved in 4% formalin. Materials retained in the sieve were then transferred to a black tray and were sorted making use of a stereomicroscope. All animals in each sample were identified upto species level, counted and stored in 4% formalin for further studies. To facilitate comparisons of values, the number of animals per haul was converted into number per square meter. This facilitates a fair comparison with quantitative surveys of the benthos from other areas (Thorson, 1957).

The core samples, taken out from the glass corer by pushing through one side, was cut into two sections, the upper 5 cm layer and the lower 5 cm layer. These two sections were preserved separately in 4% neutral formalin for further analysis. In the laboratory the sample was first sieved through a 500 um mesh to separate the macrobenthic organisms. The filtrate was sieved again through a 45 um sieve and the residue collected and preserved in 4% formalin. Rose Bengal was used to stain the organisms. A white tile was used as a background to facilitate sorting of the stained organisms.

All meiobenthic organisms in each subsample were identified upto group level, counted and stored in 4% formalin. The number of animals per subsample was converted into number per 10 cm^2.

2.4.1 Biomass

Biomass is the amount of living substance constituting the organisms which are being studied and can be expressed in units of volume, mass or energy which may refer to the whole or part of the body of the organisms. According to Crisp (1971), the biomass of aquatic organisms can be measured by weighing the organisms after removing the external water and the water present in the cavities. In the present study the biomass of the macrobenthic fauna are represented in wet weight measurements which were taken after they were preserved in formalin.

Lovegrove (1966) has shown that preservation in formalin may change the biomass, the weight loss being rapid initially after preservation and attaining an equilibrium thereafter. In the present study the wet weight of macrobenthos belonging to different groups of animals was taken separately after 8 weeks of preservation. This also included the weight of shells of small gastropods. The shells of other molluscs were removed prior to weighing.

CHAPTER III

HYDROGRAPHY

Water quality management forms an integral aspect of aquaculture operations. It is also important in controlling water pollution problems as well as environmental contamination from metabolites and oxygen depletion in culture systems. To enhance survival and production by appropriate manipulation of the aquatic environment, an understanding of the complex interactions between the ecosystem and the stocked organisms is essential.

In the present study an attempt has been made to study the hydrographic parameters of the culture systems where management is almost nil. The parameters studied were water temperature, pH, dissolved oxygen, salinity, alkalinity and nutrients such as nitrite, nitrate, ammonia, silicate and phosphate. Rainfall data was collected from the Meteorology Department of India.

The monthly variations in values of various hydrographic parameters are graphically represented and the range in the different seasons is given in Tables.

3.1 TEMPERATURE

Temperature values showed seasonal variations and were generally high in the premonsoon months (Figs. 2 and 3). In the perennial ponds, the highest water temperature of 36 ^{o}C was recorded in April 1990, at Station 4. Temperature values recorded at the different perennial systems are given below, which indicates that the values varied from 25.2 to 36 ^{o}C in these ponds.

Seasonal variation of temperature (°C) in perennial ponds

Stn.	Years	Premonsoon Min	Max	Monsoon Min	Max	Postmonsoon Min	Max
1.	1989	29 -	31	28.2 -	30.8	28 -	31.5
	1990	32.1 -	33.0	26 -	29.0	29.5 -	31
2.	1989	27.7 -	31.5	27.5 -	30.4	26 -	32.6
	1990	28.5 -	34	28 -	30.5	26 -	26.5
3.	1989	27.2 -	33	27.7 -	31.2	26 -	32.2
	1990	29 -	34.0	27 -	32.0	26 -	26.2
4.	1989	25.2 -	29.8	28 -	30.7	28 -	31.7
	1990	31 -	36.0	26 -	28.5	26.5 -	26.5

In the seasonal fields, during the premonsoon period of 1990 the temperature values were high compared to the rest of the period. (Fig. 4). The highest temperature of 36 °C was recorded at station 7 in March 1990. The seasonal variations in temperature is given in the following table. The temperature values ranged from 25.2 °C to 36 °C.

Seasonal variation of temperature (°C) in seasonal fields

Stn.	Years	Premonsoon Min	Max	Monsoon Min	Max	Postmonsoon Min	Max
5.	1989	27.2 -	31.5	26.2 -	29.7	27 -	30.6
	1990	31.2 -	35	26.5 -	31	27 -	27.5
6.	1989	28.2 -	30.5	25.7 -	29	29 -	30.5
	1990	31 -	35	25.2 -	29	26 -	26.5
7.	1989	28 -	31.3	28.4 -	30.2	30 -	32.6
	1990	31.5 -	36.0	27 -	30.5	26 -	26.5

Figs. 2 & 3. Monthly variations in temperature in the perennial ponds

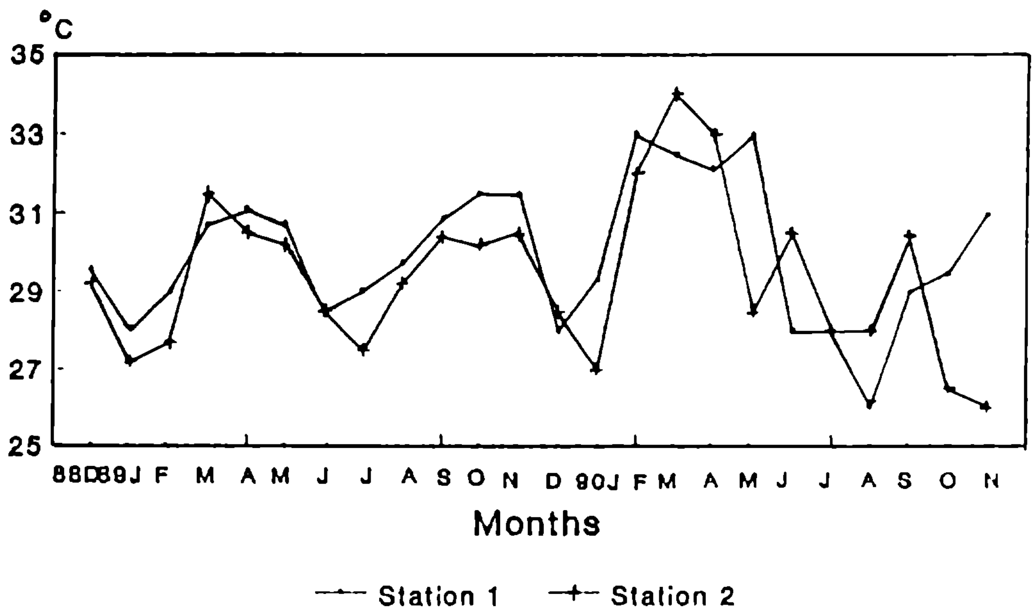

Fig. 2

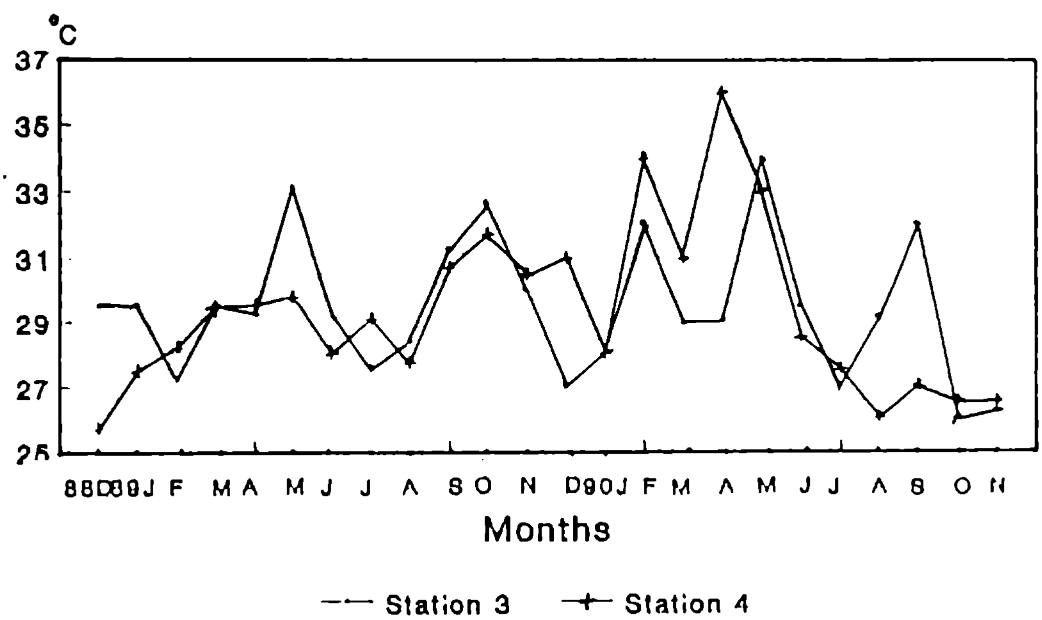

Fig. 3

Fig. 4 & 5. Monthly variations in temperature in the seasonal fields and canals.

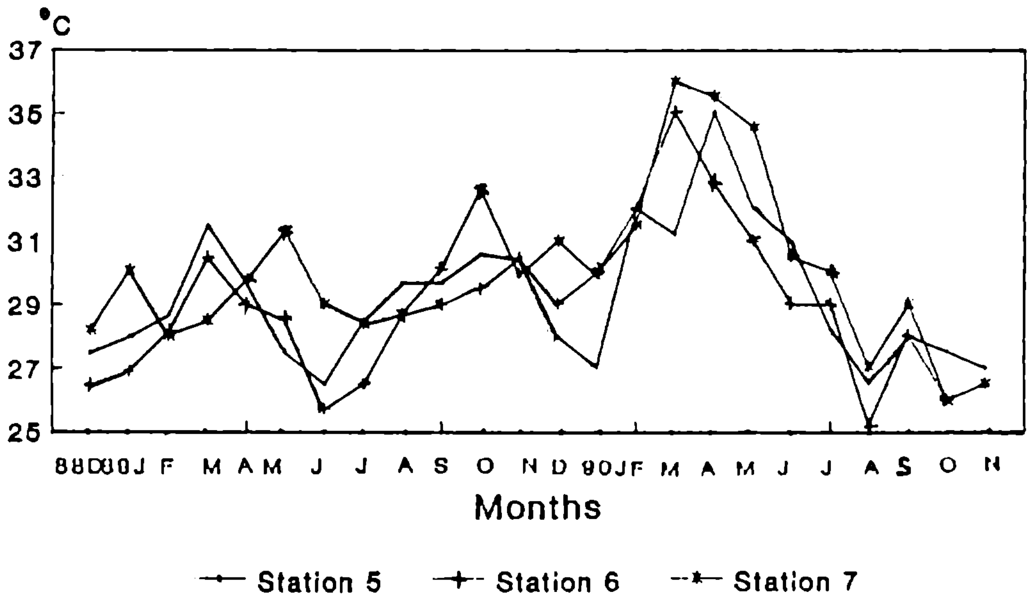

Fig. 4

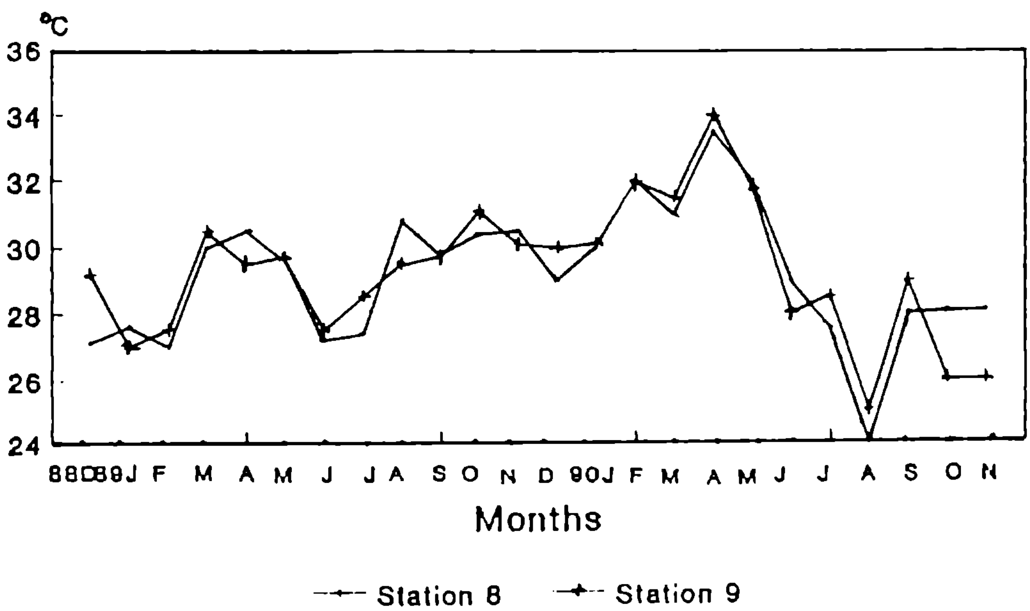

Fig. 5

In the coconut grove canals, temperature values were more or less the same, with the highest temperature of 33.5 ^{o}C at station 8 and 34 ^{o}C at station 9 being recorded in April 1990 (Fig.5). The seasonal variations are given below.

Seasonal variation of temperature (^{o}C) in canals

Stn.	Years	Premonsoon Min		Premonsoon Max	Monsoon Min		Monsoon Max	Postmonsoon Min		Postmonsoon Max
8.	1989	37	-	30.5	27.2	-	31	29	-	30.5
	1990	31	-	33.5	24	-	29	28.1	-	28.1
9.	1989	27.5	-	30.5	27.5	-	29.7	30	-	31.0
	1990	31.8	-	34.0	28	-	29	26	-	26

Temperature is an important ecological factor which influences the various processes taking place within the ecosystem as well as the biology and physiology of the fauna. The variations in water temperature are, to a large extent, due to seasonal changes in humidity, rainfall and also due to the depth of the lake/estuary. But in the shallow culture systems depth may not be an important factor determining the changes in temperature as is evident from the warm water conditions throughout the study period. High temperature values were recorded in premonsoon season, which started declining with the onset of southwest monsoon. Similar observations have been made by Ramamirtham and Jayaraman (1963), Gopinathan et al. (1982), Pillai (1977 and 1978) Srinivasan (1982) Raman et al. (1975) and Singh (1987) in the Cochin backwaters.

Sankaranarayanan and Qasim (1969) suggested that the incoming freshwater and intrusion of cold water from the sea might also cause decrease in water temperature of Vembanad lake during monsoon season. Joshy (1990), Devapiriyan (1989) and Sheeba (1992) have reported high water temperature during premonsoon in the culture systems.

In both the years the minimum temperature occurred during the period August-September and the maximum during premonsoon. The period of southwest monsoon coincides with period of minimum temperature. After the monsoon there was a rapid increase in the sediment temperature.

The pattern of variation of surface water temperature off Cochin area has been described to be bimodal (Damodaran, 1973). During April the temperature is high and there is practically no rainfall. The months of June to August can be considered as the active period of southwest monsoon. During this period, upwelling is active along the Kerala Coast (Ramamirtham and Jayaraman, 1963). In addition to precipitation, the upwelled cold water entering into the shelf waters may contribute to the decrease in temperature. The impact of southwest monsoon and upwelling lasts till the end of August and during September to October there is a rapid increase in temperature. The slight decrease during December and January may be due to the drop in atmospheric temperature.

The temperature values remained at or above 24 ^{o}C during the period of study. The fall in temperature was not very much due to the shallowness of the systems, as the water temperature rises up during day time when sampling was carried out. In these shallow systems depth may not be a factor determining the changes in temperature as evident from the warm water conditions throughout the study period.

3.2 pH

The pH values showed a range from 6.4 to 8.5 (Figs. 6 and 7) in the perennial ponds, the maximum (8.5) at station 3 and the minimum (6.4), were recorded at stations 1 and 2.

Seasonal variation of pH in perennial ponds

Stn.	Years	Premonsoon		Monsoon		Postmonsoon	
		Min	Max	Min	Max	Min	Max
1.	1989	7.2 -	7.7	6.4 -	7.5	6.6 -	6.9
	1990	7.4 -	7.8	6.7 -	8.0	7.3 -	7.9
2.	1989	6.9 -	7.9	6.4 -	7.6	6.5 -	7.1
	1990	7.0 -	8.0	7.1 -	8.1	7.2 -	7.6
3.	1989	6.9 -	8.5	6.5 -	7.8	7.6 -	8.1
	1990	7.5 -	7.9	6.9 -	7.3	7.3 -	7.4
4.	1989	6.8 -	7.7	6.5 -	7.7	6.9 -	8.0
	1990	7.3 -	7.7	6.9 -	7.3	7.0 -	7.5

Among the seasonal fields, the pH ranged from 5.6 to 8.5, at station 5, 6.5 to 8.1 at station 6 and 5.8 to 8.3 at station 7 respectively. (Fig. 8).

Fig. 6 & 7. Monthly variations in pH in the perennial ponds

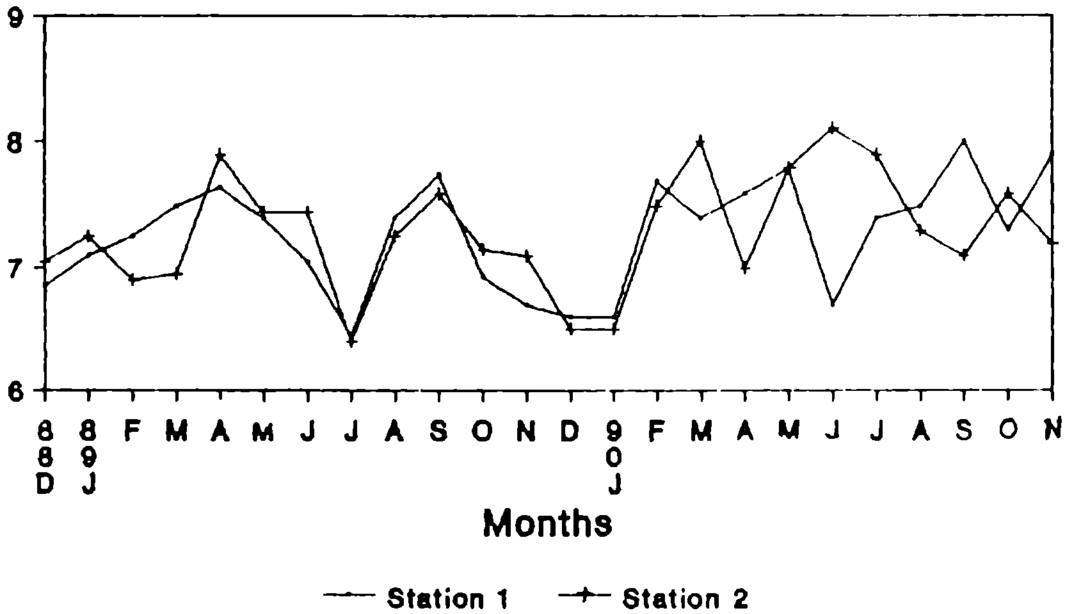

Fig. 6

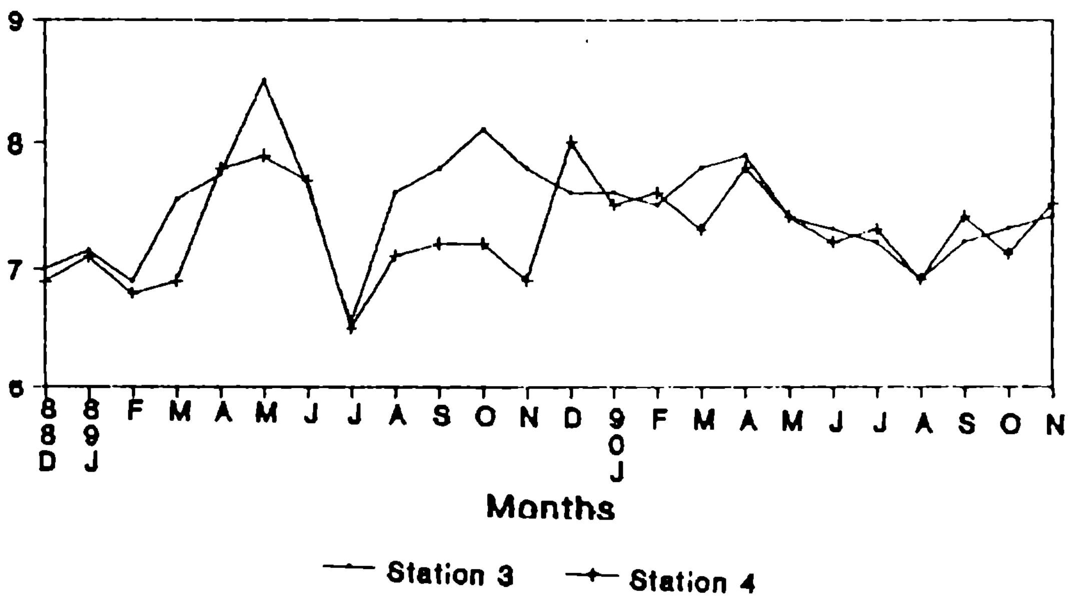

Fig. 7

Seasonal variation of pH in seasonal fields

Stn.	Years	Premonsoon Min	Premonsoon Max	Monsoon Min	Monsoon Max	Postmonsoon Min	Postmonsoon Max
5.	1989	6.9 -	7.9	5.6 -	7.4	6.1 -	7.6
	1990	7.9 -	8.2	7.2 -	8.5	7.1 -	7.8
6.	1989	7.1 -	7.7	6.5 -	7.3	6.6 -	7.0
	1990	7.4 -	8.1	6.7 -	7.7	7.3 -	7.5
7.	1989	6.8 -	8.3	5.8 -	7.7	6.9 -	8.2
	1990	7.5 -	7.8	6.6 -	7.3	7.3 -	7.6

pH values did not vary much in the coconut grove canals and the range was between 6.1 and 8.1 (Fig. 9).

Seasonal variation of pH in canals

Stn.	Years	Premonsoon Min	Premonsoon Max	Monsoon Min	Monsoon Max	Postmonsoon Min	Postmonsoon Max
8.	1989	7.0 -	7.9	6.7 -	7.0	6.2 -	7.7
	1990	7.3 -	8.0	7.4 -	7.9	7.3 -	7.9
9.	1989	6.7 -	7.9	6.1 -	7.8	6.4 -	7.0
	1990	6.9 -	7.8	7.5 -	8.1	7.3 -	7.5

The pH content of water is governed by many factors such as soil pH, concentration of carbon dioxide, carbonates and bicarbonates in water. Banerjea (1967) reported that water with an almost neutral reaction was best suited for a fish pond and the ponds having pH outside the range of 6.5 - 8.5 were all found to be unproductive. In the present study pH values did show wide fluctuation but were slightly high in

Figs. 8 & 9. Monthly variations in pH in the seasonal fields & canals

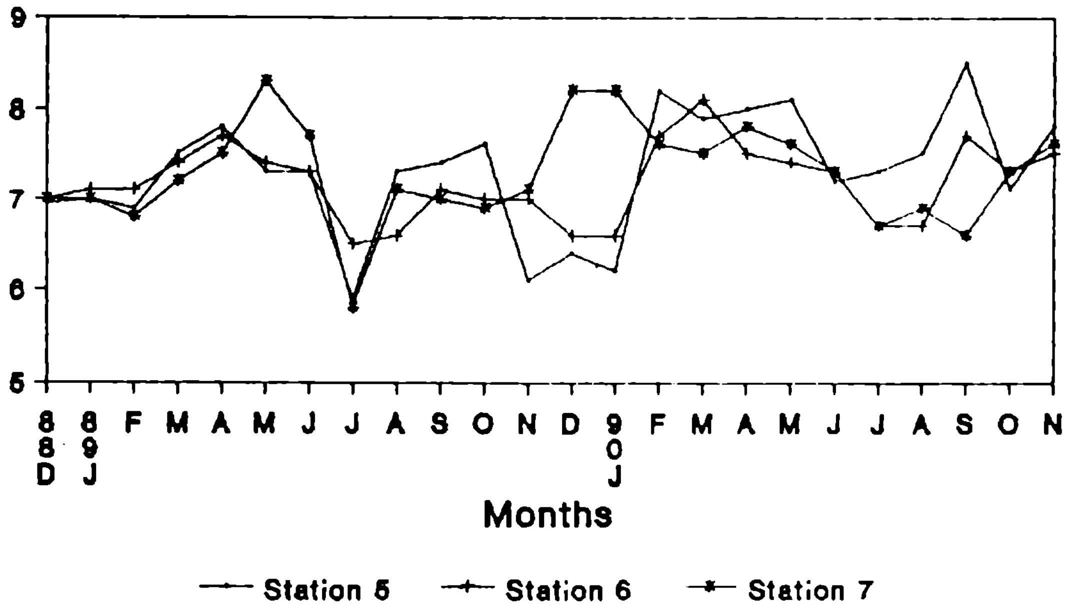

Fig. 8

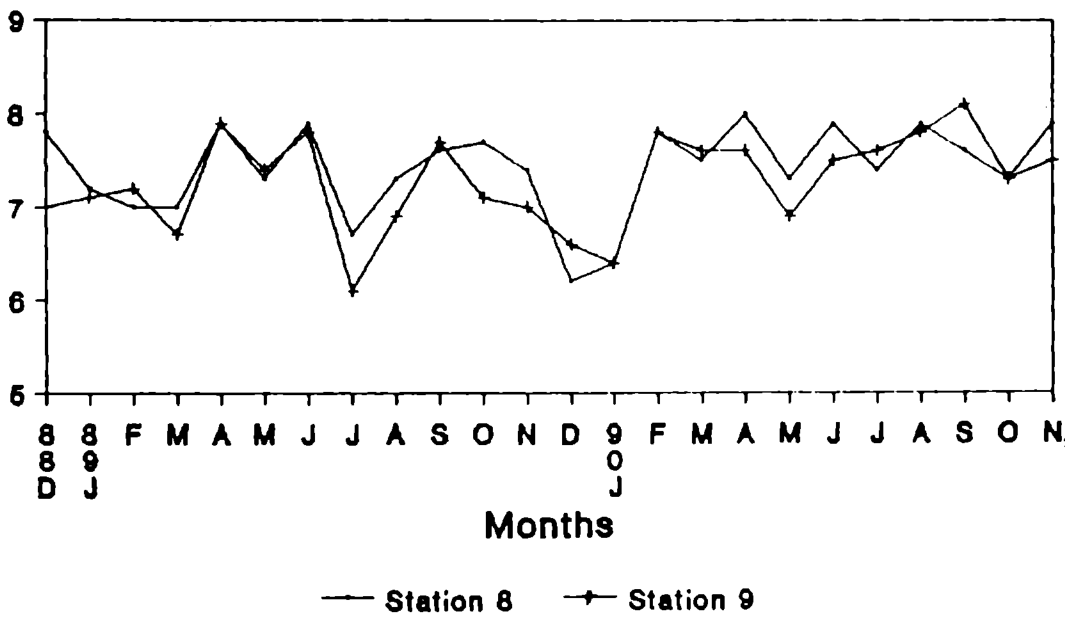

Fig. 9

premonsoon, and slightly acidic during monsoon. Subbash Chander (1986), Nair *et al*. (1984), Devapiriyan (1989), Joshy (1990) and Sheeba (1992) made similar observations in the culture systems. Sankaranarayanan and Qasim (1969) observed that during the period of freshwater discharge, the pH values decreased reaching a minimum in July-August. Increased sedimentation which reduces the decomposition of organic matter could result in near reducing conditions at the bottom (Subbash Chander, 1986). The slightly acidic nature of water during postmonsoon at Chittoor could be due to the heavy infestation of the floating weed *Salvinia molesta*. Mollah *et al*. (1979) observed low pH values in a pond and suggested that an increase of carbondioxide through respiration and decomposition, and decrease in photosynthetic activities in the water due to its remaining covered with water hyacinth resulted in low pH. Sheeba (1992) also has observed that spreading of *Salvinia* resulted in acidic water in a seasonal prawn culture field at Cochin.

3.3 SALINITY

Seasonal variations were relatively wide in the case of salinity. Owing to the onset of monsoon during the June-September period, values of salinity showed a sudden decline.

Among the perennial ponds, the highest salinity of 28.12 ppt was recorded in March 1989, at station 2, (Fig. 10). As the monsoon advanced, the values which were high in the premonsoon, dropped drastically, creating an almost freshwater condition at stations 3 and 4. In 1989, the salinity values continued to be low till October in all the perennial ponds (Fig. 11).

Seasonal variation of salinity (ppt) in perennial ponds

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
1	1989	15.94	22.10	4.03	10.62	1.37	8.42
	1990	11.40	20.43	4.46	9.62	4.54	7.00
2	1989	19.65	27.27	1.19	10.90	1.19	22.53
	1990	22.01	28.12	1.39	10.40	3.32	8.40
3	1989	4.74	14.07	0.27	2.98	0.27	13.92
	1990	6.42	21.53	0.26	3.23	0.87	14.40
4	1989	12.32	23.00	0.78	2.53	0.37	18.87
	1990	7.13	27.66	0.44	12.24	1.49	6.82

Among the seasonal fields, the highest salinity was recorded at station 6 (27.85 ppt). Station 7 had a low salinity profile with a range in salinity of 0.23 - 18.39 ppt. (Fig. 12)

Seasonal variation of salinity (ppt) in seasonal fields

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
5	1989	11.73	23.05	1.19	7.38	2.01	15.11
	1990	12.55	19.24	1.21	8.75	3.71	5.01
6	1989	18.78	25.93	0.79	13.60	1.24	20.34
	1990	22.77	27.85	1.73	9.91	4.96	5.97
7	1989	7.13	18.39	0.23	6.51	0.29	10.17
	1990	0.89	16.95	0.37	4.02	0.90	1.09

In the coconut grove canals, salinity ranged between 1.38 ppt to 19.63 (station 8) and 2.52 ppt to 20.33 ppt at station 9. The lowest salinity was recorded in October 1989 at station 8. (Fig. 13)

Figs. 10 & 11. Monthly variations in salinity in the perennial ponds.

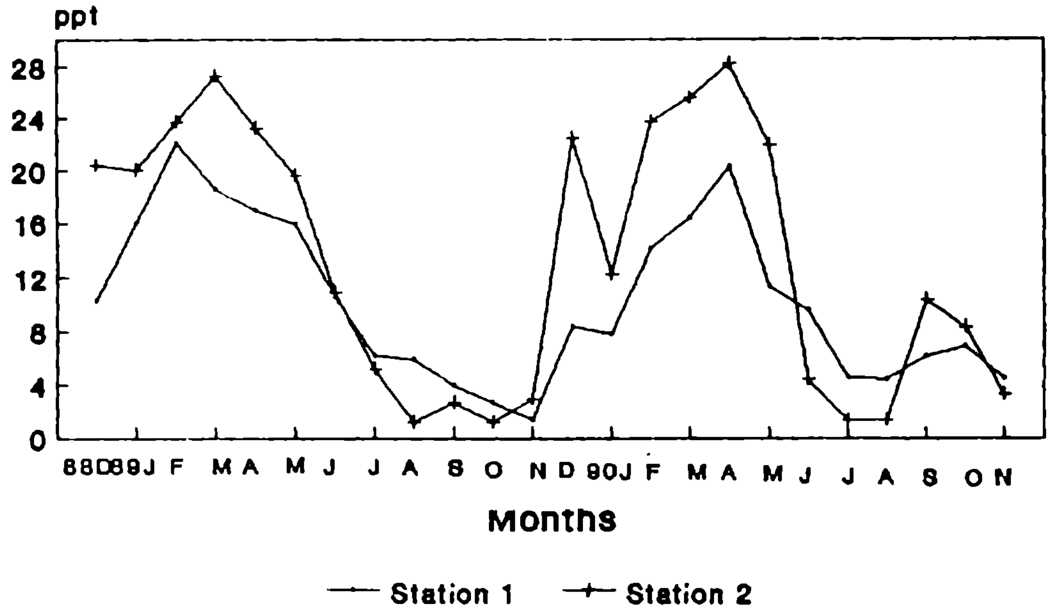

Fig. 10

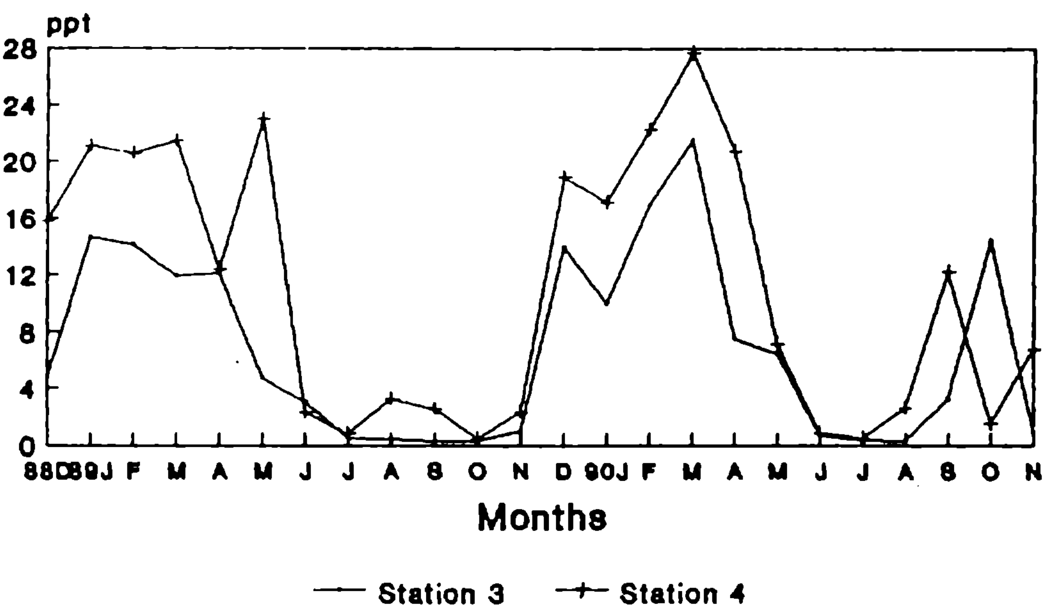

Fig. 11

Seasonal variation of salinity (ppt) in canals

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
8	1989	11.87	19.63	2.12	7.59	1.38	11.91
	1990	16.04	18.32	1.66	3.76	4.65	6.70
9	1989	8.98	17.95	5.23	8.15	2.52	8.98
	1990	12.03	20.33	2.97	8.46	4.54	4.63

Salinity is one of the most significant factors influencing the distribution of benthic fauna in an estuary. The changes in salinity are directly related to rainfall, freshwater influx, and mixing pattern within the system.

The stations at Narakkal, Edavanakkad and Cherai have evinced higher salinity ranges compared to Chittoor and Vaduthala, and this could be attributed to their proximity to the sea (Fig. 1). Chittoor and Vaduthala are located away from the bar mouth and the tidal influence felt is feeble. As these stations experience more of freshwater influx, the salinity profile is low. This is in accordance with the earlier reports of decline in salinity from the bar mouth to the upper reaches of the estuary (Pillai, 1978; Batcha, 1984 and Gilbert, 1985). Though situated away from barmouth, the station at Panangad had higher salinity values compared to Chittoor and Vaduthala. Influx of sea water is more in the canal from where water enters the pond. This canal (Chalathodu) is an extended arm of the estuary in the southern side of the bar mouth and a few specimens of marine species like Histrio histrio and jelly fishes were observed in plenty in this canal. This shows the presence of high saline water extending upto interior places through main canals.

The heavy precipitation during the south west monsoon period resulted in a drastic decrease of salinity at all the stations. During the monsoon season, owing to heavy influx of fresh water, the estuary virtually becomes filled with fresh water, and this water enters the culture systems during high tide. As the rainfall decreased, the postmonsoon months showed an increase in salinity. The postmonsoon season is a phase with salinity intermediate between the lowest salinity (in the monsoon) and the highest salinity (in the premonsoon). Such a seasonal change in salinity has been reported earlier by Sankaranarayanan and Qasim (1969), Devassy and Gopinathan (1970) Sreedharan and Salih (1974), Gopinathan et al. (1982), Batcha (1984), Singh (1987) and Joykrushna (1989) in the Cochin backwaters. In the prawn culture fields Devapiriyan (1989), Joshy (1990) and Sheeba (1992) also have reported similar seasonal fluctuations. In premonsoon the slight decrease in salinity is due to the premonsoon showers common during this period, as reported by Sankaranarayanan et al. (1984) and Sheeba (1992).

3.4 DISSOLVED OXYGEN

Among the perennial ponds dissolved oxygen content varied from 2.03 ml/l at station 1 to 8.8 ml/l at station 3. There was an increase in the oxygen content with the onset of monsoon. (Figs. 14 and 15).

Seasonal variation of dissolved oxygen (ml/l) in perennial ponds

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
1	1989	3.86	4.98	2.65	4.19	2.20	2.29
	1990	2.03	5.04	2.25	4.45	3.45	4.30
2	1989	3.43	5.38	2.05	6.70	2.04	3.75
	1990	2.54	4.06	2.40	7.00	3.75	5.75
3	1989	2.63	5.59	3.50	7.60	3.26	4.55
	1990	3.79	8.80	3.95	7.70	5.80	6.20
4	1989	3.73	5.66	2.40	6.23	3.30	4.83
	1990	2.54	4.57	3.30	5.00	3.20	4.20

Among the seasonal fields, the highest oxygen content (6.60 ml/l) was recorded at station 5 in February 1990. (Fig.16). The lowest value 1.27 ml/l was recorded at stations 5 and 7 in the postmonsoon of 1989. The values ranged from 1.27 to 6.6 ml/l at station 5, 2.35 to 6.20 ml/l at station 6 and 1.27 to 5.87 ml/l at station 7.

Seasonal variation of dissolved oxygen (ml/l) in seasonal fields

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
5	1989	3.04	4.95	1.85	3.99	1.27	2.95
	1990	2.9	6.60	3.52	4.18	3.56	4.10
6	1989	2.83	6.10	2.65	5.40	2.96	3.26
	1990	2.35	4.83	3.06	6.20	3.14	3.73
7	1989	2.71	5.87	3.43	5.87	1.27	3.66
	1990	3.81	5.33	3.05	5.09	5.10	5.70

At stations 8 and 9, the lowest oxygen content recorded were 1.59 and 1.78 ml/l respectively in the postmonsoon period of 1989, and the

Figs. 14 & 15. Monthly variations in dissolved oxygen in the perennial ponds.

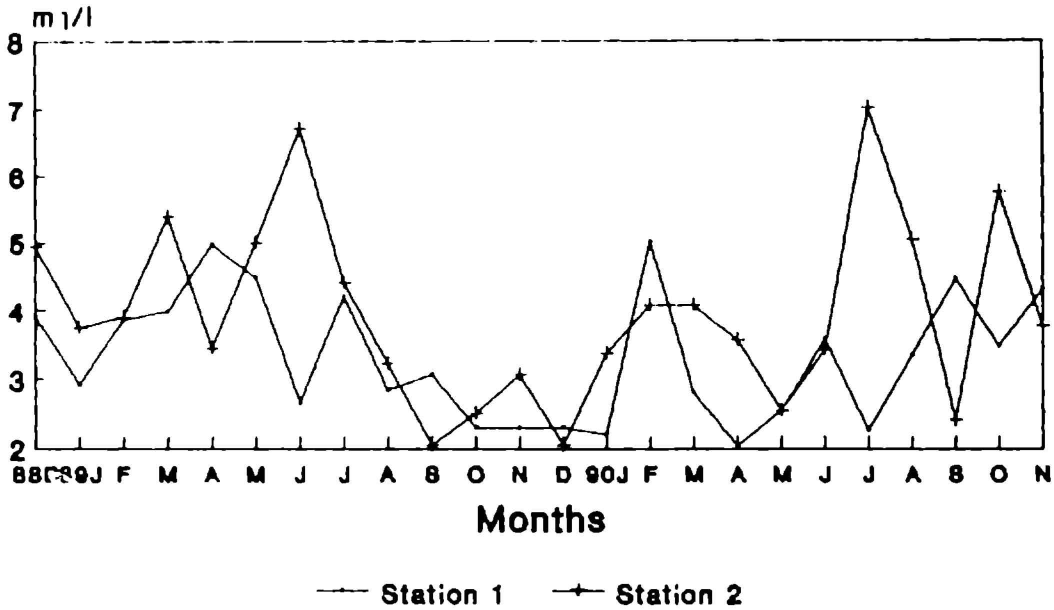

Fig. 14

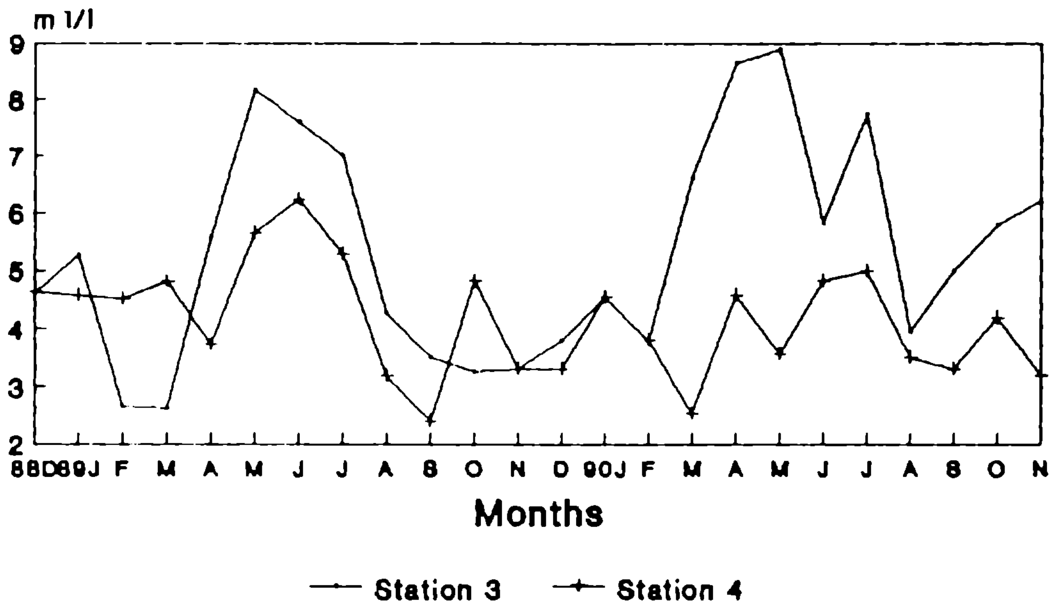

Fig. 15

Fig. 16 & 17. Monthly variations in dissolved oxygen in the seasonal fields and canals.

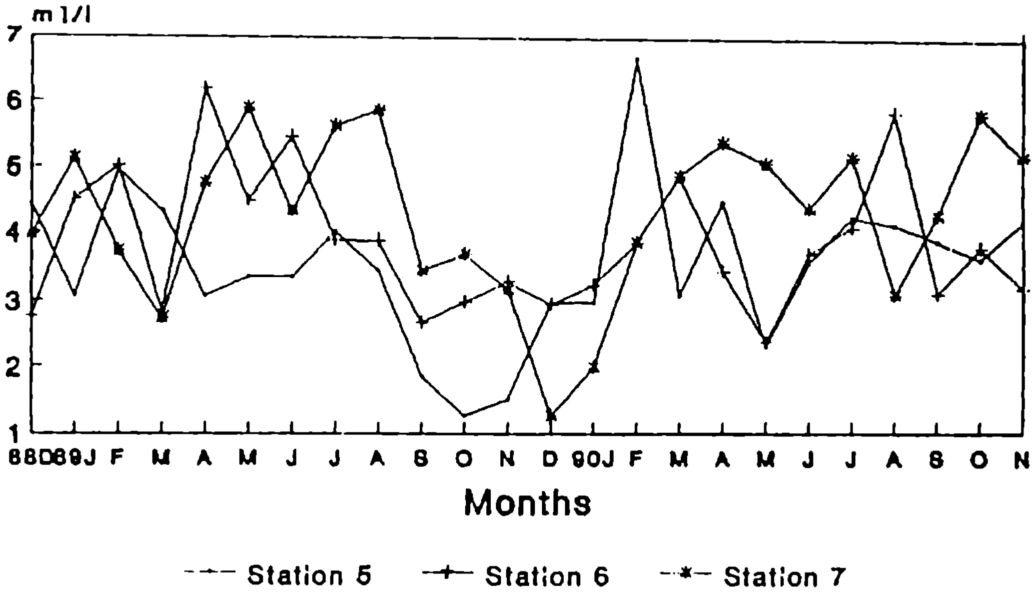

Fig. 16

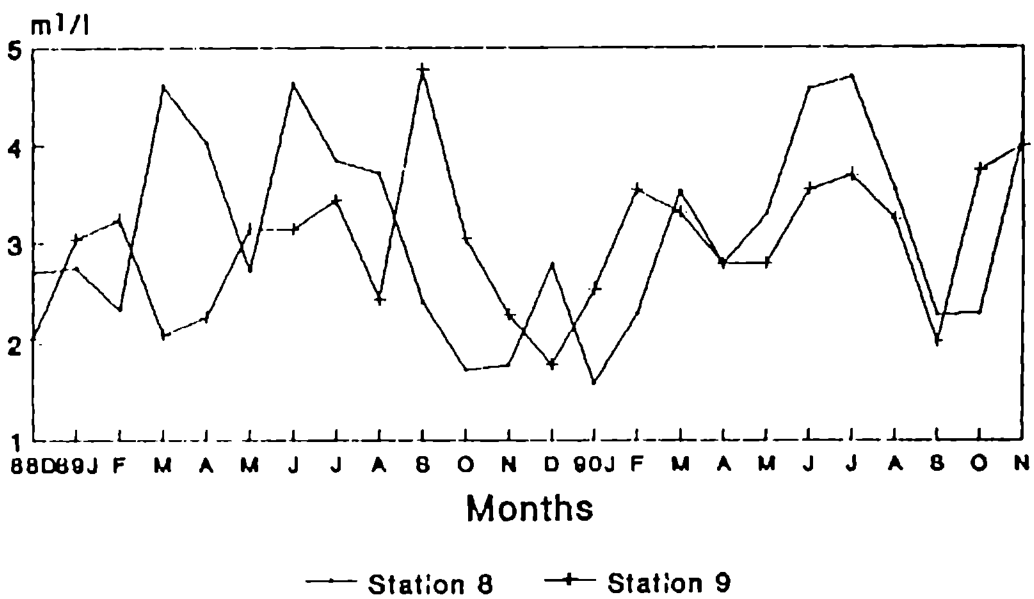

Fig. 17

highest values 4.7 and 4.77 ml/l at these stations were recorded during the monsoon season in 1989 (Fig. 17).

Seasonal variation of dissolved oxygen (ml/l) in canals

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
8	1989	2.33	4.60	2.42	4.64	1.59	2.79
	1990	2.30	3.54	2.29	4.70	2.30	4.10
9	1989	2.08	3.24	2.42	4.77	1.78	3.05
	1990	2.79	3.56	2.01	3.70	3.75	4.00

In natural waters oxygen is important as a regulator of metabolic process of plant and animal community and as an indicator of water condition. According to Ellis (1937) dissolved oxygen content of 3 ppm can lead to asphyxia and to maintain a favourable condition for a varied fish fauna, 5 ppm of dissolved oxygen is required. In the present study the highest oxygen content (8.80 ml/l) was recorded during monsoon period. Such high oxygen concentration in culture systems has been reported earlier by Srinivasan (1982), Sugunan (1983) and Sheeba (1992). In the seasonal fields the oxygen content was comparatively low which could be due to their shallowness and decomposition of organic matter by microbial activity (Sheeba, 1992). At stations 3 and 7 (Figs. 15 and 16) oxygen content was high and it is inferred that these stations are situated away from the barmouth and during monsoon season, the impact of riverine flow is more at these stations, resulting in high dissolved oxygen content. The canals were poor in oxygen content. These are narrow canals with coconut trees on both sides, which cast their shadow on the canal all through the day. Moreover, there is large amount of decaying plant material in these canals, the biological degradation of which consumes oxygen and leaves the water deficient in oxygen. Sheeba (1992) also has reported low oxygen content in canals.

The surface water had higher oxygen in May. Salinity and temperature were high during this period and this would not apparently favour an increase in dissolved oxygen. Therefore, the high oxygen content during this period must be due to some other factors. The month of May being early in the period of SW monsoon, the trade winds are fairly strong and it can bring about agitation and increased dissolution of atmospheric oxygen in the surface layers (Damodaran, 1973). This water enters the estuary and the culture systems, resulting higher oxygen values during May.

3.5 ALKALINITY

Alkalinity values were generally high during premonsoon periods in the perennial ponds (Figs. 18 and 19). At station 2 in June 1990, there was a sudden increase in alkalinity. In June 1989 there were similar high values at station 3 also. These high values were followed by steady decline in the following months.

Seasonal variation of alkalinity (mg/1) in perennial ponds

Stn	Year	Premonsoon Min. - Max.	Monsoon Min. - Max.	Postmonsoon Min. - Max.
1.	1989	58 - 87.5	56.5 - 72.5	30 - 78
	1990	40 - 104.0	72.0 - 176.0	86 - 96
2.	1989	64.5 - 92.5	40 - 85.5	24 - 84
	1990	78.0 - 108.0	38 - 94.0	66 - 76
3.	1989	23 - 100	14 - 85.5	16 - 52
	1990	42 - 76	30 - 62.0	28 - 62
4.	1989	45 - 68.5	26.5 - 45.5	10 - 72
	1990	62 - 88.0	30.0 - 60.0	36 - 36

In the seasonal fields, alkalinity values were low during the monsoon period. The highest value of 154 ppm was recorded at station 6 in May 1990. (Fig. 20). At station 5, the values remained comparatively higher during the monsoon period of 1989.

Seasonal variation of alkalinity (mg/1) in seasonal fields

Stn	Year	Premonsoon Min. - Max.	Monsoon Min. - Max.	Postmonsoon Min. - Max.
5.	1989	51 - 79.5	48 - 76.5	26 - 68
	1990	82 - 102.0	34 - 81.0	49 - 61
6.	1989	66.5 - 89	36.5 - 52	23 - 78
	1990	98.0 - 154	35.0 - 94	61 - 74
7.	1989	29.5 - 42.5	14.5 - 40	14 - 42
	1990	34.0 - 60.0	30.0 - 44	26 - 33

Figs. 18 & 19. Monthly variations in alkalinity in the perennial ponds

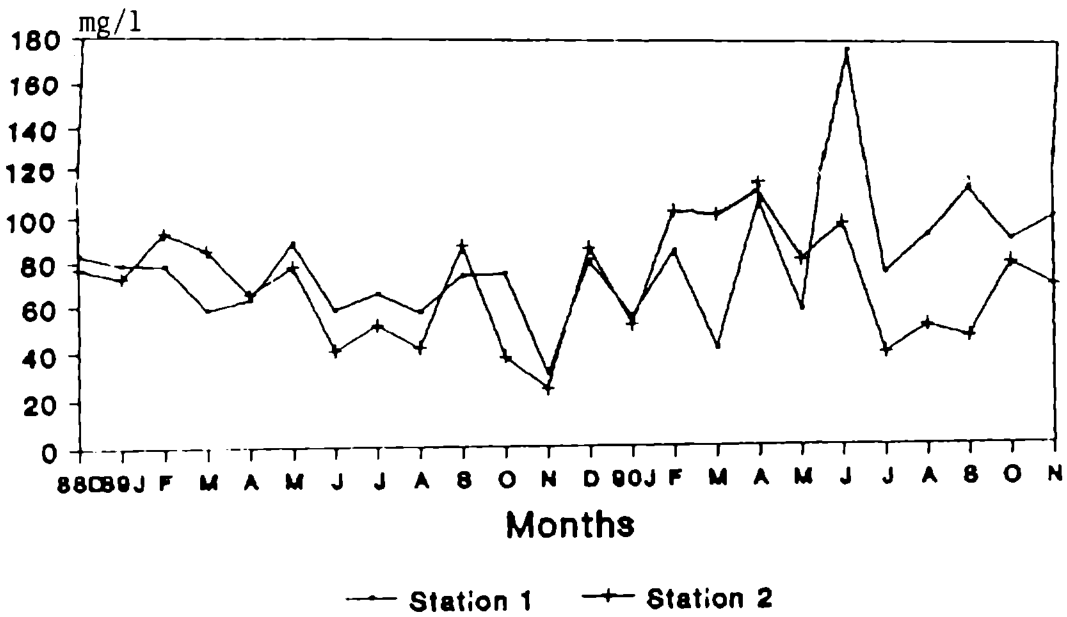

Fig. 18

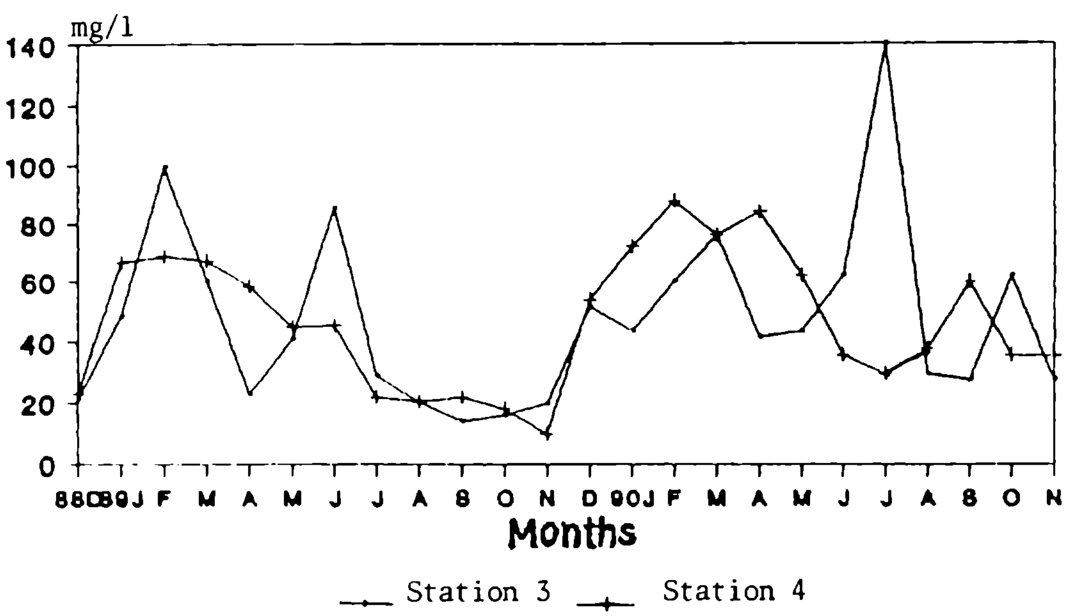

Fig. 19

Figs. 20 & 21. Monthly variations in alkalinity in the seasonal fields and canals.

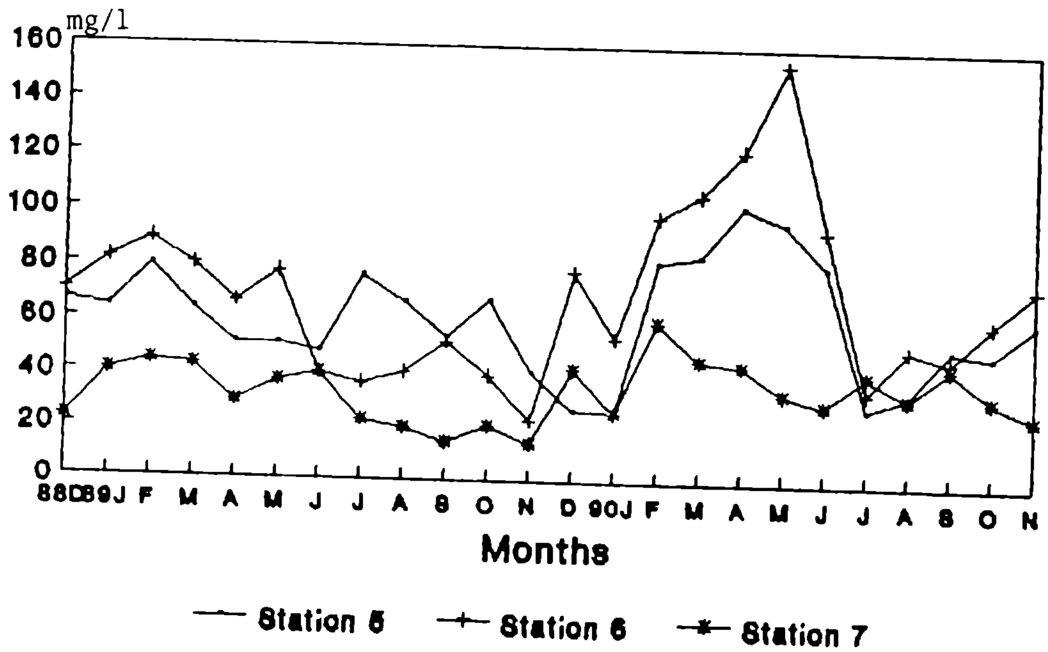

Fig. 20

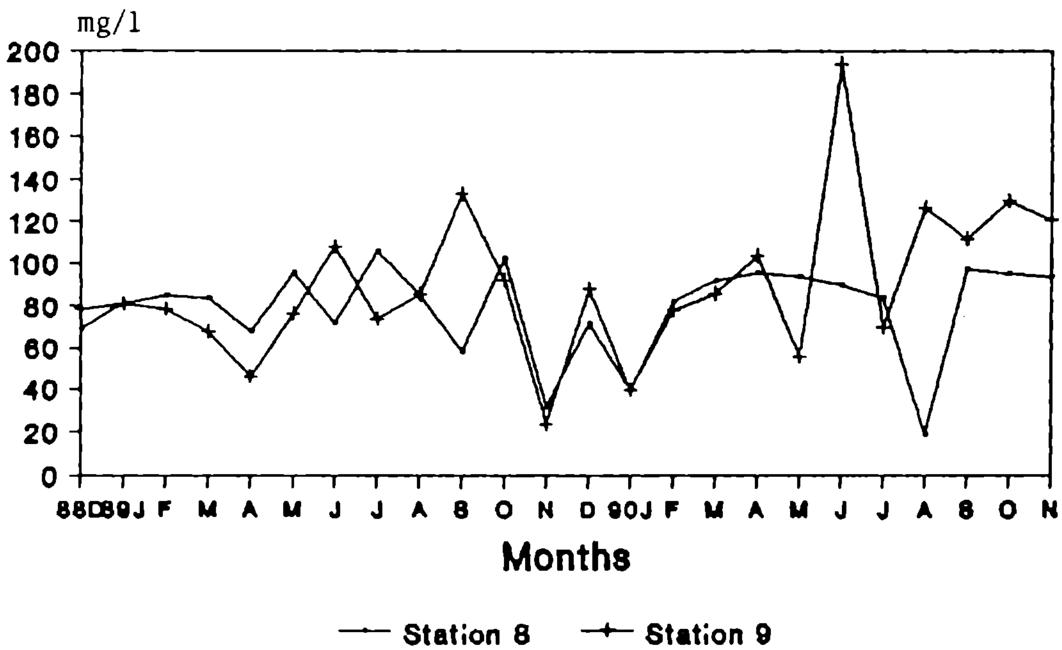

Fig. 21

In the coconut grove canals, alkalinity values showed wide fluctuations. At station 8, there was reduction in alkalinity in September 1989, whereas at station 9, the value showed an increase (Fig. 21). In 1990, there was a gradual decrease during June-July and it dropped drastically in August at station 8. At station 9, the highest value of 194 mg/l was recorded in June 1990, which was followed by a sharp decline in July.

Seasonal variation of alkality (mg/l) in coconut grove canals

Stn	Year	Premonsoon Min. - Max.	Monsoon Min. - Max.	Postmonsoon Min. - Max.
8.	1989	67.5 - 96	58 - 106	32 - 103
	1990	82.0 - 96	19 - 98	94 - 96
9.	1989	46 - 78.5	74 - 133.5	24 - 92
	1990	56 - 104	70 - 194.0	121 - 130

Banerjea (1967) classified culture systems on the basis of alkalinity profile and according to him pond having alkalinity 50 ppm is most productive, whereas 10 ppm rarely supports large crops and intermediate may produce useful results. In the present study, alkalinity values were generally high during monsoon, which is in agreement with the observations of Joshy (1990) and Sheeba (1992) in the culture systems. The highest value of alkalinity (194 ppm) was recorded at station 9, which is a coconut grove canal. Sheeba (1992) also recorded high alkalinity values in coconut grove canals. The fluctuations in alkalinity values were wide and it is in agreement with the observations of Sankaranarayanan and Qasim (1969), Qasim and Gopinathan (1969) and Silas and Pillai (1975).

3.6 NITRITE-NITROGEN

In all the perennial ponds, nitrite concentration was high during the monsoon period. The nitrite content ranged from 0.001 µg at/l at station 2 to 2.56 µg at/l at station 4 (Figs. 22 & 23). The lowest concentration was recorded in the premonsoon in 1989.

Seasonal variation of nitrite (µg at/l) in perennial ponds

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
1	1989	0.09	0.85	0.97	1.96	0.11	0.86
	1990	0.09	0.75	0.75	1.50	0.75	0.84
2	1989	0.001	0.13	0.97	1.35	0.09	0.18
	1990	0.01	0.71	0.05	1.67	0.05	0.05
3	1989	0.009	0.60	0.70	1.65	0.08	0.34
	1990	0.33	0.68	0.12	1.84	0.17	0.33
4	1989	0.008	0.85	1.58	2.50	0.39	1.51
	1990	0.17	0.83	0.90	2.56	0.01	0.84

Among the seasonal fields, station 6 had very low nitrite concentration in 1989, whereas station 5 and 7 showed higher nitrite concentration during the monsoon period (Fig. 24). The range in nitrite concentration was 0.01 to 2.13 µg at/l station 5, 0.01 to 1.81 µg at/l at station 6 and 0.05 to 2.25 µg at/l at station 7.

Figs. 22 & 23. Monthly variations in nitrite in the perennial ponds.

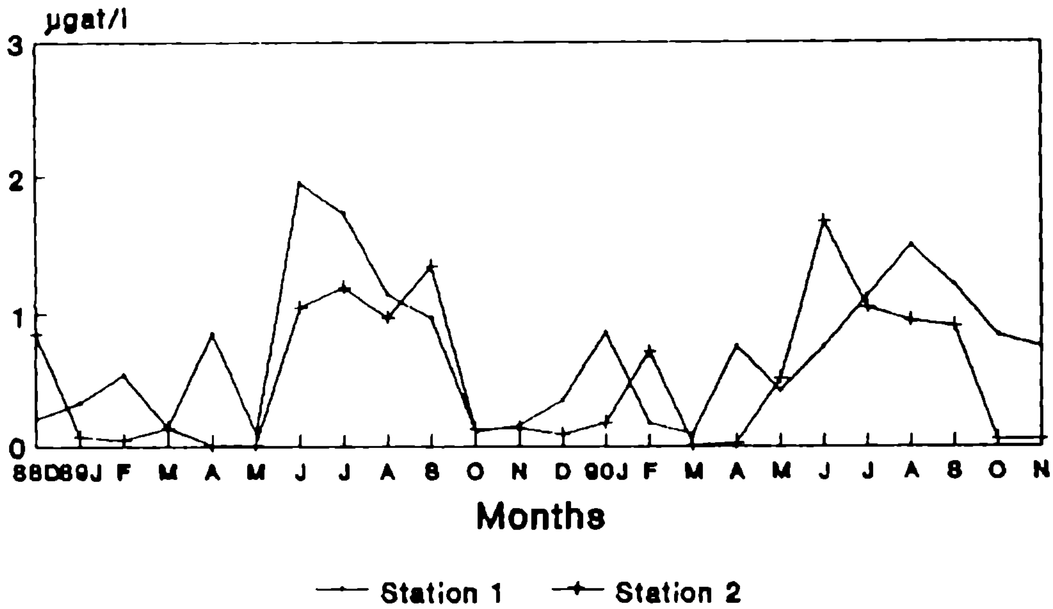

Fig. 22

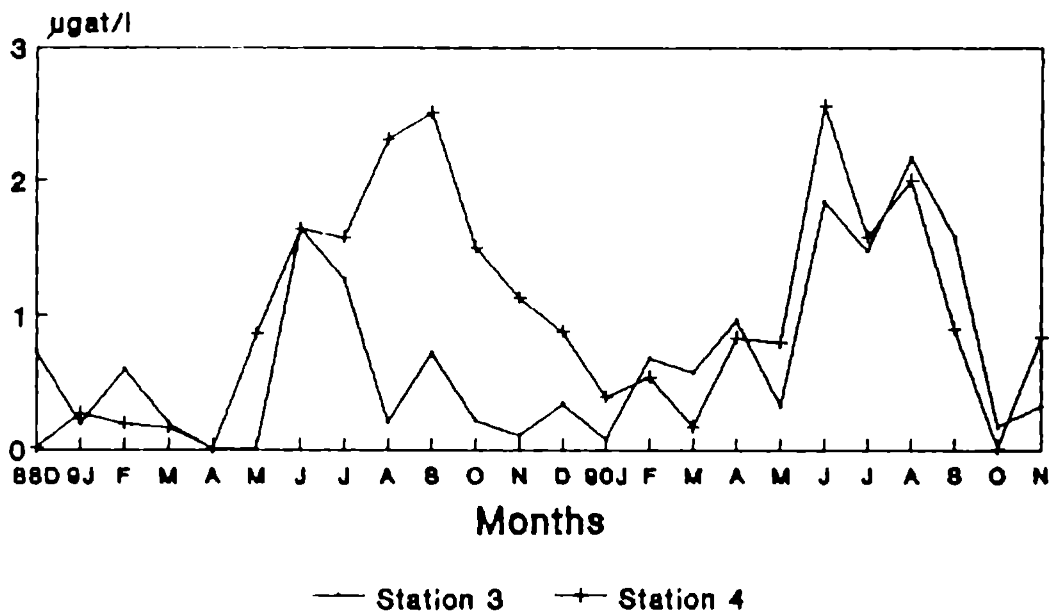

Fig. 23

Seasonal variation of nitrite (µg at/l) in seasonal fields

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
5	1989	0.03	0.41	0.80	1.36	0.01	1.37
	1990	0.09	0.71	0.01	2.13	0.21	0.99
6	1989	0.01	0.18	0.02	0.06	0.01	0.33
	1990	0.01	0.83	0.69	1.81	0.01	0.45
7	1989	0.05	0.82	0.36	1.78	0.07	0.16
	1990	0.32	1.01	1.01	2.25	0.25	0.51

The range in nitrite concentration in the canals was 0.003 to 1.67 µg at/l at station 8 and 0.008 to 2.05 µg at/l at station 9. The lowest concentrations were recorded in the premonsoon period (Fig. 25).

Seasonal variation of nitrite (µg at/l) in canals

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
8	1989	0.003	0.19	1.09	1.34	0.01	0.83
	1990	0.25	0.75	0.85	1.67	0.39	0.89
9	1989	0.008	0.54	0.07	1.15	0.50	1.34
	1990	0.09	0.33	0.82	2.05	0.17	0.42

Nitrite is formed as a result of decomposition of organic nitrogen and it is only a transitory stage in the nitrogen cycle (Sankaranarayanan and Qasim, 1969). Chandran and Ramamoorthy (1984) have shown that oxidation of ammonia and reduction of nitrate are the chief sources of nitrite in Vellar estuary. This nutrient did not show a distinct pattern of seasonal fluctuation (Sheeba, 1992) but slightly high concentration was observed during monsoon in the present study.

Figs. 24 & 25. Monthly variations in nitrite in the seasonal fields and canals.

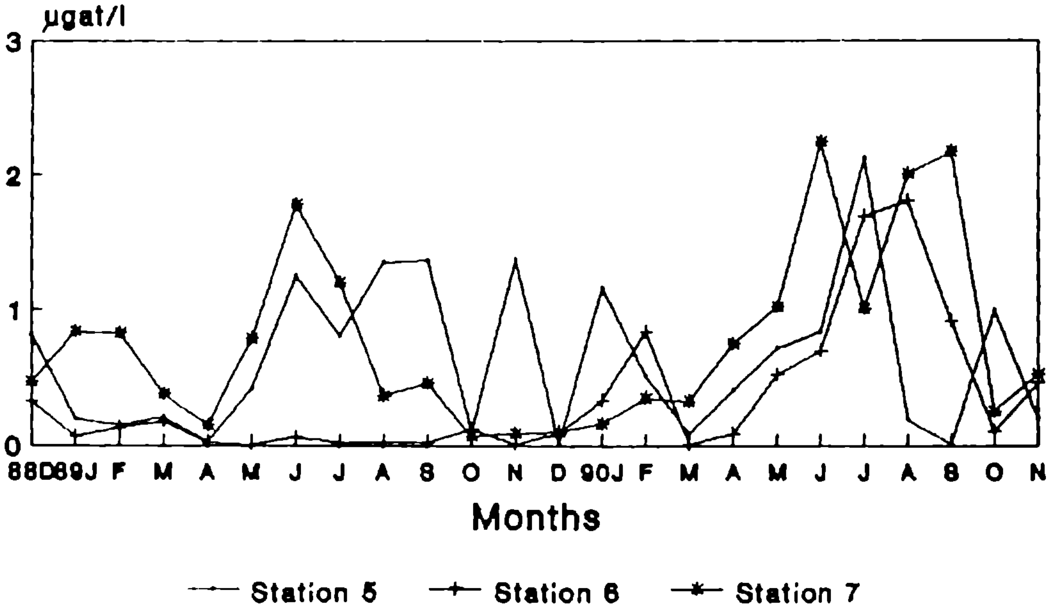

Fig. 24

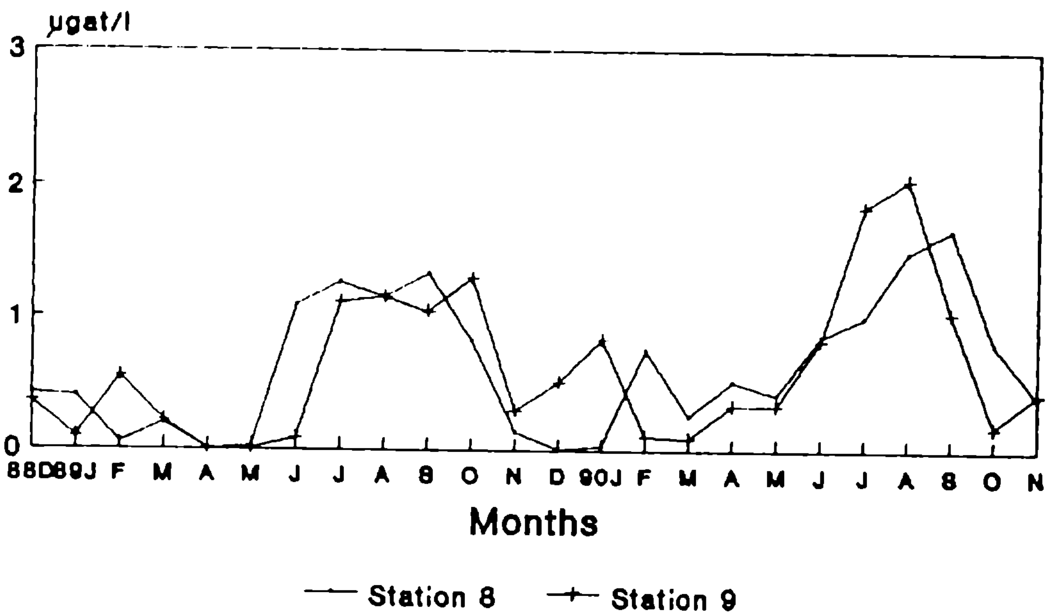

Fig. 25

High nitrite content during monsoon has been reported earlier by Nair *et al.* (1988) and Joshy (1990). At station 4, nitrite concentration was high which could be due to the discharge of domestic sewage into the pond.

Joshy (1990) suggested that substratum which is sandy harbours more nitrifying bacteria and hence oxidation of nitrite to nitrate is hastened. The difference in the nature of substratum did not show any profound influence on the nitrite concentration in the present study.

3.7 NITRATE-NITROGEN

The nitrate concentration in the perennial ponds ranged between 0.07 µg at/l at station 2 and 23.15 µgat/l at station 1. In all the stations there was an increase in nitrate concentration during the monsoon season. The lowest concentration was noticed during the premonsoon period in 1989 (Figs. 26 and 27).

Seasonal variation of nitrate (µg at/l) in perennial ponds

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
1	1989	0.65	14.07	11.86	23.15	1.1	5.4
	1990	0.70	14.30	1.18	22.35	0.9	2.0
2	1989	0.16	13.13	10.05	20.22	1.4	3.9
	1990	1.3	4.5	2.2	12.9	0.17	0.07
3	1989	0.68	4.45	12.2	18.75	1.5	10.15
	1990	2.5	9.5	13.4	20.8	1.1	3.3
4	1989	0.45	15.78	2.15	12.38	3.9	8.85
	1990	4.6	9.6	8.2	12.5	1.4	2.6

Figs. 26 & 27. Monthly variations in nitrate in the perennial ponds

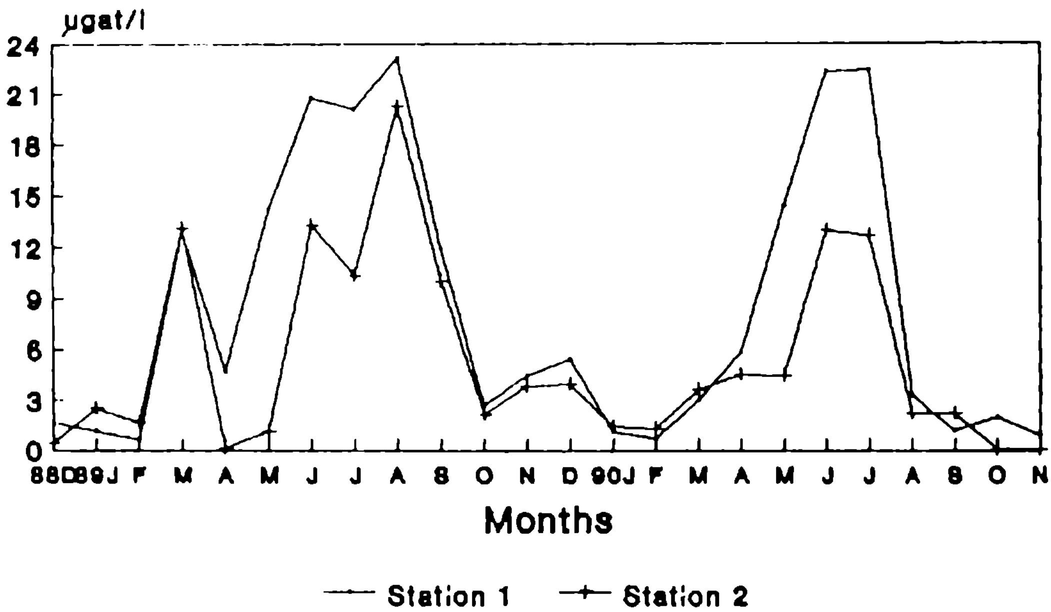

Fig. 26

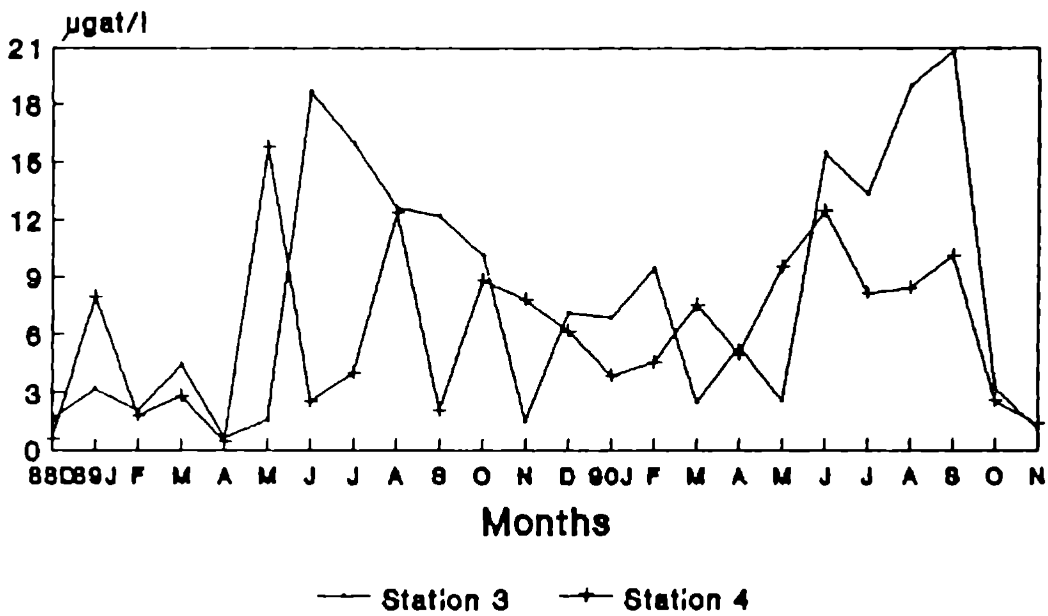

Fig. 27

In the seasonal fields, the nitrate concentration showed an increase in May and June and it declined in July (Fig. 28). The range of concentration was from 0.03 µg at/l to 19.75 µg at/l. A reduction in nitrate concentration was observed during the paddy cultivation period. Comparatively higher concentrations were recorded at station 7.

Seasonal variation of nitrate (µg at/l) in seasonal fields

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
5	1989	1.46	11.23	0.03	19.75	1.1	4.6
	1990	1.00	12.2	0.5	7.95	3.7	5.0
6	1989	0.15	11.23	0.11	3.37	1.2	3.5
	1990	1.2	6.0	2.38	13.4	1.76	1.81
7	1989	6.03	16.03	0.48	15.81	4.7	11.69
	1990	5.4	11.00	5.98	9.21	8.9	16.5

The nitrate concentration at station 8 ranged from 0.93 µg at/l to 6.15 µg at/l and at station 9 it ranged from 0.94 to 20.8 µg at/l. The nitrate concentration was low in 1989 (range 0.93 to 6.15 µg at/l) but remained relatively higher in 1990 (range 1.5 to 20.8 µg at/l) (Fig. 29)

Seasonal variation of nitrate (µg at/l) in canals

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
8	1989	0.93	2.3	2.13	6.15	1.6	3.5
	1990	2.10	5.6	2.6	15.2	2.8	3.5
9	1989	0.94	2.3	1.98	4.45	1.6	4.6
	1990	1.5	6.0	2.0	20.8	2.6	3.5

Figs. 28 & 29. Monthly variations in nitrate in the seasonal fields and canals.

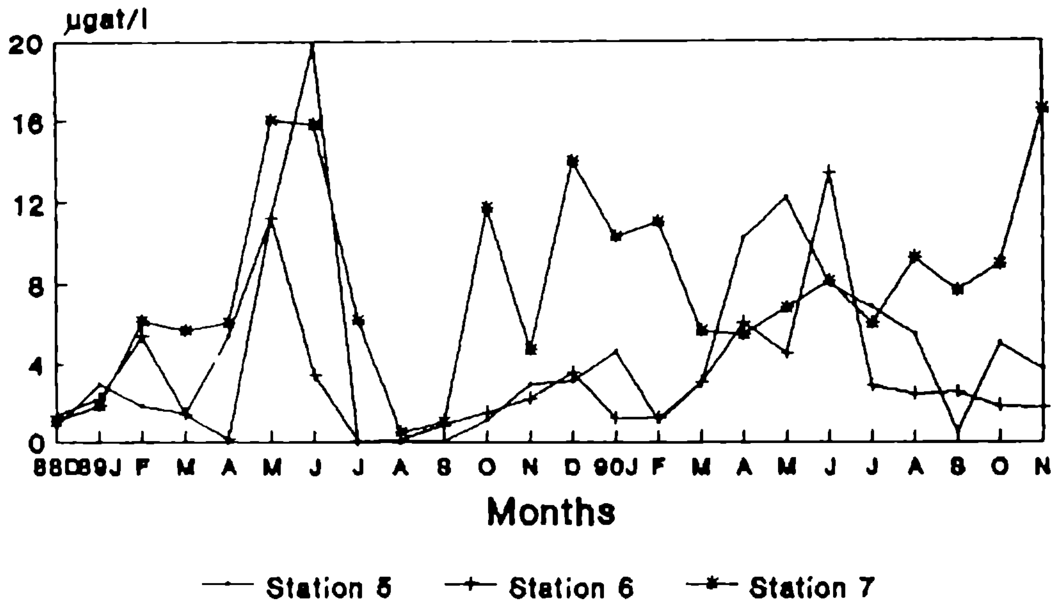

Fig. 28

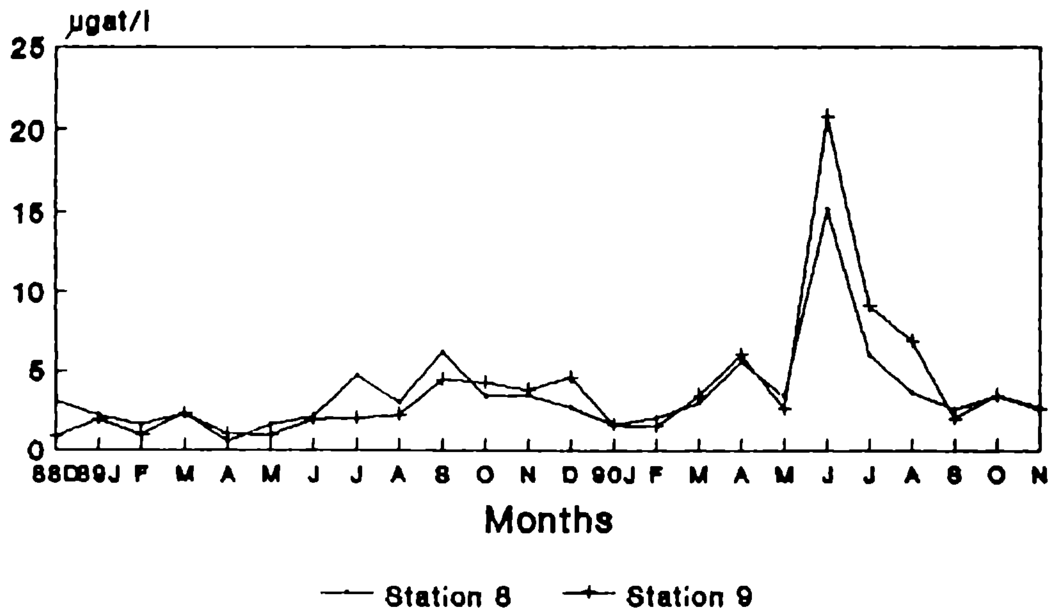

Fig. 29

Changes in nitrate concentration are the net effect of nitrification, nitrate reduction and assimilation. The nitrate concentration reached its peak during the monsoon season. The low values during the October to April period, when predominantly marine conditions prevailed shows that the contribution of nitrate from the sea is very little. It can be seen that the values are not uniformly high throughout the monsoon season. Sankaranarayanan and Panampunnayil (1979) have reported that the high values of nitrate-nitrogen are associated with the early period of monsoon when the freshwater influx is the maximum. Saha (1982) suggested that the land drainage during rainy season were the main causative factor for the steep rises of nitrate-nitrogen in pond waters. High nitrate concentration during monsoon has been reported by Sreedharan and Salih (1974), Nagarajaiah and Gupta (1983), Singh (1987), Sugunan (1983) and Reddy (1986). Joshy (1991) have observed nitrate-nitrogen to vary from 15.83 to 94.54 µgat/1 in prawn culture fields near Cochin. The decline in the concentration during postmonsoon could be attributed to biological utilization (Verlencar, 1987 and Upadhyay, 1988).

3.8 AMMONIA-NITROGEN

The concentration of ammonia in the perennial ponds fluctuated widely between 0.09 at station 1 and 89.25 µg at/1 at station 4. (Fig. 30)

Seasonal variation of ammonia (µg at/l) in perennial ponds

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
1	1989	3.56	21.80	0.09	32.34	2.65	27.13
	1990	7.14	25.70	5.40	54.98	21.42	25.70
2	1989	3.01	21.88	8.75	13.50	3.21	23.56
	1990	6.07	30.70	0.09	39.27	7.14	12.03
3	1989	3.57	51.76	16.79	34.27	28.21	49.58
	1990	6.07	39.27	8.35	39.25	8.57	9.57
4	1989	5.22	10.90	6.61	17.67	7.85	24.29
	1990	12.14	72.11	19.28	89.25	12.85	44.27

Among the seasonal fields, station 6 had a higher range of ammonia concentration and the lowest range was recorded at station 5. The highest value 89.16 µg at/l was recorded during the southwest monsoon at station 6. (Fig. 31)

Seasonal variation of ammonia (µg at/l) in seasonal fields

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
5	1989	2.30	12.05	1.41	10.44	7.80	19.90
	1990	6.44	12.50	4.21	15.21	1.95	2.05
6	1989	1.83	23.34	12.00	26.01	4.05	13.57
	1990	7.49	29.70	25.07	89.16	36.70	72.90
7	1989	9.46	61.60	8.56	12.14	10.00	60.50
	1990	21.10	70.25	19.81	52.10	20.00	64.30

In the canals the lowest ammonia concentration was recorded in the premonsoon months in 1989. During monsoon and postmonsoon of 1990, relatively high values were recorded at both the canals (Fig. 32).

Fig. 30. Monthly variations in ammonia in the perennial ponds.

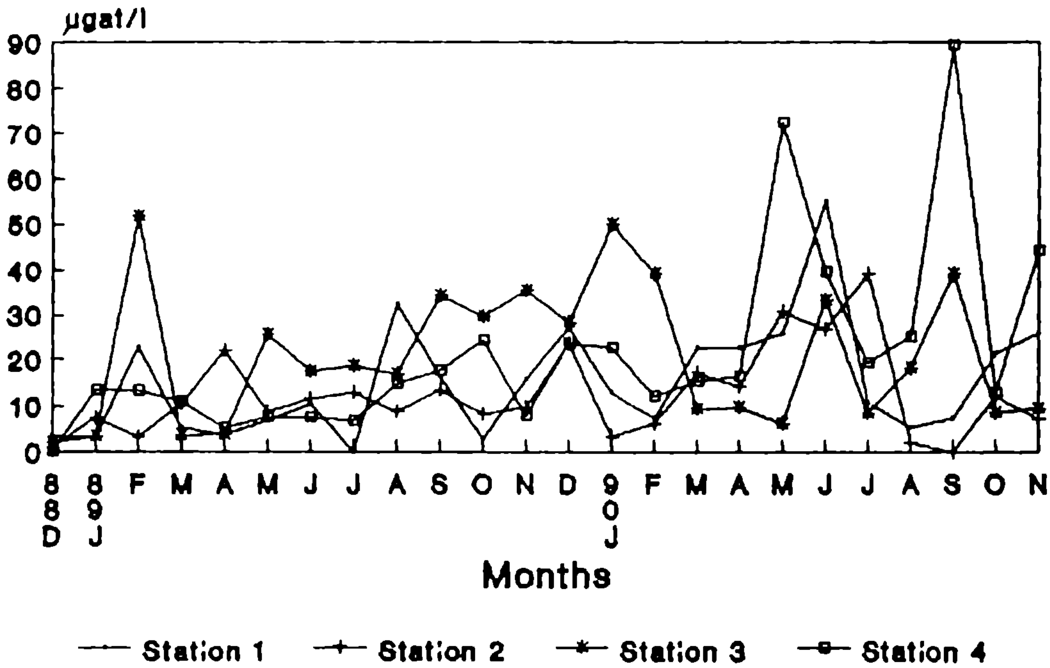

Fig. 30

Figs. 31 & 32. Monthly variations in ammonia in the seasonal fields and canals.

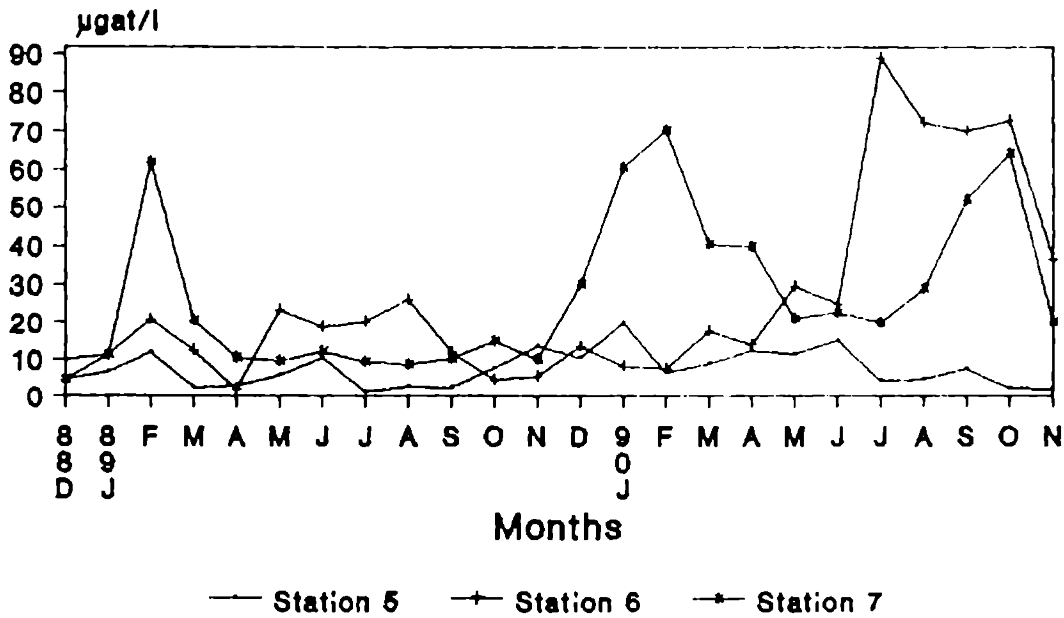

Fig. 31

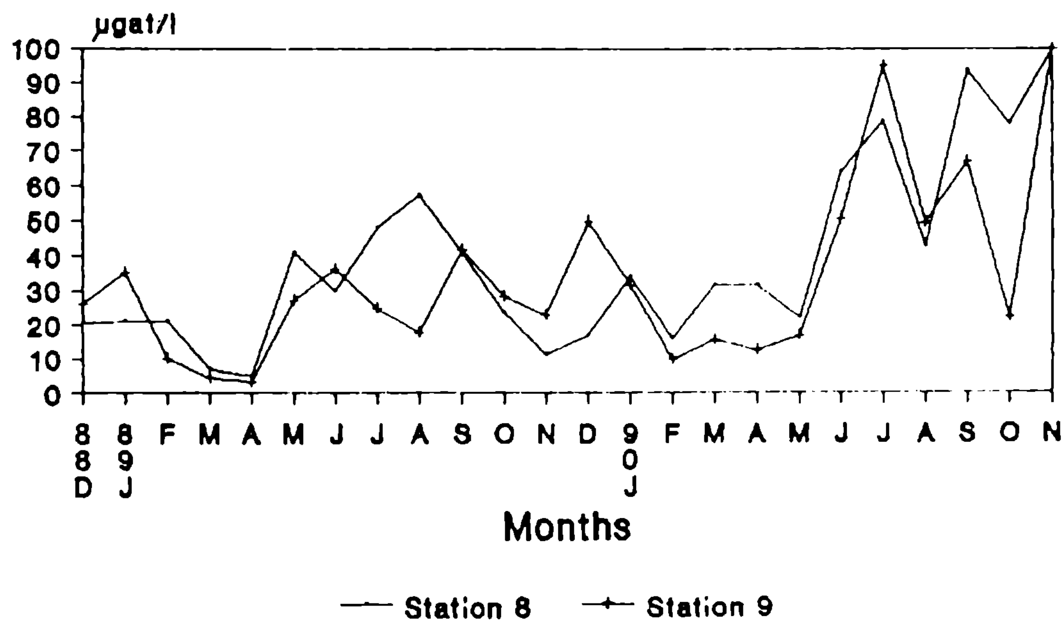

Fig. 32

Seasonal variation of ammonia (μg at/l) in canals

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
8	1989	5.18	41.06	29.90	57.50	11.42	34.27
	1990	16.06	31.77	42.86	93.53	77.82	99.96
9	1989	3.4	27.27	17.87	41.75	22.85	49.98
	1990	9.99	17.14	49.64	94.96	22.00	99.96

The concentration of ammonia-nitrogen was slightly higher during monsoon period. High values of ammonia were recorded by Venugopalan and Rajendran (1975) and they suggested that the major factor responsible for the addition of ammonia is non-biogenic and is due to rainfall and terrestrial run-off. Subhash Chander (1986) and Reddy (1986) also recorded high ammonia content during monsoon in prawn culture systems. Devapiriyan (1989) ascribed the high ammonia content during premonsoon to the accumulation of domestic wastes and metabolites. Very high concentration of ammonia was recorded in the canals and this is in agreement with the observation of Sheeba (1992). These canals were poor in oxygen content, and ammonia shows an inverse relation with dissolved oxygen content in the canals. Mollah et al. (1979) suggested that high concentration of ammonia could be due to oxygen deficiency in the pond to convert ammonia to nitrate. Sarma and Aswanikumar (1991) opined that high concentration of ammonia could be an indication of enhanced rates of nitrogen cycle taking place both in the water column and the soil. In the present study concentration of ammonia did not show any distinct pattern of seasonal fluctuation. Similar observations have been reported in the prawn culture systems by Joshy (1990) and Sheeba (1992).

3.9 PHOSPHATE

Among the perennial ponds the highest phosphate concentration of 15.6 µg at/l was recorded at station 4 in May 1990. (Fig. 33). The lowest concentration of 0.001 µg at/l was recorded at station 2 in the postmonsoon period in 1989.

Seasonal variation of phosphate (µg at/l) in perennial ponds

Stn	Year	Premonsoon Min.	Premonsoon Max.	Monsoon Min.	Monsoon Max.	Postmonsoon Min.	Postmonsoon Max.
1	1989	0.26	1.96	3.14	6.18	1.45	5.50
	1990	1.00	4.10	2.70	4.38	2.90	7.28
2	1989	1.85	4.73	3.55	6.53	0.001	2.38
	1990	0.35	6.30	3.50	8.90	0.45	0.46
3	1989	4.01	7.63	1.00	5.75	1.50	7.50
	1990	1.65	7.40	6.45	9.50	2.01	4.7
4	1989	2.59	5.08	2.65	7.16	0.105	2.30
	1990	1.0	15.60	7.40	15.10	0.50	1.01

The phosphate concentration was generally high during the premonsoon period in the seasonal fields. The highest value of 11.80 µg at/l was recorded at station 7 in March 1989. The range was from 0.01 to 11.80 µg at/l in the seasonal fields. (Fig. 34)

Fig. 33. Monthly variations in phosphate in the perennial ponds.

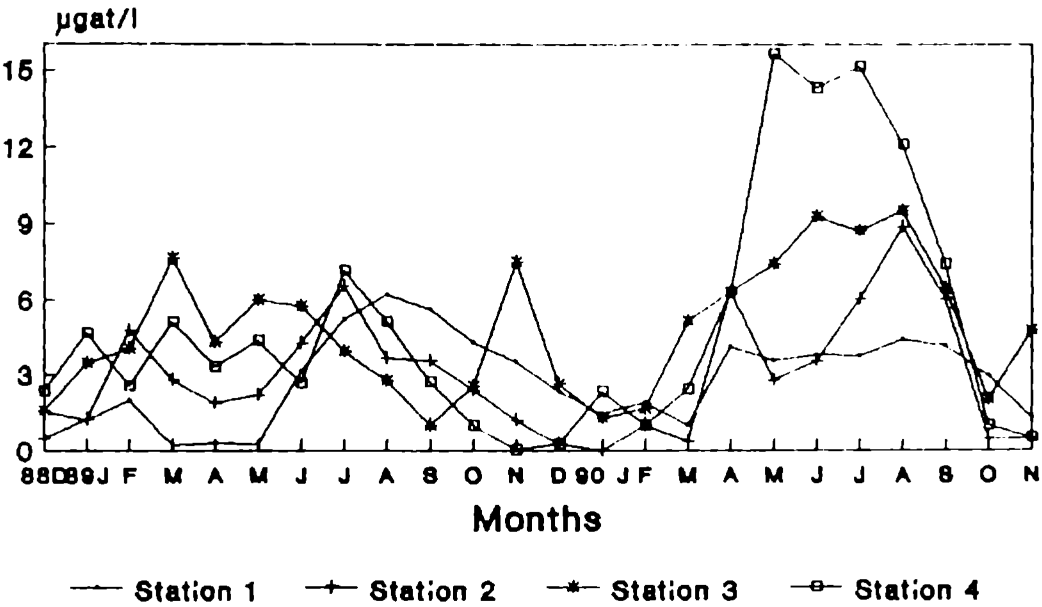

Fig. 33

Figs. 34 & 35. Monthly variations in phosphate in the seasonal fields and canals.

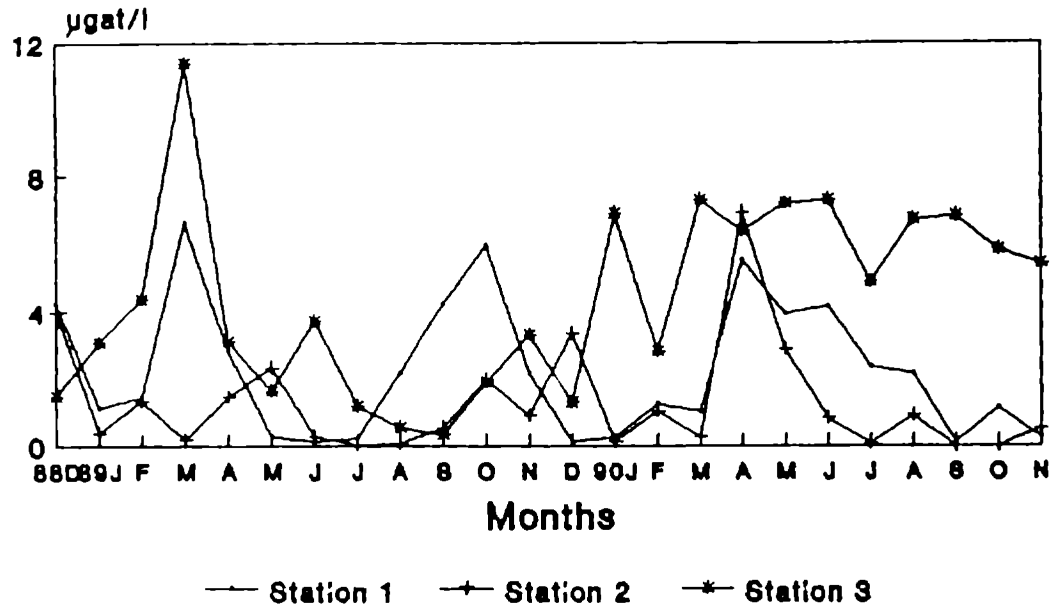

Fig. 34

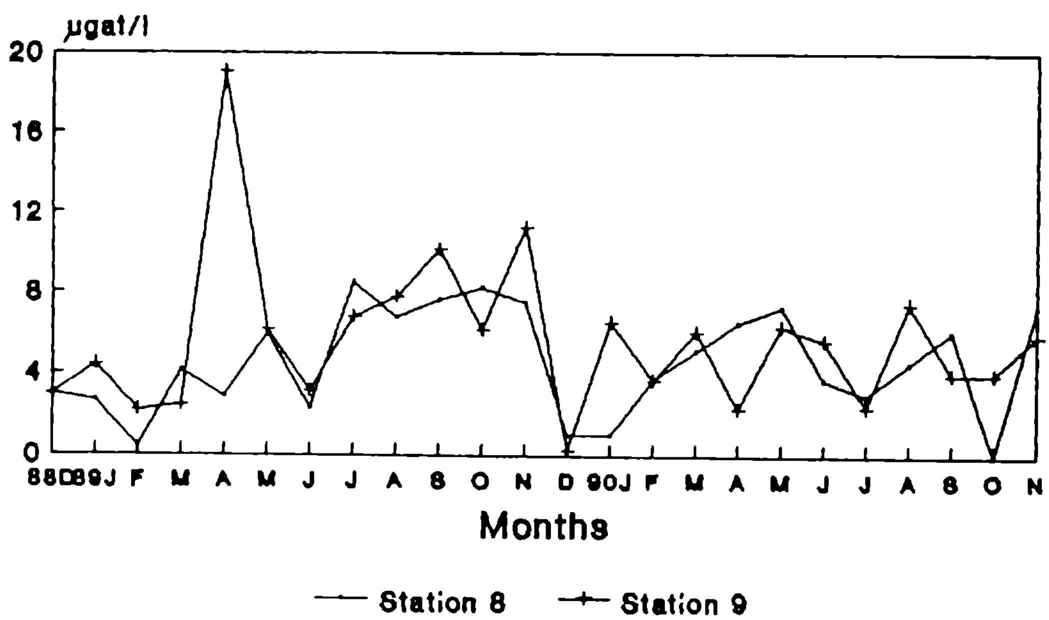

Fig. 35

Seasonal variation of phosphate (μg at/l) in seasonal fields

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
5	1989	0.27	6.65	0.12	4.20	0.13	5.90
	1990	1.00	5.50	0.10	4.12	0.25	1.10
6	1989	0.18	2.70	0.04	0.54	0.11	1.94
	1990	1.00	6.90	0.01	0.87	0.01	0.50
7	1989	1.60	11.8	0.03	3.70	1.25	6.88
	1990	2.75	7.25	4.85	7.25	5.4	5.80

In the canals, the highest value of 19.03 μg at/l was recorded in April 1989 at station 9. At station 8, the highest value 8.48 μg at/l, was recorded in July 1989 (Fig. 35).

Seasonal variation of phosphate (μg at/l) in canals

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
8	1989	0.40	5.95	2.30	8.48	1.0	8.20
	1990	3.73	7.25	2.97	6.05	0.01	7.25
9	1989	2.20	19.03	3.13	10.1	6.14	11.25
	1990	2.30	6.05	2.40	7.46	4.01	5.90

Sankaranarayanan and Qasim (1969), working on the hydrography of Cochin backwaters have shown that phosphorus contribution of the estuary is largely dependent upon external sources such as land drainage and freshwater runoff. In the present study no clear seasonal pattern was noticed in the case of concentration of phosphate. It showed wide fluctuations and higher values were generally recorded during premonsoon period. Verlencar (1987) also observed high phosphate content in the estuarine complex in Goa during premonsoon. Saraladevi *et al*. (1983) in the Cochin backwaters and Gopinathan *et al*. (1982), Subhash Chander (1986), Devapriyan (1989) and Sheeba (1992) in the prawn culture fields, have reported high phosphate content during premonsoon. Upadhyay (1988) suggested that low concentration of phosphate is due to excessive land drainage. Release from the sediment also would have contributed to higher phosphate concentration. In estuaries, the release of phosphorus to the overlying waters from silt occurs at low oxygen concentration (Rochford, 1951) and at increased pH (Carritt and Goodgal, 1954). These observations explain the high phosphate content during premonsoon period.

3.10 SILICATE

In the perennial ponds, silicate concentration fluctuated widely, from 3 µg at/l at station 4 to 129 µg at/l at station 3. (Figs. 36 & 37). At station 4 the silicate concentration was relatively low during the period of study.

Seasonal variation of silicate (µg at/l) in perennial ponds

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
1	1989	27	77	30	85	15	104
	1990	50	98	18	83	19	65
2	1989	29	59	48	82	22	58
	1990	18	37	30	62	4	16
3	1989	24	129	37	109	11	61
	1990	21	86	6	63	19	20
4	1989	3	31	41	86	12	64
	1990	15	33	25	55	18	26

Fig. 36 & 37. Monthly variations in silicate in the perennial ponds

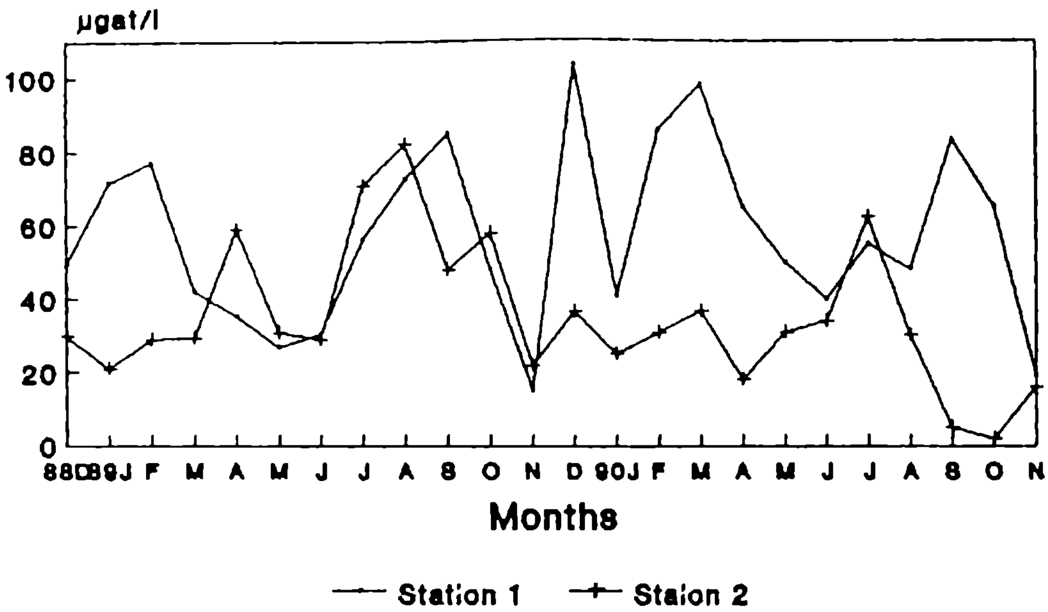

Fig. 36

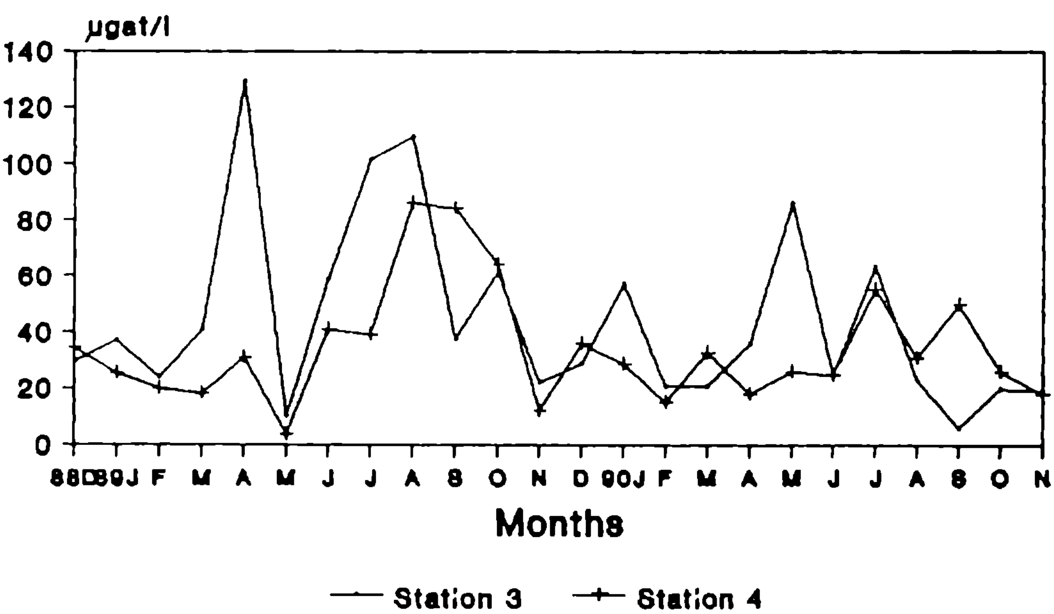

Fig. 37

The seasonal fields had low silicate concentration compared to the perennial ponds. The range in values was from 7 µg at/l to 90 µg at/l, both the values being recorded at station 5. (Fig. 38)

Seasonal variation of silicate (µg at/l) in seasonal fields

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
5	1989	17	90	31	83	10	71
	1990	23	24	7	39	12	19
6	1989	30	63	34	71	11	19
	1990	26	33	26	67	10	23
7	1989	30	71	28	52	35	68
	1990	29	58	41	68	32	41

In the canals, the silicate concentration varied from 10 to 115 µg at/l at station 8 and from 8 to 99 µg at/l at station 9. (Fig. 39)

Seasonal variation of silicate (µg at/l) in canals

Stn	Year	Premonsoon		Monsoon		Postmonsoon	
		Min.	Max.	Min.	Max.	Min.	Max.
8	1989	31	100	40	115	26	71
	1990	14	40	10	65	20	30
9	1989	45	99	36	78	17	82
	1990	24	96	8	67	19	64

According to Sankaranarayanan and Qasim (1969) high silicate values were associated with low salinity of water and vice versa, indicating an inverse relation between the two. In a few stations silicate values were slightly higher during monsoon period, indicating that the silicate cycle is associated with the freshwater influx. A noticeable influence

Figs. 38 & 39. Monthly variations in silicate in the seasonal fields and canals.

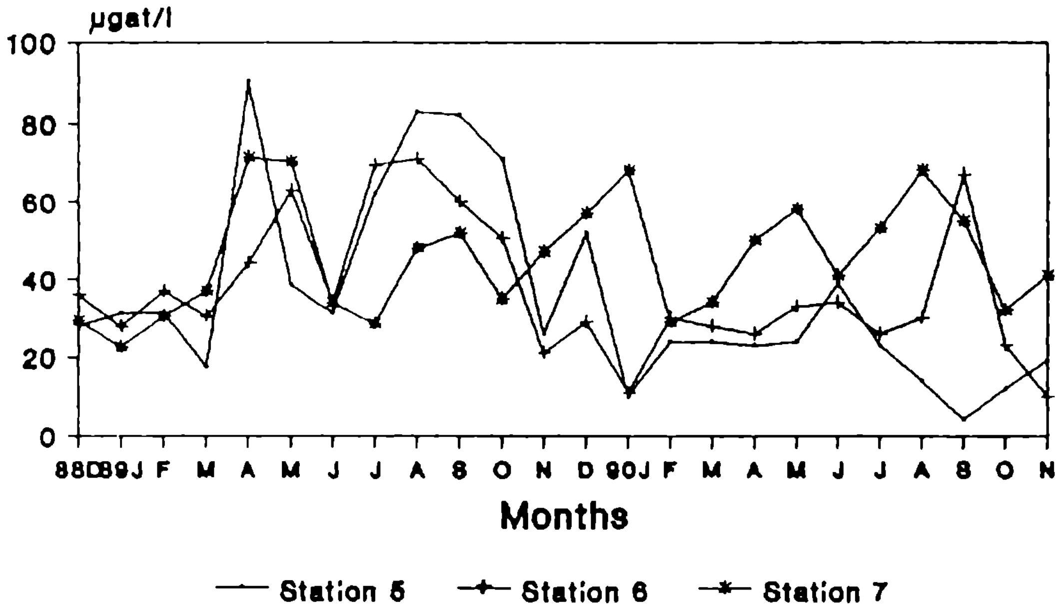

Fig. 38

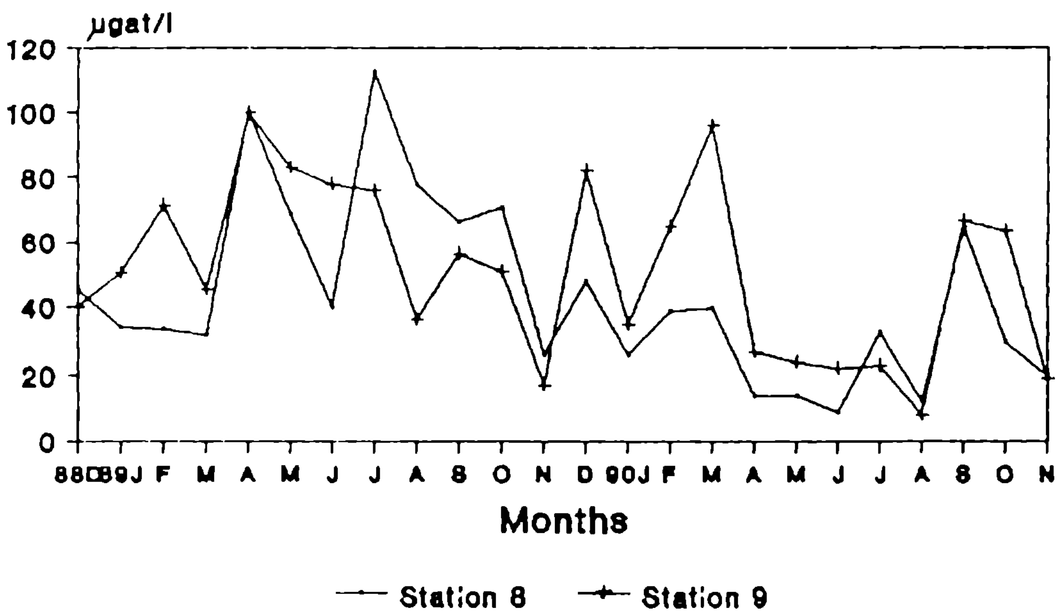

Fig. 39

of freshwater has been observed with regard to silicate concentration in the uppermost layer of seawater by Banerjee et al. (1973).

Silicate values were generally high in the culture systems studied. In the culture systems near Cochin, high silicate concentration has been recorded by Reddy (1986), Joshy (1990) and Sheeba (1992). De Sousa (1983) recorded low silicate content during monsoon and suggested that biological utilization and a biological removal by adsorption into the suspended sediments are the probable mechanisms of removal. Upadhyay (1988) opined that dilution effect due to large river run off may have considerable influence on the lowering of silicate during monsoon. Wide fluctuations, with low values of silicate during monsoon period has been observed, in the present study also.

CHAPTER IV

SEDIMENT

The sediment forms an important source of both organic and macronutrients in the pond, and is an important abiotic factor deciding the quantitative and qualitative distribution of benthic fauna. Many authors have recognized the importance of the sediment in the life of bottom fauna (Thorson, 1957 & 1958; Sanders, 1958; Bloom et al., 1972; Damodaran, 1973; Pillai, 1978; Saha, 1982 and Batcha, 1984).

The type of sediment in an area is determined by the complex interaction of many environmental factors (Swedrup et al., 1942). The grain size distribution of Cochin backwaters was investigated by Josanto (1971). Murty and Veerayya (1972 a and b) have studied the distribution of sediments in Vembanad Lake. But sedimentological studies in the culture systems are scanty. Nasser (1986) and Singh (1987) conducted short-term studies on the sediment of various prawn culture ponds near Cochin. The silt-clay fractions, organic carbon, and organic matter were studied in the present investigation.

4.1 TEXTURE OF THE SEDIMENT

The sediments were analysed for the sand, silt and clay fractions, once in each season during the study. It was observed that the composition of sediment did not show much seasonal fluctuations like the other parameters studied. Except at station 5, all the other stations had a predominantly sandy substratum with small amounts of silt and clay. Station 5 had a very high percentage of clay. Based on the nature of the substratum the 9 stations can be categorised into 2 types viz., silty-sand type and silty-clay type. From the observation it is clear that all the stations except station 5 belong to the former type and station 5 to the latter.

Nees (1946) pointed out that the pond soil should not be too sandy to allow too much leaching of nutrients, nor should be too clayey to keep all the nutrients adsorbed in it.

There was noticeable difference in texture of the sediment at different stations. The perennial systems were primarily silty-sand type, (Figs. 40 to 43) the clay fraction varying from 1.70 to 10.85% at station 1, 5% to 17.5% at station 2, 15.29% to 21.96% at station 3 and 1.5% to 9.86% at station 4. (Fig.43).

Texture of sediment in the perennial ponds

		1989			1990		
Station	%	PRM	MON	POM	PRM	MON	POM
I	Sand	74.93	75.54	73.78	74.09	74.04	76.13
	Silt	23.37	20.46	15.37	18.75	20.10	14.87
	Clay	1.70	4.00	10.85	7.16	5.86	9.00
II	Sand	68.25	66.38	64.59	65.34	65.32	60.90
	Silt	21.00	28.62	17.91	17.61	19.08	21.50
	Clay	10.75	5.00	17.50	17.50	15.40	17.50
III	Sand	55.83	55.96	53.28	54.66	53.65	53.69
	Silt	32.95	28.75	25.02	25.10	28.85	24.35
	Clay	11.17	15.29	21.70	20.24	17.50	21.96
IV	Sand	77.40	75.64	75.10	76.96	77.65	73.16
	Silt	21.00	13.50	19.90	20.80	16.85	21.84
	Clay	1.50	9.86	5.00	2.24	4.5	5.00

PRM: Premonsoon MON: Monsoon POM: Postmonsoon

Figs. 40, 41 & 42. Seasonal variations in the texture of the sediment.

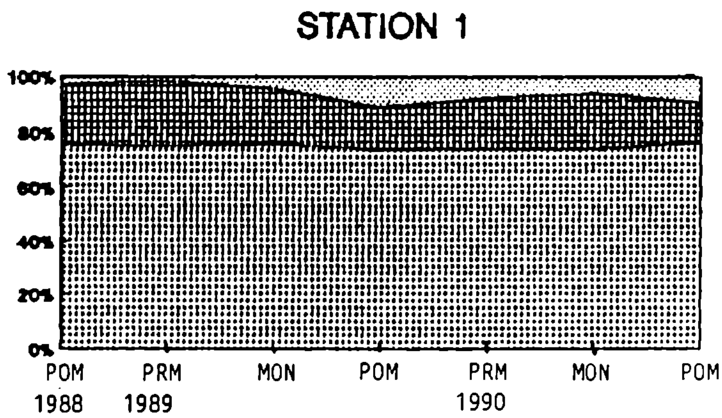

Fig. 40

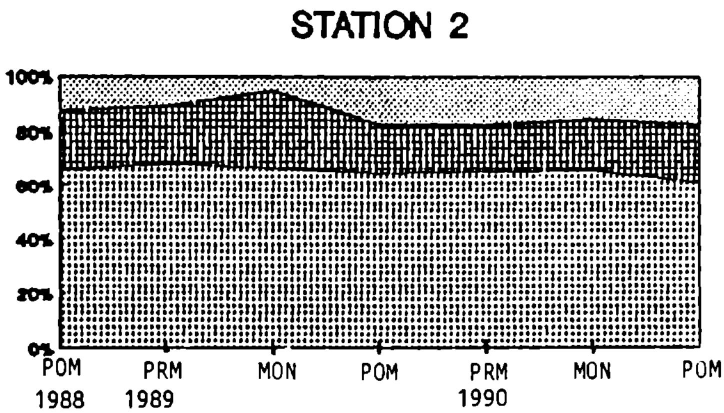

Fig. 41

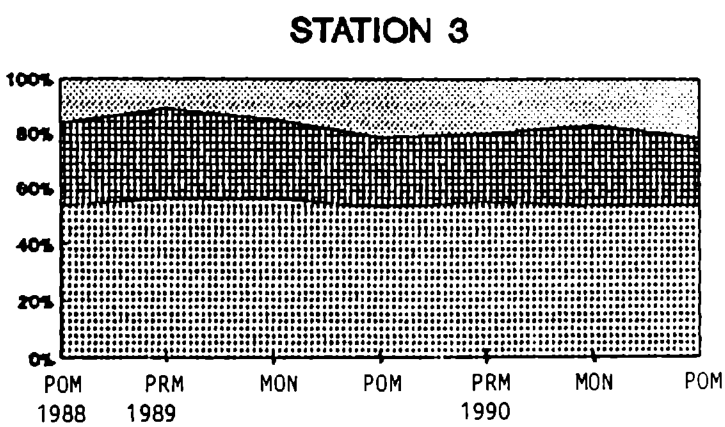

Fig. 42

Sand   Silt   Clay

PRM: Premonsoon, MON: Monsoon, POM: Postmonsoon

Among the seasonal systems at station 5 (Fig. 44) very high clay content was recorded during postmonsoon period. At station 6, (Fig. 45) clay content varied from 4.21% in monsoon to 19.96% in postmonsoon. At station 7, (Fig. 46), the sediment showed moderate presence of sand, silt and clay.

Texture of sediment in the seasonal fields

Station	%	1989 PRM	1989 MON	1989 POM	1990 PRM	1990 MON	1990 POM
V	Sand	2.68	1.07	1.59	1.3	1.27	2.05
	Silt	6.72	10.14	7.50	7.27	8.00	7.68
	Clay	89.60	88.79	90.91	91.43	91.73	90.27
VI	Sand	67.12	68.34	60.97	64.59	66.01	65.94
	Silt	23.83	27.45	19.01	17.91	20.12	20.33
	Clay	9.05	4.21	19.96	17.50	13.87	13.73
VII	Sand	56.13	57.56	52.37	58.09	57.60	60.55
	Silt	30.61	29.33	27.47	26.97	27.80	24.48
	Clay	13.26	13.11	15.16	14.94	14.60	14.97

PRM: Premonsoon MON: Monsoon POM: Postmonsoon

The primary type of sediment particles present in the canal systems was represented by sand and silt. Stations 8 and 9 had predominantly sandy substratum. The sand fraction was the highest in monsoon and lowest in postmonsoon. (Figs.47 & 48).

Figs. 43, 44 & 45. Seasonal variations in the texture of the sediment.

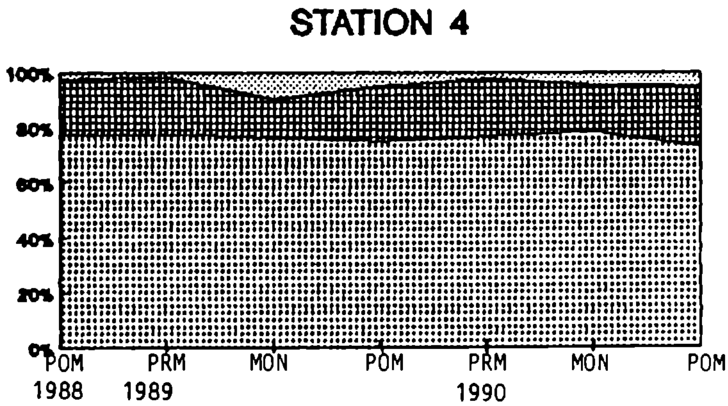

Fig. 43

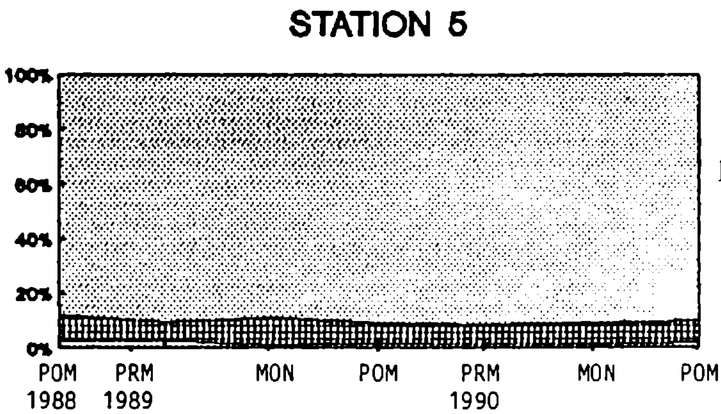

Fig. 44

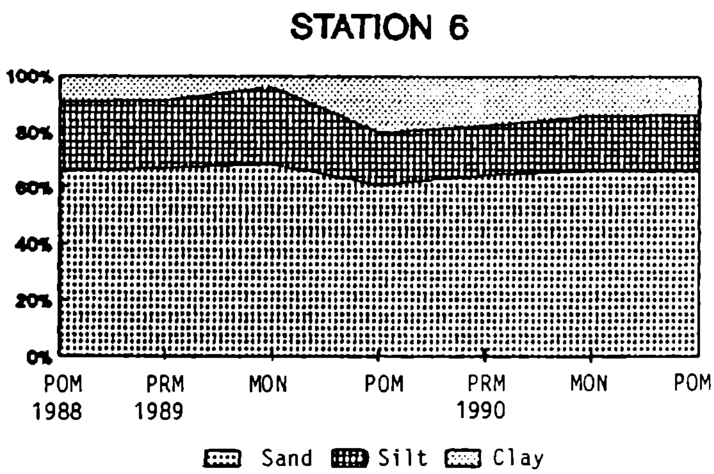

Fig. 45

PRM: Premonsoon, MON: Monsoon, POM: Postmonsoon

Figs. 46, 47 & 48. Seasonal variations in the texture of the sediment.

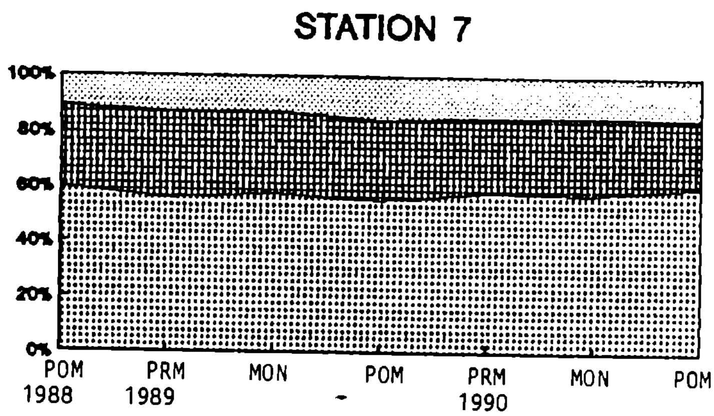

Fig. 46

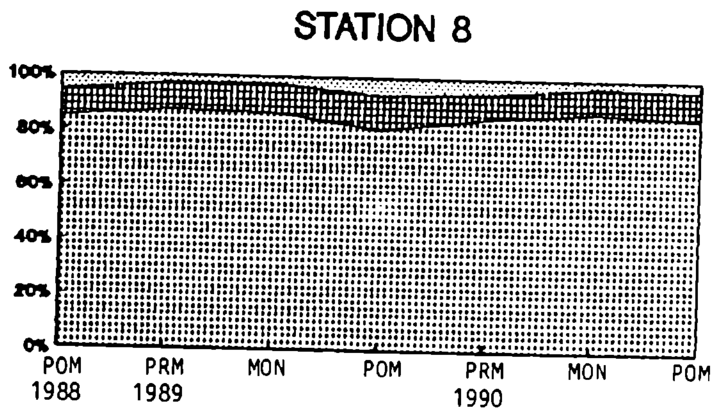

Fig. 47

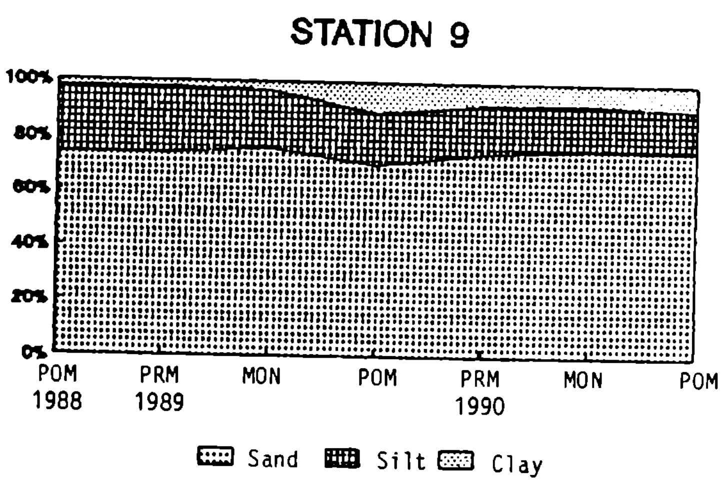

Fig. 48

PRM: Premonsoon, MON: Monsoon, POM: Postmonsoon

Texture of sediment in the canals

		1989			1990		
Station	%	PRM	MON	POM	PRM	MON	POM
VIII	Sand	87.69	67.11	81.13	85.47	87.88	80.10
	Silt	9.55	10.26	12.36	9.21	9.18	10.32
	Clay	2.76	2.63	6.51	5.32	2.94	3.58
IX	Sand	74.11	76.01	69.96	74.53	75.90	75.81
	Silt	23.54	20.64	19.18	17.77	16.48	15.42
	Clay	2.35	3.35	10.86	7.70	7.26	8.77

PRM: Premonsoon MON: Monsoon POM: Postmonsoon

The grain size distribution of Cochin backwaters has been studied by Josanto (1971), Kurian (1973), Pillai (1978), Batcha (1984) and Singh (1987). They have reported a seasonal shift in the primary sediment composition. The present study shows that the sediments of the ponds did not undergo wide seasonal fluctuations in their composition, though slight changes occurred. The soil texture of each pond which remained almost the same throughout the investigation might be an indication of homogeneity of the constituents due to the age of the pond (Mollah et al., 1979). In all the stations there was a very slight reduction in sand content during the postmonsoon season. During the monsoon season there is heavy influx of silt and clay-ladden freshwater into the estuary. During high tide period this water enters the culture ponds and the suspended silt-clay particles settle down in the pond resulting in a higher clay content in the sediment. This could be the reason for the marginal increase in clay and silt fractions by the end of monsoon and in postmonsoon seasons.

4.2 ORGANIC CARBON

Organic Carbon content of the estuarine sediment at Cochin has been studied by Pillai (1978), Sankaranarayanan and Panampunnayil (1979) Batcha (1984) and Joshy (1991). Only short term studies have been made on the sedimentological features of prawn culture fields. Srinivasan (1982), Reddy (1986) and Nasser (1986) studied the organic carbon content of the prawn culture ponds. In the present investigation the monthly variation in the organic carbon content of the prawn culture systems was studied over a period of 2 years. An attempt to assess the increase in organic carbon content in the seasonal prawn culture fields after the paddy has been harvested is also made.

In the perennial ponds the organic carbon content varied from 0.83% to 4.9%. The percentage of organic carbon was the highest at station 2 in monsoon. (Figs. 49 and 50).

The seasonal fields had higher organic carbon content compared to the other culture systems (Fig. 51) and higher values were recorded during postmonsoon. After the paddy cultivation there was an increase in the organic carbon content. A peak value was reached by November which declined in the next month. There was a second peak, though smaller, during March-April. (Fig. 51)

In the canal systems the organic carbon content ranged from 0.53% to 4.11% and high values were obtained during August-September period (Fig. 52).

Figs. 49 & 50. Monthly variations in the organic carbon content of the soil in the perennial ponds.

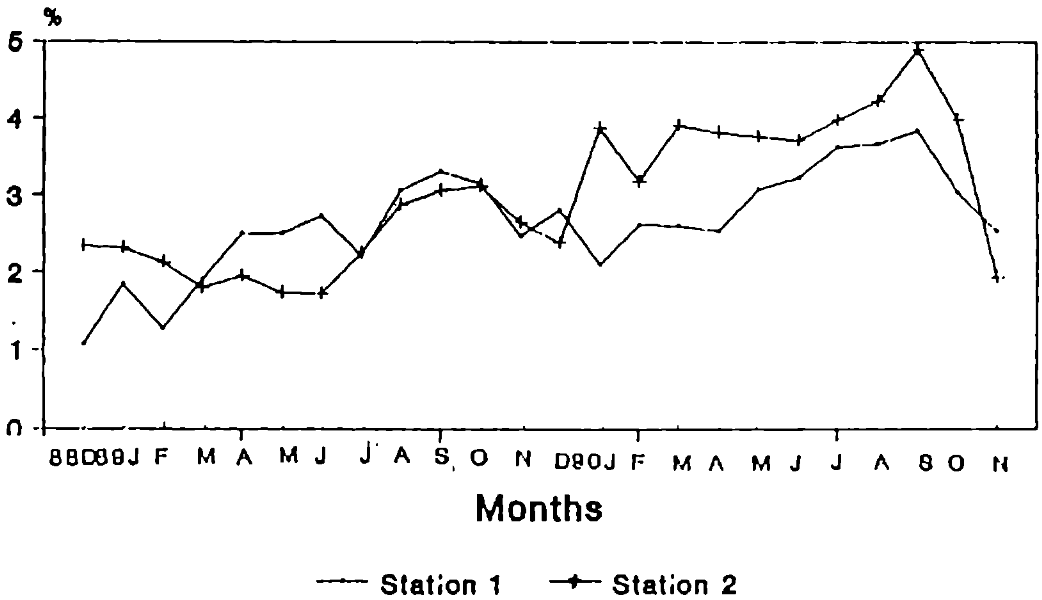

Fig. 49

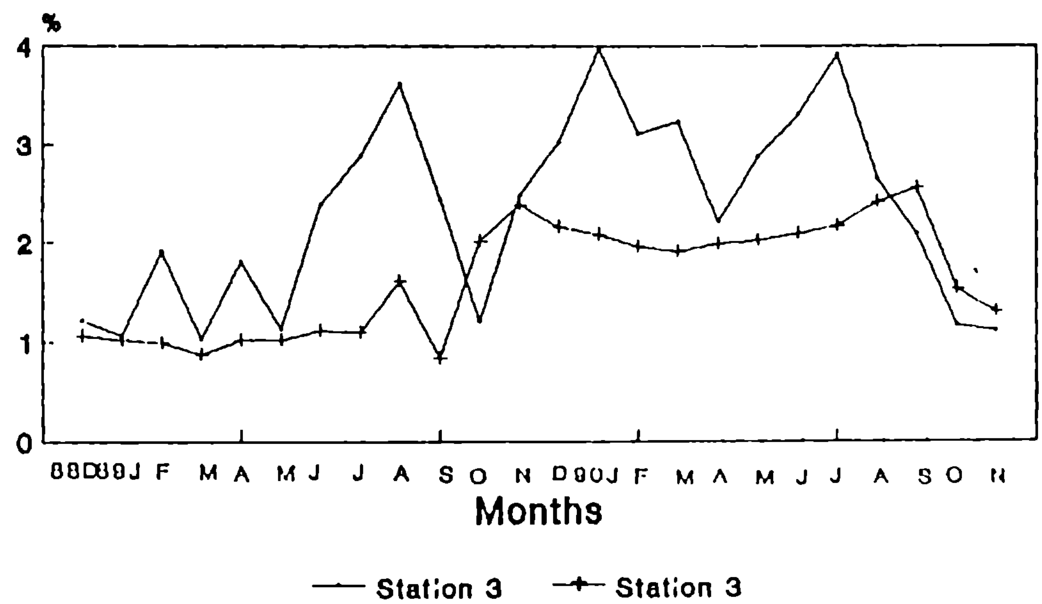

Fig. 50

Fig. 51 & 52. Monthly variations in the organic carbon content of the soil in the seasonal fields and canals.

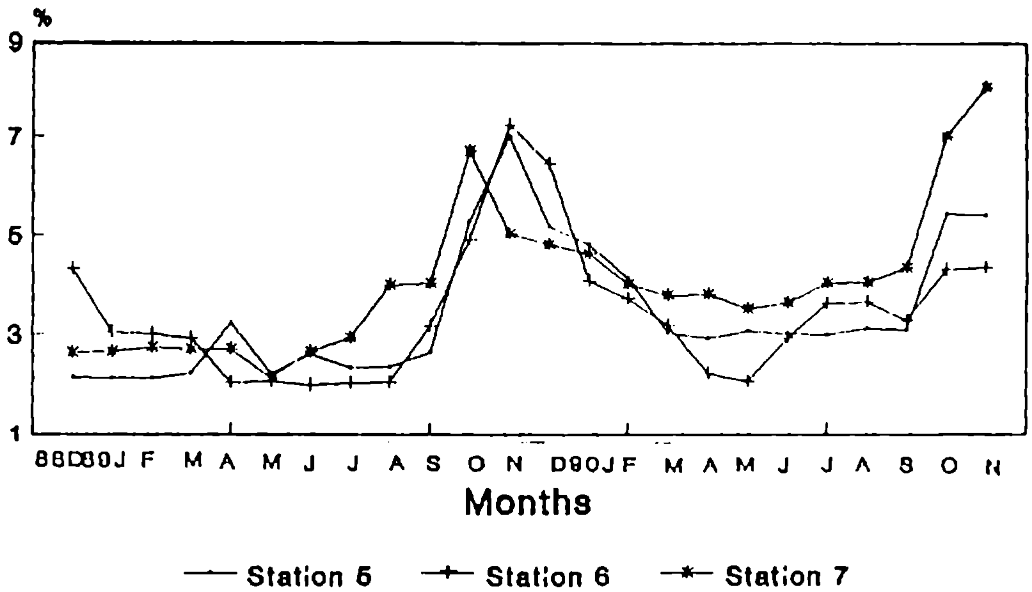

Fig. 51

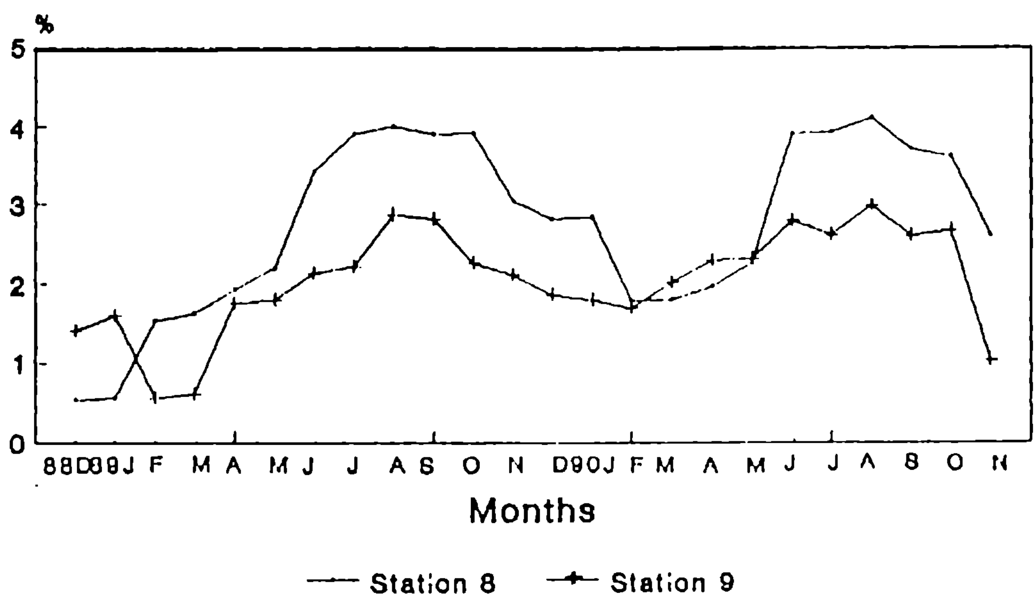

Fig. 52

Tang and Chen (1967) classified organic carbon content of algal pasture soils of milkfish ponds as low (1.5%), medium (1.6 - 3.5%) and high (> 3.6%). Classification of the culture systems into low, medium or high is not attempted here as they show wide seasonal fluctuations in organic carbon content.

From the earlier description of the clay-silt fractions, it is clear that the composition varied from station to station. Due to this variation, there is difference in the degree of concentration of organic carbon found in the sediment. Organic carbon is predominantly trapped by clay and to a lesser degree by fine silt, coarse silt and sand (Russel, 1950). According to Sanders (1956), all clay minerals except Kaolin, bind organic matter. Thus, the area with a high percentage of clay is capable of holding a high proportion of organic matter.

The maximum organic carbon can be expected in a clayey sediment and there is a direct correlation between organic carbon content and clay percentage in the sediment. Such a close relationship between organic matter and texture of sediment has been attributed to the similar settling velocities of organic matter and fine mineral particles (Pillai, 1978). The results of this study is in agreement with the findings of Bader (1954), Rao (1960), Murty and Veerayya (1972), Nasser (1986) and Singh (1987), who reported higher organic carbon content in finer sediments.

There is more fresh water influx into the estuary during monsoon and the water that enters the ponds carry more suspended organic detritus which settles there resulting in higher organic content.

Another reason can be that, owing to the sudden fall in salinity with the onset of monsoon, the stenohaline benthic population drastically declined, which is evident from the forthcoming description on the abundance of benthic fauna. The benthic organisms which were less tolerant to sudden drop in salinity, could not survive in the monsoon season, and as a result they mostly ceased to exist. The bilogical degradation that occurs thereafter, converts them to organic matter. This can also be attributed to the enrichment of organic carbon in the sediment during the monsoon and postmonsoon periods. The same reason is also applicable to the coconut grove canals. In the coconut grove canals another reason for high organic content is the high amount of plant material undergoing decomposition within the system, as these canals are bordered on either side by rows of coconut trees.

In the seasonal fields, paddy cultivation lasts from June to September and during this period there was a reduction in the organic carbon content which could be due to the intake by the crop. The harvest of paddy takes place by the end of September and the paddy stumps and hay are left to rot and decay in the field. As a result, the organic carbon content gradually increased in the sediment as more and more plant materials decomposed and the organic matter leached in the soil. This is evident from the high values of organic carbon in the seasonal fields in November at stations 5 and 6, and in October at station 7. Gopinathan et al. (1982) reported high organic carbon content in seasonal culture systems. In culture ponds in Vypeen Island, Cochin, Ramesan (1990) recorded high organic carbon content during premonsoon and correlated it with the organic deposition and minimum decomposition due to non-availability of the required amounts of oxygen.

CHAPTER V

BOTTOM FAUNA

5.1 DISTRIBUTION AND COMPOSITION OF BOTTOM FAUNA

The distribution of fauna in backwaters is based on the complexity of changing environmental parameters that limit colonization to a restricted number of organisms with a wide range of ecological adaptations. In general, the bottom fauna of a tropical backwaters comprises marine, brackish and freshwater forms. The benthos of the Cochin backwaters has been well documented in the works of Kurian et al. (1975) Pillai (1977 and 1978) and Batcha (1984). They reported a large number of benthic species from the Cochin backwaters. In the present investigation the number of species collected from the culture fields was however low compared to the figures obtained from the backwaters as reported by earlier workers. Singh (1987) in a comparative study of bottom fauna in Cochin area has reported that the number of benthic species in prawn culture systems was less compared to that in the open backwaters.

5.1.1 MACROBENTHOS

The important macrobenthic groups obtained during the present investigations were Polychaeta, Crustacea and Mollusca. Altogether 38 taxa were identified during the sampling period from December 1988 to November 1990. These taxa included one species of coelenterate, 9 species of polychaetes, 8 species of molluscs, 18 species of cruştaceans and 2 species of fishes. The number of animals present in each sample taken from nine stations is given in Tables 1 to 9.

5.1.1.1 Coelenterata

Coelenterates occurred in small numbers at station 1 among perennial ponds and stations 5 and 6 among the seasonal fields. Their abundance was the highest in the coconut grove canals. Paracondylactis sp. was the only coelenterate collected during this study. Their highest abundance $3492/m^2$ was recorded at station 9 in August 1990. At stations 2, 3, 4 and 7 they were totally absent. In all the other stations their highest number was noticed during the premonsoon period.

5.1.1.2 Polychaeta

Dendronereis aestuarina occurred in fairly large numbers in the perennial ponds (stations 1 to 4) in all the seasons. The maximum abundance of this species was observed at station 4 where the highest number, $2743/m^2$ was recorded during July 1990. At this station D. aestuarina formed 82.4% of the total polychaete fauna. In the seasonal fields, (stations 5 to 7), this species formed more than 60% of the total polychaete count. At station 6, this species was totally absent in 1990. Station 7 had higher abundance of D. aestuarina, with the highest number $1020/m^2$ being recorded in August 1990. In the canals, (stations 8 and 9) also D. aestuarina was the most abundant polychaete. This species formed 69.9% and 88.3% of the total polychaete fauna at stations 8 and 9 respectively.

Prionospio polybranchiata also showed a wide distribution over seasons but higher numbers were recorded during premonsoon. Among the perennial ponds, stations 1 and 4 had highest numbers of this species.

At station 1, this species formed 17.4% of the total polychaete count. At station 2 P. polybranchiata was totally absent in 1990. In all the seasonal fields and the canals this species was abundant during 1989, and their occurrence was restricted to a few months in 1990.

Perinereis cavifrons showed a restricted distribution. The highest number of P. cavifrons was recorded at station 1 among perennial ponds. They were absent during the monsoon period. Among the seasonal fields this species was abundant at station 7 but at stations 5 and 6 its occurrence was noticed only once during the period of study. The highest abundance of P. cavifrons was recorded at the canal, station 8, where it formed 9.5% of the polychaete fauna. At station 9 it was collected in very small numbers twice during the study.

In the perennial ponds Notophygos sp. was recorded only at station 1 and was totally absent during monsoon period. In the seasonal fields Notophygos sp. occurred only in a few months and was recorded in small numbers from stations 6 and 7. At station 6, they occurred during the monsoon period. Among the canal stations this species was recorded only at station 8.

Ancistrocyllis constricta occurred at the perennial ponds in all seasons and their highest abundance was recorded at station 1. A. constricta was recorded at stations 5 and 6 among the seasonal fields. At canals this species occurred (45/m^2) only in March 1989 and was recorded at station 8.

Lumbrioconereis simplex occurred at stations 1 and 2 among the perennial ponds and were more in number during 1989. Among the seasonal fields, this species occurred only at station 6 during the monsoon period of 1989. L. simplex was recorded in small numbers from the canals, during 1989.

Paraheteromastus tenuis was recorded at stations 3 and 4 among the perennial ponds and stations 6 and 7 among the seasonal fields. Their abundance was the highest at station 4, where they occurred in all seasons.

The highest total number ($318/m^2$) of Nereis chilkensis was observed at station 4. The perennial ponds, stations 1 and 2, also had stray occurrence of this species. Among the seasonal fields, N. chilkensis was recorded only from station 7 in small numbers N. chilkensis was recorded at station 8 among the canals only once during the period of study.

Among the perennial ponds, Nephthys oligobranchia was present only at station 4. They occurred in all seasons and formed 4.2% of the total polychaete fauna at this station. N. oligobranchia was recorded only once during the period of study at station 6 among the seasonal fields. In the canals, this species was not encountered.

5.1.1.3 Mollusca

Molluscs were represented by bivalves and gastropods. A total of eight species of molluscs were recorded which formed about 21% of the total benthic population of the culture systems. Four species each of the two groups were collected during this study.

Bivalves

Nuculana mauritiana was present in the perennial ponds (stations 3 and 4), seasonal fields (stations 5 to 7) and canals (stations 8 and 9). The black clam, Villorita cyprinoides var. cochinensis and Modiolus sp. were collected from stations 1, 8, and 9. Meretrix meretrix was recorded only from station 1. In general, bivalves were present in all the perennial ponds. Villorita cyprinoides was the most abundant bivalve and among the perennial ponds they occurred only at station 1. They occurred throughout the year with the highest number, $408/m^2$ in August 1990. V. cyprinoides was collected in small numbers from station 8 and were abundant during August. At station 9, this species was abundant during postmonsoon with the highest number $1656/m^2$, being recorded in October 1990.

N. mauritiana was the only bivalve collected from stations 2, 3 and 4. At staion 2 their highest number, $1587/m^2$ was recorded in October 1989. At station 3, they were observed only twice during the period of study but at station 4 they were present from April 1989 onwards with an abundance during monsoon. N. mauritiana was the only bivalve recorded from the seasonal fields, stations 5 and 6. At these stations their occurrence was high during monsoon season ($1429/m^2$ in August 1990 at station 5 and $363/m^2$ in June 1989 at station 6). At station 7 they occurred more during premonsoon and showed a decline with the onset of monsoon. N. mauritiana occurred in small numbers at station 8. Though the canal, station 9, had a higher abundance of bivalves, N. mauritiana was not recorded here. Modiolus occurred at both the canals during premonsoon period.

Gastropods

During the study gastropods constituted 18.56% of the total macrobenthos. Littorina sp. was the abundant form in the perennial ponds (station 1 to 4) and also in stations 6, 7, 8 and 9. Nassarius sp. occurred at station 5 only during the first year of study. Nerita sp. occurred at station 3 and Cerethidia fluviatilis at station 1. Broken shells of Telescopium sp. were found in large numbers at station 4.

At station 1 among the perennial ponds, Littorina sp. occurred throughout the year but their abundance was high during monsoon period. At station 2, this species occurred only in March and at station 3 it occurred only during the monsoon season. Gastropods were poorly represented at station 4. At station 1 Cerithidia fluviatilis were recorded in March 1989 ($91/m^2$) and February 1990 ($23/m^2$).

The seasonal fields had higher abundance of gastropods. At station 5, the only gastropod collected in the first year of study was Nassarius sp. which constituted the major portion (67%) of the total benthic fauna. Beginning with $181/m^2$ in December 1988, they showed an increasing trend and reached a peak value of 25,169 individuals/m^2 in July 1989. There was a sudden fall in their number from August onwards. In July, shells of Nassarius sp. varying in size from 0.30mm to 17mm were observed in the samples. From August onwards the number of small-sized shells (<5mm) in the samples declined. This species was totally absent during the second year and Littorina sp. started appearing in the samples from February 1990 onwards. Their number reached a peak value of $3107/m^2$ in June and from July onwards their number declined. Littorina was the only gastropod collected from stations 6 and 7. The highest occurrence ($8370/m^2$) of this species was recorded at station 6 in November 1990. At station 7, Littorina occurred from March to July in 1989 and April to November in 1990 in small numbers. In the canals also Littorina was the only gastropod recorded. In both the canals they occurred in good numbers during monsoon period.

5.1.1.4 Crustaceans

The crustacean fauna was represented by 18 species belonging to 10 genera. Amphipods were the dominant group followed by tanaids.

The crustacean fauna was widely distributed and was very rich in terms of number at different culture systems. They formed 73.2% in the perennial ponds, 43.3% in seasonal fields and 74.5% in the canals. Caprellids, tanaids, amphipods, isopods, harpacticoids, ostracods, cumaceans, mysids and decapods were the major components of the crustacean fauna.

Caprellidae

Caprellid sp. was recorded at all the stations in varying numbers. They occurred in very large numbers at stations 1, 4, 7 and 8. In the perennial ponds, caprellids were abundant at station 1 and their peak occurrence $4308/m^2$ was noticed in January 1989. At stations 1 and 2 they were absent during monsoon, whereas at stations 3 and 4 they occurred during monsoon also.

Among the seasonal fields, station 7 had the highest occurrence of caprellids where they occurred from April to September in 1989 and June to November in 1990. Station 5 had the lowest abundance of caprellids and at station 6, they occurred in large numbers during the postmonsoon season. The highest number, $1542/m^2$ was recorded during September 1990.

Among all the stations under the present study, caprellids were the most abundant in the canals, and at station 8 an estimated total of $3016/m^2$ was recorded in August 1990. They occurred in all the seasons and higher number was observed during monsoon. At station 9 also, their highest number, $2222/m^2$ was recorded in August 1990.

Tanaids

Apseudes chilkensis and *A. gymnophobia* were the two species of tanaids encountered during this study. They formed a major component of the crustacean fauna in the perennial ponds. Among the perennial ponds, *A. chilkensis* outnumbered *A. gymnophobia* at stations 1 and 2 and vice versa at stations 3 and 4. At station 1, *A. chilkensis* occurred in very small numbers in 1989, but were abundant in 1990. At station 2, this species was found in large numbers ($4105/m^2$) in July 1989 and their number declined drastically in the next month. Their number remained low during the monsoon and showed an increasing trend during postmonsoon. From February 1989 onwards *A. chilkensis* occurred in good numbers at station 3 with the highest number, $3651/m^2$ in February 1990. At station 4, their occurrence was limited.

A. gymnophobia was found only in small numbers at station 1. At station 2, their highest number, $3809/m^2$ was recorded in July 1989.

There was a sharp decline in number from August onwards and they reappeared in the samples only in April 1990. At station 3 *A. gymnophobia* occurred in fairly large numbers. The highest number 7314/m^2 was noticed during September 1989, which showed a decline in the following months. In 1990 they occurred only in January. At station 4, they appeared in large numbers (highest being 1746/m^2 in August) during the monsoon of 1989, whereas they were totally absent during the corresponding period of 1990.

In the seasonal fields also tanaids were the most abundant crustaceans. *A. chilkensis* was the dominant species occurring throughout the year. Their highest number (2381/m^2) at station 5 was recorded in July 1990. At station 6, *A. chilkensis* was recorded in very large numbers (highest being 3535/m^2 in April 1989). At station 7, their occurrence was restricted to a few months. *A. gymnophobia* was recorded in large numbers at station 6 (highest number being 6599/m^2 in April 1989) where they occurred in fairly good numbers during monsoon season also. At stations 5 and 7, their abundance was noticed during premonsoon. In the canals also *A. chilkensis* was the dominant species. In both the canals (stations 8 and 9). *A. chilkensis* was abundant during pre- and postmonsoon seasons. *A. gymnophobia* was observed more at station 9 and the highest number 2599/m^2 was noticed in April 1989. At station 8, they occurred in all months in 1989, but were totally absent in 1990.

Amphipods

Amphipods formed 18.94% of the total benthic macrofauna. The most abundant species was Corophium triaenonyx followed by Melita zeylanica and Quadrivisso bengalensis.

In the perennial ponds, C. triaenonyx was observed almost throughout the period of study and was were abundant during postmonsoon at station 1. At station 2, they occurred in large numbers during the monsoon seasons of 1989 and 1990. At station 3, the highest abundance was noticed during premonsoon season. At station 4 the highest number, $2245/m^2$ was recorded during July 1987 whereas in 1990, they were found only during premonsoon.

In the seasonal fields C. triaenonyx was less abundant. At station 5, this species occurred upto August 1989 and was totally absent during the rest of the period of study. At station 6, they were present in all the seasons, with the highest abundance in premonsoon ($2630/m^2$ in 1989 and $819/m^2$ in 1990). At station 7, they were observed from February 1990 onwards in small numbers. In the canals, C. triaenonyx was the dominant amphipod. At station 8, they were present throughout 1989, the highest number, $4399/m^2$ being recorded in June. In 1990, they occurred only in July and September. At station 9, they were present throughout the period of study and the highest number, $2404/m^2$ was recorded in January 1990. In 1989, they were absent during the monsoon period, but in 1990 they appeared in fairly good numbers during monsoon also.

M. zeylanica was second in abundance in the perennial ponds. At station 1, they were encountered in all the seasons, but the highest occurrence ($2381/m^2$) was recorded in September 1990. At station 2, their number was the highest ($2744/m^2$) in September 1989. In 1990, this species did not occur during the April - October period. Though the occurrence of this species was limited to a few months at station 3, a large number, ($2925/m^2$) was encountered in July 1989. Among the perennial ponds the lowest occurrence of M. zeylanica was noticed at station 4. From October 1989 to October 1990 they were totally absent at this station.

M. zeylanica occurred only in the first year of study at station 5 and the highest number, $680/m^2$ was recorded in March 1989. At station 6, this species was observed from January to October in 1989 and only in May ($23/m^2$) in 1990. The pattern of occurrence at station 7 was similar to that at station 5. Here the highest number, $204/m^2$ was recorded in March 1989. Between the two canals, station 9 had larger numbers of M. zeylanica. At station 8, the highest numbers recorded were $476/m^2$ in August 1989 and $658/m^2$ in September 1990. They occurred in all seasons at station 9 with the highest numbers during premonsoon seasons ($702/m^2$ and $1542/m^2$ in January 1989 and 1990 respectively).

In general the occurrence of Quadrivisso bengalensis was greater during the first year of study. Among the perennial ponds station 2 had the highest abundance of this species. Among the seasonal fields, station 6 had the maximum abundance of Q. bengalensis with the highest number $1225/m^2$ (June 1989) being recorded during monsoon. Among canals, station 8 had higher abundance of Q. bengalensis where it occurred in all months upto October in 1989 with the highest number, $1315/m^2$ in May.

In 1990 they were totally absent during monsoon season. At station 9 this species was noticed from January to September in 1989, and from June to August in 1990.

Isopods: Cirolana sp. was recorded only at stations 1 and 6 during premonsoon period.

Harpacticoids: were found only at station 1 in very small numbers ($23/m^2$) during premonsoon.

Ostracods: were present only at station 1 and 9, where they were recorded during the monsoon season.

Cumaceans: Campylaspis sp. was recorded only from station 1 during the present study.

Mysids: Mysis sp. was recorded in October 1989 from station 1.

Decapoda: Though all the stations had many species of prawns including Penaeus indicus, Metapenaeus dobsoni, M. monoceros and non-penaeids, they were rarely present in the grab samples. The presence of different species was observed at all stations during the cast-net operations.

A small-sized single specimen of the crab, Scylla serrata occurred once at station 1. Likewise, one specimen of Matuta sp. also was recorded in the grab sample from station 2.

5.1.1.5 Chironomidae

Chironomus larvae were collected from all the stations except station 2. They occurred in large numbers at stations 4, 8 and 9. In

Table 1

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 1

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA	-	-	-	-	-	-	-	-	-	-	-	-
POLYCHAETA												
Dendronereis aestuarina	295	478	317	381	295	385	544	136	181	23	272	227
Prionospio polybranchiata	204	317	91	-	45	181	-	45	23	-	68	181
Perinereis cavifrons	-	45	45	68	-	23	-	-	-	-	136	68
Notophygos sp.	68	113	-	91	-	68	-	-	-	-	-	-
Ancistrocyllis constricta	136	181	-	45	-	45	-	-	-	-	91	-
Lumbriconereis simplex	45	45	23	-	-	23	-	-	-	-	45	-
Nereis chilkensis	-	-	-	-	-	23	23	-	-	-	-	-
CRUSTACEA												
Caprellid	-	4308	249	91	1927	2336	1837	-	-	-	1225	1338
Ostracod	-	-	-	-	-	-	-	-	-	-	-	-
Corophium triaenonyx	-	-	181	227	-	182	431	430	227	159	272	861
Quadrivisso bengalensis	-	204	68	45	45	522	434	159	68	317	91	-
Melita zeylanica	136	1088	-	-	23	-	-	45	68	-	1111	952
Apseudes chilkensis	-	-	-	-	46	-	-	91	-	-	-	-
Apseudes gymnophobia	-	-	-	-	-	45	-	23	-	-	-	-
Chironomus larva	-	-	567	-	-	-	-	-	68	-	-	136
Isopod	-	23	-	-	-	-	-	-	-	-	-	-
Mysid	-	-	-	-	-	-	-	-	-	-	159	-
Harpacticoid	-	23	-	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	-	-	-	-	45	23	-	-	-	-	-	-
Modiolus Sp.	-	-	-	-	68	-	-	-	-	-	-	-
Villorita cyprinoides	-	-	-	91	363	90	272	113	204	23	113	93
Meretrix meretix	-	-	-	-	-	-	-	-	-	-	-	-
Littorina littorina	-	-	136	-	-	45	476	113	386	-	45	-
Nassarius Sp.	-	-	-	-	-	-	-	-	-	-	-	-
Cerethedia fluriatilis	-	-	-	-	-	91	-	-	-	-	-	-
Scylla serrata	-	23	-	-	-	-	-	-	-	-	-	-
TOTAL	884	6846	1677	1039	2948	4982	4017	1155	1225	522	3628	3856

Table 1 (Contd.)

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 1

	D	1990 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA	-	-	-	159	-	317	-	-	159	635	431	-
POLYCHAETA												
Dendronereis aestuarina	295	317	317	-	363	272	-	377	317	-	23	363
Prionospio polybranchiata	-	-	45	68	-	136	-	68	68	-	-	136
Perinereis cavifrons	-	-	91	-	-	23	-	-	-	-	-	-
Notophygos sp.	-	-	23	-	-	68	-	-	-	-	-	-
Ancistrocyllis constricta	-	-	-	-	-	91	-	-	68	-	-	-
Lumbriconereis simplex	-	-	-	-	-	45	-	-	-	-	-	-
Nereis chilkensis	-	-	-	-	-	-	45	23	-	-	-	-
CRUSTACEA												
Caprellid	585	544	434	314	204	-	-	522	1088	23	249	23
Ostracod	-	-	-	-	-	-	-	-	-	2222	-	-
Corophium triaenonyx	625	726	317	-	521	703	45	23	-	-	-	363
Quadrivisso bengalensis	-	-	-	181	68	-	-	-	-	-	-	159
Melita zeylanica	680	-	-	68	136	317	-	-	-	2381	45	-
Apseudes chilkensis	-	1315	-	816	1973	3356	45	703	1429	3492	68	748
Apseudes gymnophobia	-	-	-	-	204	272	-	-	-	-	-	-
Chironomus larva	-	-	-	-	-	-	-	-	-	-	-	-
Isopod	-		45	-	-	-	-	-	-	-	-	-
Mysid	-	-	-	-	-	-	-	-	-	-	-	-
Harpacticoid	-	-	-	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	-	-	-	-	-	-	-	-	-	-	-	-
Modiolus Sp.	-	-	-	-	-	-	-	-	-	-	-	-
Villorita cyprinoides	-	45	68	68	68	-	91	24	408	-	23	91
Meretrix meretix	-	-	-	-	-	-	-	-	-	23	45	-
Littorina littorina	-	-	-	-	-	-	476	-	159	476	45	-
Nassarius Sp.	-	-	-	-	-	-	-	-	-	-	-	-
Cerethedia fluviatilis	-	-	-	23	-	-	-	-	-	-	-	-
Scylla serrata	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	2185	2947	1363	1697	3537	5600	662	1740	3696	9252	929	1883

Table 2

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 2

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
POLYCHAETA												
Dendronereis aestuarina	-	23	-	159	408	431	362	-	-	136	68	189
Prionospio polybranchiata	136	-	-	68	136	113	68	-	-	-	-	-
Perinereis cavifrons	-	-	-	91	-	-	23	-	-	-	-	-
Ancistrocyllis constricta	-	-	-	-	136	113	91	-	-	-	45	-
Lumbriconereis simplex	-	-	-	-	91	91	68	-	-	-	-	-
Nereis chilkensis	-	-	-	-	23		68	-	-	-	-	-
CRUSTACEA												
Caprellid	385	317	91	-	45	45	-	-	-	-	-	159
Corophium triaenonyx		-	136	317	413	-	-	-	929	-	91	590
Quadrivisso bengalensis	294	45	498	68	136	431	-	2087	-	91	-	91
Melita zeylanica	45	136	317	68	-	340	-	860	-	2744	1767	1587
Apseudes chilkensis	136	46	681	317	-	91	-	4105	91	23	771	159
Apseudes gymnophobia	884	181	1043	590	45	612	68	3809	45	-	-	-
Cumacean	-	-	45	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	23	-	45	-	-	363	-	68	-	159	1587	476
Littorina littorina	-	-	-	-	-	-	-	-	-	-	-	-
Fish larva	-	-	-	-	23	-	-	-	-	-	-	-
Matuta sp.	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	1903	748	2856	1678	1456	2630	478	10929	1045	3153	4329	3251

Table 2 (Contd.)

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 2

	D	1990 J	F	M	A	M	J	J	A	S	O	N
POLYCHAETA												
Dendronereis aestuarina	226	-	-	-	249	181	113	-	-	226	159	-
Prionospio polybranchiata	-	-	-	-	-	-	-	-	-	-	-	-
Perinereis cavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Ancistrocyllis constricta	-	-	-	-	-	-	-	-	-	-	-	-
Lumbriconereis simplex	-	-	-	-	45	-	-	-	-	-	-	-
Nereis chilkensis	-	-	-	-	23	-	-	-	-	-	-	-
CRUSTACEA												
Caprellid	-	249	-	159	-	-	-	204	-	-	-	849
Corophium triaenonyx	413	317	-	45	159	226	272	315	226	-	91	45
Quadrivisso bengalensis	-	-	-	-	-	-	23	-	-	-	-	-
Melita zeylanica	1542	-	181	136	-	-	-	-	-	-	-	24
Apseudes chilkensis	-	-	-	362	454	612	668	-	-	-	-	221
Apseudes gymnophobia	-	-	-	-	23	23	-	-	-	-	-	1426
Cumacean	-	-	-	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	254	-	-	-	226	272	340	476	-	-	23	-
Littorina littorina	-	-	-	91	-	-	-	-	-	-	-	-
Fish larva	-	-	-	-	-	-	-	-	-	-	-	-
Matuta sp.	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	2435	566	181	793	1179	1294	1416	995	226	226	273	2565

Table 3

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 3

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
POLYCHAETA												
Dendronereis aestuarina	-	113	91	68	91	226	226	226	317	-	-	-
Prionospio polybranchiata	-	91	45	23	68	-	-	68	68	-	23	-
Perinereis cavifrons	-	-	-	-	-	68	227	91	645	-	-	-
Ancistrocyllis constricta	-	-	-	-	-	136	-	159	-	-	-	-
CRUSTACEA												
Caprellid	-	23	227	159	-	317	408	521	68	476	-	-
Corophium triaenonyx	-	272	-	1338	113	45	-	-	91	-	-	-
Quadrivisso bengalensis	-	182	159	1089	996	317	-	23	-	-	68	91
Melita zeylanica	-	136	91	-	91	23	-	2925	431	-	-	-
Apseudes chilkensis	-	-	45	-	23	-	-	-	-	204	718	922
Apseudes gymnophobia	476	317	454	2879	566	91	-	726	6077	7314	2063	1362
Chironomus larva	-	23	90	68	159	123	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	-	-	-	-	-	-	136	-	-	-	-	-
Nerita sp.	-	-	-	-	-	-	249	23	23	-	-	-
TOTAL	476	1157	1202	5624	2107	1346	1246	4762	7660	7994	2872	2375

Table 3 (Contd.)

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 3

	D	1990 J	F	M	A	M	J	J	A	S	O	N
POLYCHAETA												
Dendronereis aestuarina	-	-	-	136	362	362	23	-	-	-	-	-
Prionospio polybranchiata	-	-	-	-	45	-	-	-	-	-	-	-
Perinereis cavifrons	-	-	-	113	-	-	-	-	-	-	-	-
Ancistrocyllis constricta	-	-	-	-	23	23	-	-	-	-	-	-
CRUSTACEA												
Caprellid	-	-	-	-	-	-	-	499	680	590	703	476
Corophium triaenonyx	-	-	45	23	23	91	23	-	-	-	-	-
Quadrivisso bengalensis	-	-	-	-	-	-	-	-	-	-	-	23
Melita zeylanica	-	-	-	-	-	-	-	-	-	-	23	-
Apseudes chilkensis	590	703	3651	68	-	-	-	45	-	68	136	204
Apseudes gymnophobia	480	295	-	-	-	-	-	-	-	-	-	-
Chironomus larva	-	-	-	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	-	-	45	-	-	-	-	-	-	-	-	-
Nerita sp.	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	1070	998	3741	340	453	476	46	544	680	658	862	703

Table 4

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 4

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
POLYCHAETA												
Dendronereis aestuarina	-	113	295	136	-	135	23	1610	2638	657	702	520
Prionospio polybranchiata	-	-	136	-	-	-	-	181	272	45	-	-
Perinereis cavifrons	-	-	45	-	-	-	-	-	113	-	45	23
Ancistrocyllis constricta	-	-	-	-	-	-	-	-	91	-	-	-
Paraheteromastus tenuis	-	-	23	68	-	-	-	-	45	-	-	-
Nereis chilkensis	-	-	-	-	-	-	-	-	68	-	-	-
Nephthys oliigobranchia	-	-	23	-	-	-	-	136	113	-	-	-
CRUSTACEA												
Caprellid	-	-	-	91	907	1224	136	4784	1995	181	204	23
Corophium triaenonyx	91	236	250	159	250	136	181	2245	45	1020	-	-
Quadrivisso bengalensis	-	91	91	-	-	227	477	272	45	-	-	-
Melita zeylanica	45	113	90	91	-	-	-	-	658	-	23	-
Apseudes chilkensis	-	158	158	23	-	23	-	-	45	-	227	114
Apseudes gymnophobia	-	114	635	227	-	-	-	159	1746	566	68	-
Chironomus larva	-	68	385	181	68	522	23	68	-	-	-	23
MOLLUSCA												
Nuculana mauritiana	-	-	-	-	23	-	726	68	725	430	340	91
Littorina littorina	-	-	-	-	90	23	-	-	-	-	-	-
TOTAL	136	833	2131	956	1338	2290	1546	9523	8599	2899	1609	794

Table 4 (Contd.)

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 4

	D	1990 J	F	M	A	M	J	J	A	S	O	N
POLYCHAETA												
Dendronereis aestuarina	181	181	204	391	323	771	181	2743	2245	2721	-	91
Prionospio polybranchiata	-	-	-	23	68	68	-	317	181	204	-	-
Perinereis cavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Ancistrocyllis constricta	-	-	-	-	-	23	-	68	-	68	-	-
Paraheteromastus tenuis	-	23	-	45	45	-	-	23	23	113	-	-
Nereis chilkensis	-	-	23	68	-	45	-	-	23	91	-	-
Nephthys oliigobranchia	-	-	45	23	113	113	-	91	68	136	-	-
CRUSTACEA												
Caprellid	-	-	-	-	-	68	-	680	1905	-	-	-
Corophium triaenonyx	-	-	-	-	204	181	-	-	-	-	-	-
Quadrivisso bengalensis												
Melita zeylanica	-	-	-	-	-	-	-	-	-	-	-	23
Apseudes chilkensis	-	-	-	-	136	226	-	-	-	-	-	-
Apseudes gymnophobia	-	-	-	-	23	68	-	-	-	-	23	68
Chironomus larva	-	-	-	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	-	-	-	-	181	317	-	-	-	-	-	249
Littorina littorina	-	-	-	-	-	23	-					
TOTAL	181	204	272	550	1073	1903	181	3902	4445	3333	23	431

Table 5

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 5

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA	-	-	-	-	-	-	-	-	-	-	-	-
POLYCHAETA												
Dendronereis aestuarina	232	295	232	68	-	-	-	-	-	-	-	-
Prionospio polybranchiata	159	-	91	-	45	-	-	-	-	-	-	-
Perinereis cavifrons	-	23	-	-	-	-	-	-	-	-	-	-
Ancistrocyllis constricta	-	-	-	-	23	23	-	-	-	-	-	-
CRUSTACEAE												
Caprellid	-	-	-	91	91	23	-	-	-	-	-	-
Corophium triaenonyx	91	181	-	340	-	-	-	136	159	-	-	-
Quadrivisso bengalensis	504	761	227	249	68	-	-	113	-	-	-	23
Melita zeylanica	-	113	522	680	-	23	-	204	-	-	-	-
Apseudes chilkensis	-	91	953	794	975	91	-	136	23	272	317	544
Apseudes gymnophobia	159	1383	68	227	340	45	-	1361	-	23	45	-
Cumacean	-	-	-	-	-	-	-	45	-	-	-	-
Chironomus larva	-	1609	-	181	-	-	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	-	-	-	-	23	-	-	-	-	-	23	-
Nassarius sp.	181	1315	2199	2425	6395	5692	9728	25169	11724	5896	5759	725
Littorina littorina	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	1326	5771	4292	5055	7960	5897	9728	27164	11906	6191	6144	1292

Table 5 (Contd.)

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 5

	D	1990 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA	-	-	-	-	-	-	-	-	-	181	-	-
POLYCHAETA												
Dendronereis aestuarina	102	136	-	-	-	91	-	590	1111	136	-	68
Prionospio polybranchiata	-	-	-	-	-	23	45	-	-	-	-	-
Perinereis cavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Ancistrocyllis constricta	-	-	-	-	-	-	-	-	-	-	-	-
CRUSTACEAE												
Caprellid	-	-	-	-	-	-	-	-	-	181	-	-
Corophium triaenonyx	-	-	-	-	-	-	-	-	-	-	-	-
Quadrivisso bengalensis	-	136	-	-	-	-	-	-	-	-	-	91
Melita zeylanica	-	-	-	-	-	-	-	-	-	-	-	-
Apseudes chilkensis	-	-	-	45	91	23	1723	2381	295	-		
Apseudes gymnophobia	-	91	-	-	-	-	-	226	317	-	23	68
Cumacean	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus larva	-	-	-	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Nuculana mauritiana	-	-	-	-	-	-	-	748	1429	-	-	23
Nassarius sp.	249	48	-	-	-	-	-	-	-	-	-	
Littorina littorina	-	-	431	226	1406	2172	3107	2086	318	159	408	91
TOTAL	351	411	431	271	1497	2309	4875	6031	3470	657	431	341

Table 6

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 6

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA												
POLYCHAETA	-	-	-	-	-	-	-	-	-	-	-	-
Dendronereis aestuarina	-	-	91	23	159	272	657	2902	23	-	249	363
Prionospio polybranchiata	-	204	-	91	113	91	182	544	-	181	-	-
Perinereis cavifrons	-	-	-	-	-	-	-	-	-	-	68	-
Notophygis	-	-	-	45	-	-	91	181	-	-	-	-
Ancistrocyllis constricta	-	-	-	45	-	-	-	-	-	-	-	-
Lumbriconereis simplex	-	-	-	-	-	-	23	91	-	-	-	-
Paraheteromastus tenuis	-	-	-	-	-	-	136	136	-	-	-	91
Nephthys oligobranchia	-	-	-	-	-	-	-	68	-	-	-	-
CRUSTACEA												
Caprellid	-	-	-	204	-	-	-	91	-	498	1021	2061
Corophium triaenonyx	45	91	-	340	2222	68	68	385	113	-	-	830
Quadrivisso bengalensis	-	421	816	590	317	23	839	1225	295	136	23	-
Melita zeylanica	-	226	590	295	-	-	91	317	23	454	658	-
Apseudes chilkensis	227	1380	953	839	3535	-	952	953	68	45	23	504
Apseudes gymophobia	680	489	1020	726	6599	45	1406	5747	91	-	-	-
Isopod	-	45	-	-	-	-	-	-	-	-	-	-
Chironomus larva	-	-	-	23	-	23	-	-	91	-	-	-
MOLLUSCA												
Nuculana mauritiana	-	23	-	23	-	-	363	159	-	361	45	23
Littorina Littorina	-	-	-	-	-	-	-	-	1020	-	-	-
Fish larva	-	-	-	-	23	-	-	-	-	-	68	-
TOTAL	952	2879	3470	3244	12968	522	4808	12799	1724	1675	2155	3872

Table 6 (Contd.)

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 6

	D	1990 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA												
POLYCHAETA	-	-	-	-	-	-	-	-	-	2041	-	-
Dendronereis aestuarina	-	-	-	-	-	-	-	-	-	-	-	-
Prionospio polybranchiata	181	-	-	-	-	-	-	-	-	-	-	-
Perinereis cavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Notophygis	-	-	-	-	-	-	-	-	-	-	-	-
Ancistrocyllis constricta	-	-	-	-	-	-	-	-	-	-	-	-
Lumbriconereis simplex	-	-	-	-	-	-	-	-	-	-	-	-
Paraheteromastus tenuis	-	-	-	-	-	-	-	-	-	-	-	-
Nephthys oligobranchia	-	-	-	-	-	-	-	-	-	-	-	-
CRUSTACEA												
Caprellid	930	-	-	-	-	-	-	68	249	363	544	635
Corophium triaenonyx	680	1020	544	159	41	45	91	-	226	-	-	-
Quadrivisso bengalensis	136	226	-	-	-	-	-	-	-	317	-	23
Melita zeylanica	-	-	-	-	-	23	-	-	-	-	-	-
Apseudes chilkensis	1950	2154	-	91	499	844	1655	930	499	634	68	91
Apseudes gymophobia	226	454	-	-	-	-	-	-	-	794	45	23
Isopod	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus larva	-	-	-	-	-	-	-	23	249	317	-	-
MOLLUSCA												
Nuculana mauritiana	-	-	-	-	-	-	-	68	91	-	-	-
Littorina Littorina	-	-	-	-	-	-	-	-	-	-	-	-
Fish larva	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	4103	3854	544	250	540	912	1746	1029	1314	4466	657	772

Table 7

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 7

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
POLYCHAETA												
Dendronereis aestuarina	-	45	45	68	-	-	68	204	431	476	226	91
Prionospio polybranchiata	-	-	-	-	-	45	-	-	317	-	-	-
Perinereis cavifrons	-	23	-	23	-	-	-	-	317	-	136	-
Notophygos	-	-	-	-	-	-	-	-	-	-	-	-
Paralateromastus tenuis	-	-	-	23	-	-	-	-	-	-	-	-
Nephthys chilkensis	-	-	-	-	-	-	-	-	-	-	-	-
CRUSTACEA												
Capellid	-	-	-	-	907	385	-	340	204	-	-	-
Corophium triaenonyx	-	68	-	91	136	113	-	182	-	-	-	-
Quadrivisso bengalensis	-	45	226	1088	-	45	134	-	-	-	-	-
Melita zeylanica	-	-	68	204	-	-	-	91	23	-	-	-
Apsendes chilkensis	-	68	136	-	-	-	-	3152	45	-	-	-
Apsendes gymnophobia	-	45	-	681	-	-	498	136	-	-	-	-
Chironomus larva	45	113	113	91	68	-	23	-	-	-	-	-
MOLLUSCA												
Villorita cyprinoides	-	-	-	68	23	23	45	-	91	-	-	-
Nuculana mauritiana	-	-	-	-	-	-	-	-	-	-	-	-
Littorina littorina	-	-	-	136	90	45	-	114	-	-	-	-
TOTAL	45	407	588	2473	1224	656	768	4219	1428	476	362	91

Table 7 (Contd.)

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 7

	1990 J	F	M	A	M	J	J	A	S	O	N	D
POLYCHAETA												
Dendronereis aestuarina	317	479	431	1020	839	159	68	-	-	-	-	159
Prionospio polybranchiata	-	-	-	68	91	-	-	-	-	-	-	-
Perinereis cavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Notophygos	-	-	-	113	45	-	-	-	-	-	-	-
Paralateromastus tenuis	-	-	-	-	-	-	-	-	-	-	-	-
Nephthys chilkensis	-	-	-	23	113	-	-	-	-	-	-	-
CRUSTACEA												
Capellid	-	-	-	-	-	658	771	1111	1542	1202	1156	-
Corophium triaenonyx	-	226	-	-	-	159	-	-	-	-	-	-
Quadrivisso bengalensis	-	-	-	-	-	204	68	-	-	-	-	-
Melita zeylanica	-	-	-	-	-	-	-	-	-	-	-	-
Apsendes chilkensis	-	385	-	-	-	476	91	-	-	45	45	-
Apsendes gymnophobia	-	-	-	-	-	45	23	-	-	23	-	-
Chironomus larva	-	-	-	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Villorita cyprinoides	-	91	-	-	-	-	-	-	-	-	-	-
Nuculana mauritiana	-	-	-	226	-	204	23	-	-	-	-	-
Littorina littorina	-	-	-	317	-	23	91	-	-	-	68	-
TOTAL	317	1181	431	1767	1088	1928	1135	1111	1542	1270	1269	159

Table 8

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 8

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA	-	-	-	-	-	-	-	-	-	-	-	-
POLYCHAETA												
Dendronereis aestuarina	-	223	-	544	1043	657	1043	249	249	68	136	-
Prionospio polybranchiata	91	-	45	-	570	68	113	-	-	68	136	-
Perinereis cavifrons	-	-	-	113	68	295	113	68	-	-	-	-
Notophygos	-	159	-	-	45	45	-	-	91	-	-	-
Ancistrocyllis cpmstricta	-	-	-	-	45	23	-	-	-	-	-	-
Lumbrioconeresis simplex	-	-	-	-	136	113	-	-	-	-	-	-
Nereis chilkensis	-	-	-	-	-	-	23	-	-	-	-	-
CRUSTACEA												
Caprellid	-	544	634	1406	2730	-	1503	2789	2063	-	1270	566
Corophium triaenonyx	-	113	181	91	907	456	4399	2172	1315	136	614	182
Quadrivisso bengalensis	380	748	159	181	407	1315	1111	204	317	226	181	-
Melita zeylanica	-	136	45	91	-	-	-	136	476	-	-	23
Apseudes chilkensis	317	430	-	91	68	-	-	-	-	544	340	521
Apseudes gymnophobia	159	317	499	204	45	477	23	45	-	355	158	23
Chironomus larva	-	-	45	45	91	-	68	-	-	-	831	249
MOLLUSCA												
Villorita cyprinoides	-	-	-	45	-	68	-	113	91	113	-	91
Littorina littorina												
TOTAL	947	2670	1608	2811	6155	3517	8396	5776	4602	1510	3666	1635

Table 8 (Contd.)

The mean No. of various groups of macrobenthic organisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 8

	D	1990 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA	-	-	-	23	-	226	-	-	-	136	-	-
POLYCHAETA												
Dendronereis aestuarina	-	-	-	-	-	204	-	476	907	-	-	-
Prionospio polybranchiata	-	-	113	-	-	-	-	-	-	-	-	-
Perinereis cavifrons	-	-	-	-	-	23	-	-	-	-	-	-
Notophygos	-	-	-	-	68	-	-	-	-	-	-	-
Ancistrocyllis cpmstricta	-	-	-	-	-	-	-	-	-	-	-	-
Lumbrioconeresis simplex	-	-	-	-	-	-	-	-	-	-	-	-
Nereis chilkensis	-	-	-	-	-	-	-	-	-	-	-	-
CRUSTACEA												
Caprellid	431	567	703	1771	-	159	-	-	3016	181	-	-
Corophium triaenonyx	-	-	-	-	-	-	-	23	-	136	-	-
Quadrivisso bengalensis	-	-	-	-	-	45	-	-	-	-	23	136
Melita zeylanica	-	-	-	-	-	23	-	-	-	658	91	159
Apseudes chilkensis	414	181	45	-	-	-	-	-	-	317	-	317
Apseudes gymnophobia	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus larva	113	45	-	-	-	-	-	-	159	-	-	23
MOLLUSCA												
Villorita cyprinoides	-	-	23	-	-	-	-	-	319	-	-	-
Littorina littorina												
TOTAL	958	793	884	1794	68	680	-	499	4401	1428	114	615

Table 9

The mean No. of various groups of macrobenthic oranisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 9

	1988 D	1989 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA	-	-	-	-	-	-	-	-	-	-	-	-
POLYCHAETA												
Dendronereis aestuarina	136	249	-	-	2313	-	317	-	-	362	-	-
Prionospio polybranchiata	-	-	113	-	-	181	-	-	-	-	91	-
Perinereis cavifrons	45	-	-	-	-	-	91	-	-	-	-	-
Lumbriconoreis simplex	-	-	-	-	-	-	159	-	-	45	-	-
CRUSTACEA												
Caprellid	-	-	-	91	-	68	-	91	612	-	-	-
Ostracod	-	-	-	-	-	-	-	-	-	-	-	-
Corophium triaenonx	-	521	383	204	-	318	91	-	-	-	363	635
Quadrivisso bengalensis	-	385	453	204	91	23	68	-	136	23	-	-
Melita zeylanica	295	702	318	295	113	-	45	330	-	-	23	476
Apseudes chilkensis	-	-	544	226	3535	23	-	-	-	-	-	1088
Apseudes gymnophobia	-	158	522	68	2599	-	-	308	-	-	-	-
Chironomous larva	-	-	68	226	-	590	-	-	-	45	-	408
MOLLUSCA												
Villorita cyprinoides	-	952	23	181	-	113	249	159	249	23	68	23
Modiolus sp.	-	68	-	-	-	-	-	-	23	-	-	-
Littorina littorina	521	385	23	91	-	68	589	-	159	-	45	-
TOTAL	997	3420	2447	1586	8651	1384	1609	888	1179	498	590	2630

Table 9 (Contd.)

The mean No. of various groups of macrobenthic oranisms (expressed per $1M^2$) in samples collected fortnightly (first year) and monthly (second year) during the period from December 1988 to November 1990 at Station 9

	D	1990 J	F	M	A	M	J	J	A	S	O	N
COELENTERATA	-	-	-	-	-	-	-	-	3492	2041	1837	1814
POLYCHAETA												
Dendronereis aestuarina	181	294	-	294	204	204	317	363	476	-	-	-
Prionospio polybranchiata	-	23	-	-	-	-	-	-	-	-	-	-
Perinereis cavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Lumbriconoreis simplex	-	-	-	-	-	-	-	-	-	-	-	-
CRUSTACEA												
Caprellid	-	45	91	23	23	113	23	839	2222	2199	-	1409
Ostracod	-	-	-	-	-	-	-	-	2696	-	-	-
Corophium triaenonx	1111	2404	-	204	159	91	-	204	317	794	-	499
Quadrivisso bengalensis	-	-	-	-	-	-	68	248	340	-	-	-
Melita zeylanica	720	1542	64	-	-	45	-	-	-	476	-	590
Apseudes chilkensis	1950	2585	4150	-	521	-	-	-	499	204	431	1610
Apseudes gymnophobia	-	-	-	-	91	-	-	45	-	317	-	23
Chironomous larva	-	226	-	-	-	-	-	-	-	-	-	-
MOLLUSCA												
Villorita cyprinoides	133	249	363	-	-	23	23	23	45	-	1656	-
Modiolus sp.	-	-	-	-	-	-	-	-	-	-	113	-
Littorina littorina	-	-	45	-	-	-	-	-	-	-	-	-
TOTAL	4095	7365	4713	521	998	476	431	1722	10087	6031	4037	5945

general, chironomus larvae were abundant during 1989, and in many stations they were totally absent during 1990. Among perennial ponds at stations 1, 3 and 4, they occurred only in 1989 with the highest number being recorded during premonsoon. The highest abundance was recorded in February 1989 at station 1 ($567/m^2$), in April 1989 at station 3 ($159/m^2$) and in May 1989 at station 4 ($522/m^2$). Among the seasonal fields, at stations 5 and 7, they occurred only upto March and June respectively in 1989. At station 6, they were observed in very small numbers in March ($23/m^2$), June ($23/m^2$) and August ($91/m^2$) in 1989, and from July to September in 1990. The canals had greater abundance of chironomus larvae. At station 8, they were present in both the years with the highest number, $831/m^2$, in October 1989. At station 9 they were recorded only during 1989 and the highest number ($590/m^2$) was observed in May.

5.1.1.6 Pisces

Though many species of fish were present at all the stations, only single specimens of two species of fish were collected by the grab. An elver of _Anguilla_ sp. from station 2 and two gobiid larvae from station 6 were obtained.

5.1.2 MEIOBENTHOS

The important meiobenthic groups obtained during the present study are nematodes, oligochaetes, polychaetes, bivalves and crustaceans.

The 0-5 cm layer harboured 79.5% of the total meiobenthic population. The perennial ponds had the maximum abundance of meiobenthos

(69.9%), followed by the canals (17.9%), and seasonal fields (12.2%). The meiobenthic organisms showed a marked decline in number during the southwest monsoon period. The total meiobenthic count (No/10 cm^2) for all the stations are given in Tables 10 to 18. In the perennial ponds their number varied from 239/10cm^2 to 525/10cm^2 in the 0-5 cm layer and from nil to 187/10cm^2 in the 5-10 cm layer.

5.1.2.1 Nematoda

Among the various meiobenthic groups nematodes were the most dominant, forming 79.6% and they were present at all the stations in the upper 5 cm layer of the sediment and at stations 1, 2, 4, 5, 8 and 9 in the 5-10 cm layer also. As indicated by the density ranking, nematodes were most abundant at station 4, followed by stations 2, 1 and 8. Nematodes reached upto 395/10cm^2 in the upper 5 cm layer and upto 152/10cm^2 in the lower 5 cm layer. The highest number of nematodes was recorded at station 4, where they formed 74.3% of the total meiofauna. In the seasonal fields their number was low and they occurred only in the 0-5 cm layer.

5.1.2.2 Harpacticoida

Harpacticoids were the second dominant meiobenthic organisms and were obtained from all the stations from the 0-5 cm layer. Their highest abundance was recorded at station 1, followed by stations 2, 3 and 4. They were very poorly represented in the 5-10 cm layer. Harpacticoids formed 13.4% of the total meiofaunal population. The perennial ponds had comparatively higher numbers of harpacticoids than the seasonal fields

Table 10

Numerical Abundance (No/$10cm^2$) of Meiofauna at station 1

	Nematodes		Harpacticoids		Polychaetes	
	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	37	14	7	3	3	-
1989 Jan	30	17	17	4	-	-
Feb	33	16	17	3	-	-
Mar	31	12	12	8	-	-
Apr	34	14	5	-	8	-
May	21	10	4	2	-	-
Jun	-	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	3	-	-	-	-	-
Dec	11	5	8	-	-	-
1990 Jan	10	7	9	1	-	-
Feb	19	9	11	6	2	-
Mar	23	10	16	4	-	-
Apr	30	13	13	-	6	-
May	26	11	6	-	-	-
Jun	16	9	5	-	-	-
Jul	10	5	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	-	-	-	-	-	-

Table 11

Numerical Abundance (No/10cm^2) of Meiofauna at station 2

	Nematodes		Harpacticoids		Polychaetes	
	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	26	11	-	-	-	-
1989 Jan	28	15	3	-	-	-
Feb	33	14	8	-	-	-
Mar	33	14	10	3	-	-
Apr	23	9	-	-	-	-
May	-	4	-	-	-	-
Jun	3	3	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	Nil	Nil
Oct	4	-	-	-	-	-
Nov	4	-	-	-	-	-
Dec	-	-	-	-	-	-
1990 Jan	24	11	7	-	-	-
Feb	29	7	2	-	-	-
Mar	49	19	11	2	-	-
Apr	48	13	10	-	-	-
May	34	10	7	-	-	-
Jun	19	7	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	-	-	-	-	-	-

Table 12

Numerical Abundance (No/10cm^2) of Meiofauna at station 3

	Nematodes		Harpacticoids		Polychaetes	
	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	-	-	-	-	-	-
1989 Jan	-	-	-	-	-	-
Feb	-	-	-	-	-	-
Mar	44	-	9	-	-	-
Apr	27	-	7	-	-	-
May	-	-	-	-	-	-
Jun	-	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	Nil	Nil
Sep	-	-	-	-	-	-
Oct	14	-	-	-	-	-
Nov	-	-	-	-	-	-
Dec	-	-	-	-	-	-
1990 Jan	19	-	3	-	-	-
Feb	23	-	7	-	-	-
Mar	21	-	9	-	-	-
Apr	24	-	6	-	-	-
May	-	-	-	-	-	-
Jun	9	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	-	-	-	-	-	-

Table 13

Numerical Abundance (No/10cm^2) of Meiofauna at station 4

	Nematodes		Harpacticoids		Polychaetes		Oligochaete		Ostracod	
	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	34	11	4	-	-	-	-	-	-	-
1989 Jan	51	16	7	3	3	-	-	-	-	-
Feb	47	19	4	1	3	-	-	-	-	-
Mar	48	20	7	-	8	-	-	-	-	-
Apr	31	4	3	-	6	-	-	-	-	-
May	22	11	8	-	-	-	-	-	-	-
Jun	-	-	-	-	-	-	-	-	-	-
Jul	-	5	-	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-	-	-
Sep	-	-	-	-	Nil	Nil	Nil	Nil	Nil	Nil
Oct	-	-	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-	-	-
Dec	23	4	-	-	-	-	-	-	-	-
1990 Jan	21	4	1	-	-	-	-	-	-	-
Feb	23	11	7	-	-	-	-	-	-	-
Mar	27	9	6	-	-	-	-	-	-	-
Apr	25	11	8	-	-	-	-	-	-	-
May	-	7	-	-	-	-	-	-	-	-
Jun	17	5	-	-	-	-	-	-	-	-
Jul	14	-	-	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-	-	-	-
Oct	-	-	-	-	-	-	-	-	-	-
Nov	12	-	-	-	-	-	-	-	-	-

Table 14

Numerical Abundance (No/10cm^2) of Meiofauna at station 5

	Nematodes		Harpacticoids		Polychaetes	
	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	11	-	-	-	-	-
1989 Jan	12	-	6	-	1	-
Feb	16	8	4	-	-	-
Mar	10	4	-	-	-	-
Apr	9	6	-	-	-	-
May	11	-	-	-	-	-
Jun	-	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	Nil	Nil
Oct	-	-	-	-	-	-
Nov	-	-	-	-	-	-
Dec	4	-	-	-	-	-
1990 Jan	7	-	-	-	-	-
Feb	6	6	-	-	-	-
Mar	11	-	-	-	-	-
Apr	10	6	-	-	-	-
May	-	-	-	-	-	-
Jun	4	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	6	-	-	-	-	-

Table 15

Numerical Abundance (No/10cm^2) of Meiofauna at station 6

	Nematodes		Harpacticoids		Polychaetes	
	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	4	-	-	-	-	-
1989 Jan	14	-	-	-	-	-
Feb	16	-	2	-	-	-
Mar	8	-	-	-	-	-
Apr	6	-	-	-	-	-
May	-	-	-	-	-	-
Jun	-	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	4	-	-	-	Nil	Nil
Oct	-	-	-	-	-	-
Nov	-	-	-	-	-	-
Dec	4	-	-	-	-	-
1990 Jan	-	-	-	-	-	-
Feb	6	-	-	-	-	-
Mar	24	-	7	-	-	-
Apr	31	-	4	-	-	-
May	13	-	-	-	-	-
Jun	-	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	4	-	-	-	-	-
Nov	-	-	-	-	-	-

Table 16

Numerical Abundance (No/10cm^2) of Meiofauna at station 7

	Nematodes		Harpacticoids		Polychaetes	
	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	-	-	-	-	-	-
1989 Jan	-	-	-	-	2	-
Feb	13	-	5	-	-	-
Mar	19	1	-	-	-	-
Apr	7	-	1	-	-	-
May	-	-	-	-	-	-
Jun	6	-	-	-	-	-
Jul	4	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	6	-	-	-	-	-
Dec	-	-	-	-	-	-
1990 Jan	-	-	-	-	-	-
Feb	4	-	-	-	-	-
Mar	8	-	-	-	-	-
Apr	6	-	-	-	-	-
May	-	-	-	-	-	-
Jun	-	-	-	-	-	-
Jul	4	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	-	-	-	-	-	-

Table 17

Numerical Abundance (No/10cm^2) of Meiofauna at station 8

	Nematodes		Harpacticoids		Polychaetes	
	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	-	-	-	-	-	-
1989 Jan	12	-	-	-	1	-
Feb	22	4	11	-	-	-
Mar	26	12	5	2	-	2
Apr	9	9	5	-	-	-
May	-	-	-	-	-	-
Jun	-	-	-	-	-	-
Jul	-	4	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	4	-	-	-	-	-
Dec	6	6	-	-	-	-
1990 Jan	12	10	2	-	2	-
Feb	20	10	4	-	4	-
Mar	33	11	7	-	3	-
Apr	23	-	3	-	-	-
May	19	-	1	-	1	-
Jun	6	-	-	-	-	-
Jul	4	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	6	-	-	-	-
Nov	10	6	-	-	-	-

Table 18

Numerical Abundance (No/$10cm^2$) of Meiofauna at station 9

	Nematodes		Harpacti-coids		Poly-chaetes		Bivalves		Tanaids		Amphipods	
	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10
1988 Dec	-	4	-	-	-	-	-	-	-	-	-	-
1989 Jan	6	-	-	-	-	-	-	-	-	-	-	-
Feb	10	4	-	-	-	-	1	-	-	-	-	-
Mar	7	4	2	-	2	-	-	-	-	-	-	-
Apr	8	-	2	-	1	-	-	-	1	-	-	-
May	-	6	-	-	-	-	-	-	-	-	-	-
Jun	-	-	-	-	-	-	-	-	-	-	-	-
Jul	6	-	3	-	-	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-	-	-	-	-	-
Oct	-	-	-	-	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-	-	-	-	-
Dec	4	-	-	-	-	-	-	-	-	-	-	-
1990 Jan	8	7	3	3	1	-	-	-	-	-	-	-
Feb	16	12	4	4	5	-	-	-	-	-	-	-
Mar	21	-	10	-	8	-	-	-	-	-	-	1
Apr	17	-	4	-	4	-	-	-	-	-	-	1
May	11	4	2	-	2	-	-	-	-	-	-	-
Jun	-	-	-	-	-	-	-	-	-	-	-	-
Jul	3	-	-	-	-	-	-	-	-	-	-	-
Aug	4	-	-	-	-	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-	-	-	-	-	-
Oct	-	-	-	-	-	-	-	-	-	-	-	-
Nov	-	4	-	-	-	-	-	-	-	-	-	-

and canals. At all the stations the occurrence of harpacticoids was maximum during premonsoon period. A sharp decline in abundance was noticed at the onset of monsoon.

5.1.2.3 Polychaeta

Polychaetes ranked 3rd and their highest abundance was recorded at station 4 followed by stations 9, 1 and 8. Polychaetes were not recorded in the 5-10 cm layer with the exception of station 8. They were totally absent at stations 2 and 3. Polychaetes were smaller in number and formed only 2.7% of the total meiofaunal count. Their highest number ($23/10cm^2$) was recorded at station 9 and their occurrence was restricted to pre- and postmonsoon periods.

The other meiofaunal groups such as oligochaetes, bivalves, ostracods, tanaids and amphipods had only stray occurrences and they formed a meagre 0.3% of the total meiofaunal population. Oligochaetes and ostracods were recorded at station 4 and bivalve, tanaid and amphipod at station 9. All of them occurred during the premonsoon period.

5.2 SPECIES DIVERSITY OF POLYCHAETES AND CRUSTACEANS

A diversity index is a measure of the way in which individuals in an ecological community are distributed among species. Diversity is at a minimum when all the individuals belong to the same species and at a maximum when each individual belongs to different species. A large number of species is a reflection of mature biological community and one under minimum stress. The backwater habitat in general is considered to be ecologically severe and as a result species diversity is low (Hedgepeth, 1957).

The species diversity of polychaetes and crustaceans has been found out for the different seasons and stations. (Tables 19 & 20)

Among polychaetes, the species diversity was the highest in stations 2 and 1 (H' = 1.509 and 1.504 respectively). The diversity index was very low in the case of perennial ponds during postmonsoon and the lowest value of diversity at station 3 was observed during postmonsoon.

The lowest species diversity in the seasonal fields was recorded at station 5. Here, the diversity index H' was 0.650 during premonsoon, 0.005 during monsoon and 0.387 in postmonsoon. At station 6, the highest diversity (H' = 1.114) was recorded during monsoon period, whereas at station 7, it was during premonsoon (H' = 1.239). Between the two canals, station 8 had higher species diversity and the highest value of H' = 1.349 was recorded during monsoon. At station 9, H' varied from 0.009 during premonsoon to 0.611 during premonsoon.

Table 19

Species diversity of Polychaetes

Stations	PRM	MON	POM
1.	1.504	0.984	1.368
2.	1.509	1.303	1.574
3.	1.114	1.007	0.009
4.	1.430	1.175	0.562
5.	0.650	0.005	0.387
6.	0.726	1.114	0.808
7.	1.239	0.692	0.009
8.	1.277	1.349	0.692
9.	0.009	0.608	0.611

PRM: Premonsoon, MON: Monsoon, POM: Postmonsoon

Among the perennial ponds, the highest species diversity (H' = 1.761) of crustaceans was observed in postmonsoon period at station 4. During the monsoon period the diversity values were comparatively low. The lowest value of diversity was found at station 3 during monsoon (H' = 0.956).

At station 5 among the seasonal fields, species diversity was very high during premonsoon whereas at station 6, the lowest species diversity was noticed during premonsoon. At station 7, the highest species diversity was in premonsoon and the lowest (H' = 0.758) during postmonsoon. In both the canals, the species diversity was the lowest (1.279 at station 8 and 1.286 at station 9 during premonsoon).

Table 20

Species diversity of Crustaceans

Stations	PRM	MON	POM
1.	1.327	1.420	1.469
2.	1.707	1.604	1.597
3.	1.544	0.956	1.260
4.	1.599	1.221	1.761
5.	1.461	1.041	1.310
6.	1.421	1.483	1.546
7.	1.685	1.237	0.758
8.	1.279	1.323	1.593
9.	1.286	1.390	1.392

PRM: Premonsoon, MON: Monsoon, POM: Postmonsoon

5.3 BIOMASS

In general a marked seasonal variation in biomass values of the bottom fauna was observed. The biomass of macro- and meiobenthos were higher during premonsoon season. Pillai (1978) and Batcha (1984) have also reported similar trend in biomass values in the Vembanad lake. The decline in biomass coincided with the onset of monsoon.

The macrobenthic biomass at the different stations are given in Table 21. The range in biomass was from 146.2 g/m^2 to 283.53g/m^2. There was a marked decline in meiobenthic biomass during the southwest monsoon period in all stations except station 4.

Table 21

Macrobenthic biomass (g/m^2) taken fortnightly in the first year and monthly in the second year

Stn. Month	1		2		3		4		*5		6		7		8		9	
1988 D	-	1.27	8.56	5.70	1.84	0.19	-	1.22	3.52	2.69	3.67	4.89	0.41	-	1.22	1.43	9.13	10.35
1989 J	9.38	12.8	6.96	2.04	6.12	4.08	4.28	3.56	14.26	41.43	5.49	21.13	1.43	2.84	2.84	21.85	10.35	12.20
F	4.69	4.69	12.15	8.18	6.32	2.65	10.61	8.55	54.1	26.96	14.69	6.53	5.31	1.22	17.75	5.31	10.27	12.42
M	2.04	6.93	14.53	3.25	3.88	24.49	7.35	1.43	43.90	47.34	11.65	7.55	3.46	15.72	10.04	4.48	5.67	3.85
A	6.32	4.49	-	9.38	9.18	9.80	1.63	2.25	28.38	50.34	21.23	24.48	0.81	1.23	20.41	21.63	23.35	23.38
M	2.66	12.64	10.75	5.71	4.37	4.27	1.53	15.12	26.46	24.59	3.47	1.23	1.98	0.40	2.25	18.17	4.54	23.81
J	8.72	1.22	1.22	4.89	2.24	6.73	2.86	4.09	27.44	29.02	18.99	15.10	8.47	3.85	3.47	6.11	1.34	13.15
J	4.31	4.07	11.20	19.63	2.85	14.29	17.31	10.20	27.89	40.86	17.56	17.37	5.31	1.64	6.73	9.38	15.42	11.11
A	2.04	5.71	0.61	0.61	5.99	9.93	13.70	12.60	25.43	27.21	6.34	5.51	4.28	2.85	5.51	1.22	1.36	23.36
S	4.08	1.61	0.20	19.39	14.07	10.48	17.53	6.51	28.12	26.69	4.89	7.53	2.03	1.22	0.72	-	1.35	-
O	2.03	10.40	26.26	-	12.45	9.40	5.51	5.11	25.44	24.87	9.99	1.64	1.82	1.43	6.73	1.02	1.27	1.36
N	12.13	6.51	17.65	-	12.03	9.34	4.09	2.24	20.54	7.57	2.50	4.89	1.43	1.64	11.64	12.85	7.03	9.29
D	8.41		21.05		9.63		1.63		11.71		18.76		2.85		17.26		10.20	
1990 J	9.62		0.24		8.98		1.84		11.57		14.89		10.81		22.86		5.69	
F	7.95		2.03		23.67		12.45		14.74		4.89		3.88		24.25		14.54	
M	10.00		8.16		2.04		23.73		5.22		2.25		15.90		1.84		4.76	
A	11.23		6.16		4.49		11.44		17.64		5.31		8.82		9.18		7.03	
M	15.41		11.73		4.69		18.13		26.30		8.21		17.35		3.27		11.36	
J	5.92		12.21		0.41		1.63		25.10		5.71		4.29		2.62		4.56	
J	10.62		13.24		0.41		6.29		32.94		9.8		3.06		7.54		7.71	
A	14.29		10.39		0.68		13.86		18.48		9.59		3.88		19.79		12.04	
S	13.06		4.56		0.61		8.46		9.52		6.93		1.54		8.77		6.94	
O	14.32		2.85		1.43		2.86		18.35		9.79		1.62		7.76		9.20	
N	15.94		2.04		6.33		1.63		12.26		26.74		1.02		10.03		4.76	

* Includes weight of shells

From the earlier description of the distribution and composition of benthic fauna it could be seen that, the biomass was constituted mainly by polychaetes, tanaids and bivalve molluscs in the perennial ponds. The highest biomass values were recorded during premonsoon (station 1) and postmonsoon (stations 2 and 3) periods. At station 4, the biomass (42.31 g/m^2) recorded during monsoon period was higher than that of premonsoon. Here polychaetes were the important contributors of biomass and the total biomass varied from 1.22 to 23.73 g/m^2.

During the premonsoon and postmonsoon periods greater values of biomass was observed. At station 6, tanaids and polychaetes formed the major part of biomass. The total biomass was estimated to be 264.54 g/m^2. Polychaetes were the major components contributing to the biomass at station 7.

At stations 8 and 9 the total biomass recorded were 233.55 and 216.49 g/m^2 respectively. At station 9 the high value of biomass during monsoon of 1989, was due to the presence of clams (Villorita cyprinoides var cochinensis). During August to November 1990, anemones occurred in large number at station 9, which contributed to the biomass considerably.

The meiobenthic biomass at the different stations are given in Tables 22a to 22c. As in the case of macrobenthos, the perennial ponds had higher meiobenthic biomass. The range in meiobenthic biomass at the different stations was from 0.84 $mg/10cm^2$ to 5.74 $mg/10cm^2$. During the monsoon season the biomass values decreased drastically. In all the stations nematodes formed the major share of the biomass. Harpacticoids and polychaetes contributed only negligibly to the biomass.

Table 22a

Meiobenthic biomass ($mg/10cm^2$) in the 0-5cm and 5-10cm layers of the sediment at different stations.

	Station 1		Statiion 2		Station 3	
	0-5	5-10	0-5	5-10	0-5	5-10
1988 D	0.630	0.120	0.251	0.097	-	-
1989 J	0.510	0.140	0.270	0.133	-	-
F	0.451	0.115	0.347	0.125	-	-
M	0.428	0.086	0.347	0.125	0.649	-
A	0.469	0.101	0.243	0.080	0.398	-
M	0.289	0.072	-	0.035	-	-
J	-	-	0.014	0.014	-	-
J	-	-	-	-	0.311	-
A	-	-	-	-	-	-
S	-	-	-	0.018	-	-
O	-	-	0.043	-	0.247	-
N	0.041	-	0.043	-	-	-
D	0.150	0.044	-	-	-	-
1990 J	0.137	0.062	0.257	0.098	0.335	-
F	0.291	0.079	0.299	0.062	0.027	-
M	0.352	0.088	0.504	0.169	0.024	-
A	0.458	0.115	0.494	0.116	0.028	-
M	0.398	0.097	0.349	0.089	-	-
J	0.162	0.077	0.167	0.050	-	-
J	0.102	0.043	-	-	-	-
A	-	-	0.061	-	-	-
S	-	-	-	0.029	-	-
O	-	-	-	-	-	-
N	-	-	-	-	-	-

Table 22b

Meiobenthic biomass (mg/10cm^2) in the 0-5cm and 5-10cm layers of the sediment at different stations.

		Station 4		Station 5		Station 6	
		0-5	5-10	0-5	5-10	0-5	5-10
1988	D	0.343	0.098	0.132	-	0.035	-
1989	J	0.514	0.142	0.144	-	0.125	-
	F	0.057	0.023	0.149	0.075	0.149	-
	M	0.057	0.023	0.093	0.037	0.075	-
	A	0.037	0.004	0.084	0.056	0.056	-
	M	0.026	0.013	0.103	-	-	-
	J	-	-	-	-	-	-
	J	-	0.045	-	-	-	-
	A	-	-	-	-	-	-
	S	-	-	-	-	0.035	-
	O	-	-	-	-	-	-
	N	-	-	-	-	-	-
	D	0.226	0.039	0.036	-	0.036	-
1990	J	0.207	0.039	0.062	-	-	-
	F	0.295	0.141	0.053	0.053	0.066	-
	M	0.346	0.115	0.098	-	0.266	-
	A	0.321	0.141	0.089	0.053	0.344	-
	M	-	0.089	-	-	0.144	-
	J	0.151	0.044	0.035	-	-	-
	J	0.124	-	-	-	-	-
	A	-	-	-	-	-	-
	S	-	-	-	-	-	-
	O	-	-	-	-	0.534	-
	N	0.107	-	0.053	-	-	-

Table 22c

Meiobenthic biomass ($mg/10cm^2$) in the 0-5cm and 5-10cm layers of the sediment at different stations.

		Station 7		Station 8		Station 9	
		0-5	5-10	0-5	5-10	0-5	5-10
1988	D	-	-	-	-	-	0.036
1989	J	-	-	0.058	-	0.053	-
	F	0.019	-	0.087	0.016	0.072	0.029
	M	0.028	-	0.103	0.047	0.051	0.029
	A	0.010	-	0.036	0.036	0.058	-
	M	-	-	-	-	-	0.043
	J	0.233	-	-	-	-	-
	J	0.156	-	-	0.035	0.021	-
	A	-	-	-	-	-	-
	S	-	-	-	-	-	-
	O	-	-	-	-	-	-
	N	0.053	-	0.047	-	-	-
	D	-	-	0.070	0.070	0.028	-
1990	J	-	-	0.141	0.117	0.056	0.048
	F	0.036	-	0.236	0.118	0.295	0.221
	M	0.382	-	0.389	0.129	0.388	-
	A	0.287	-	2.271	-	0.314	-
	M	0.287	-	2.224	-	0.203	0.074
	J	-	-	2.053	-	-	-
	J	0.036	-	0.036	-	0.027	-
	A	-	-	-	-	0.035	-
	S	-	-	-	-	-	-
	O	-	-	-	-	-	-
	N	-	-	0.196	-	-	0.036

In the perennial ponds the range in total biomass was from 2.19 to 5.74 $mg/10cm^2$. Station 4 had higher meiobenthic biomass. The seasonal fields were poor in meiobenthic fauna. Stations 5 and 6 had almost similar values of biomass. The range in biomass was from 0.84 to 1.41 $mg/10cm^2$. In the canals also the biomass values were low.

5.4 METABOLIC INDEX

Metabolic Index is a relative factor used to compare the nutritional status of the different seasons and stations. A clear picture of the trophic pyramid involving meio-and macrobenthos can be given with the help of metabolic index.

The meiobenthos are five times metabolically more active than macrobenthos (Gerlach, 1971) and hence, a rough metabolic index can be estimated using the equation,

$$\text{Metabolic Index, MI} = 5m + M$$

where m = biomass of meiobenthos and

M = biomass of macrobenthos (Elmgren, 1975)

Using this equation, the metabolic indices at the different stations have been found out.

In the perennial ponds, station 1 had very high Metabolic Index, followed by station 3. The MI was found to be high during premonsoon and postmonsoon periods. At station 3 the low MI was due to the low macrobenthic biomass and the complete absence of meiobenthos.

In the seasonal fields high values of MI was recorded during premonsoon season.

The canals had high MI in the premonsoon period. The low values were recorded during monsoon season.

Figures 53 to 61 show the relationship between the meio- and macrobenthic biomass and metabolic index.

In general the MI had showed 2 peaks corresponding to the peaks in benthic biomass. In the perennial ponds, (Figs. 53 to 56) at station 1 and 2 the 1st and 2nd modes occurred during premonsoon seasons in 1989 and 1990 respectively. At station 3, the first mode was in the premonsoon, 1989 and the 2nd mode in post monsoon of the same year. At station 4, a smaller mode occurred in the postmonsoon of 1988 and the 2nd higher mode in premonsoon 1990.

In the seasonal fields (Figs. 57 to 59) stations 6 and 7 showed a similar trend in the distribution of MI. In both these stations the higher peak was found during the premonsoon of 1990. But at station 5, the higher mode was found during premonsoon of 1989. This shows that the values sharply declined in the next season and from postmonsoon onwards they gradually increased, with a small mode during premonsoon of 1990.

The two canal systems (Figs. 60 and 61) were very similar to each other in the pattern of distribution of this factor. During 1989, the values remained low with a small peak during the premonsoon (at station 8) and postmonsoon of 1988 (at station 9). After the monsoon the values increased, reaching a peak value in the premonsoon of 1990. It was followed by a sharp decline with the onset of monsoon.

Figs. 53, 54 & 55. Seasonal variations in Metabolic Index

Station 1

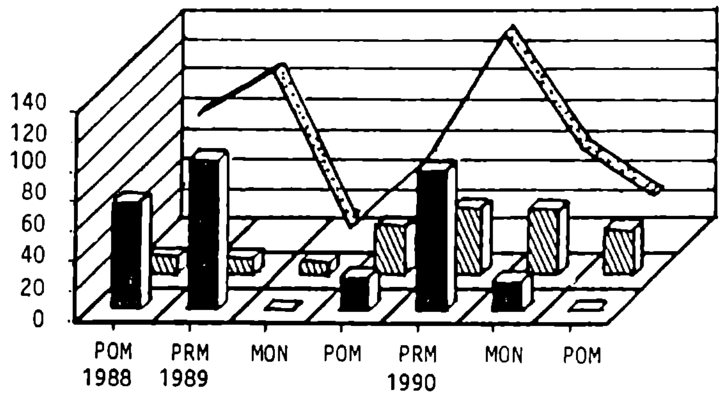

Fig. 53

Station 2

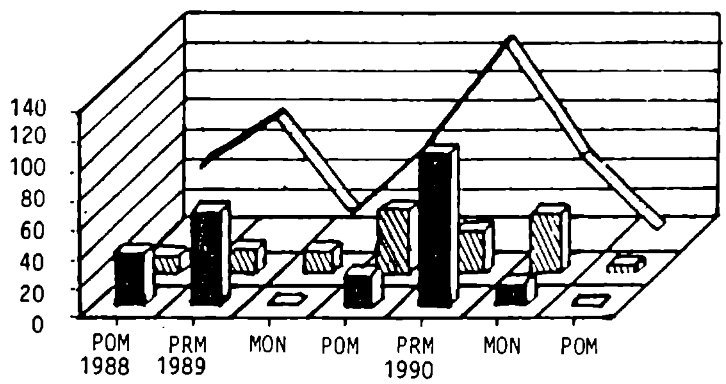

Fig. 54

Station 3

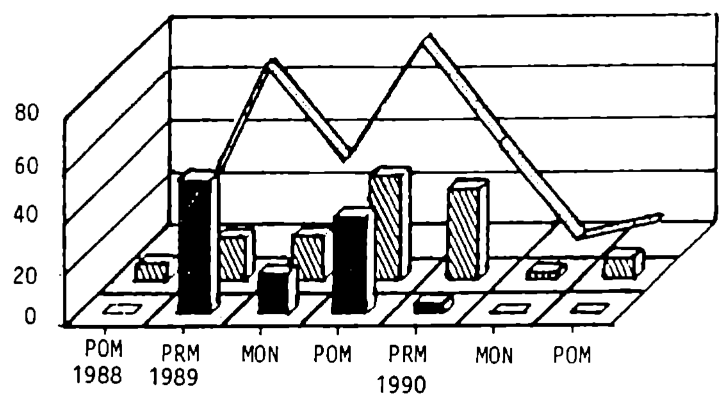

Fig. 55

PRM: Premonsoon, MON: Monsoon, POM: Postmonsoon

Meiobenthic biomass   Macrobenthic biomass

Metabolic Index

Figs. 56, 57 & 58. Seasonal variationss in Metabolic Index

Station 4

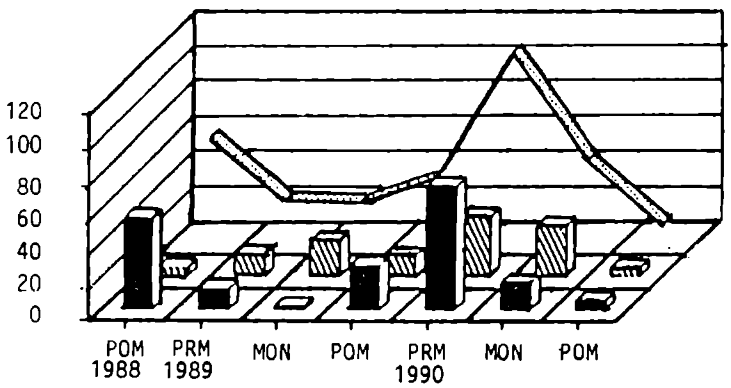

Fig. 56

Station 5

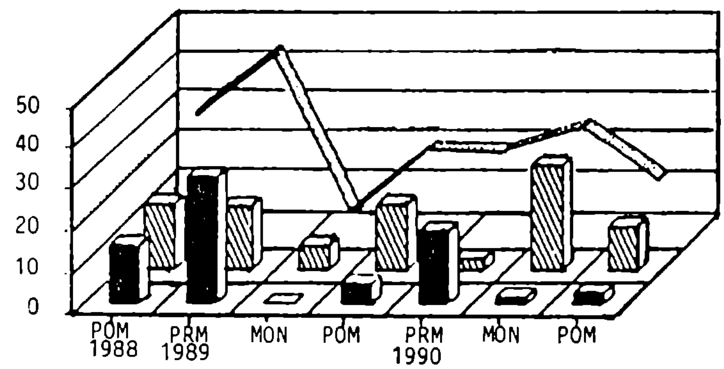

Fig. 57

Station 6

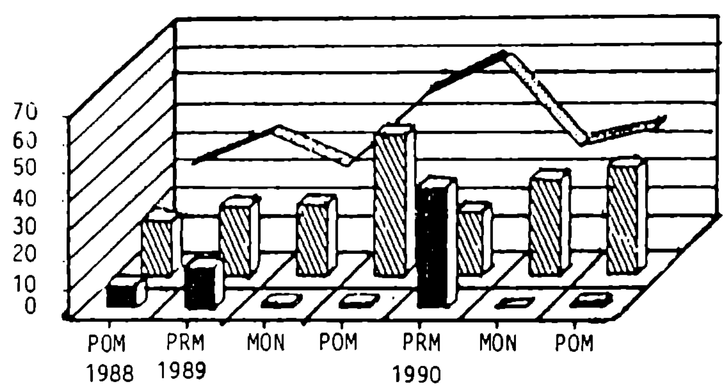

Fig. 58

PRM: Premonsoon, MON: Monsoon, POM: Postmonsoon

Meiobenthic biomass   Macrobenthic biomass

Metabolic Index

Fig. 59, 60 & 61. Seasonal variations in Metabolic Index.

Station 7

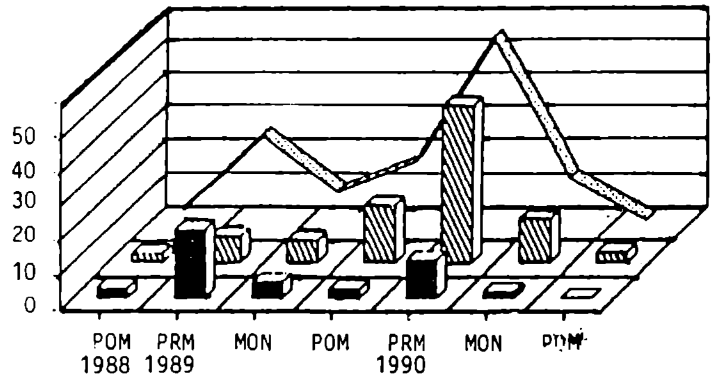

Fig. 59

Station 8

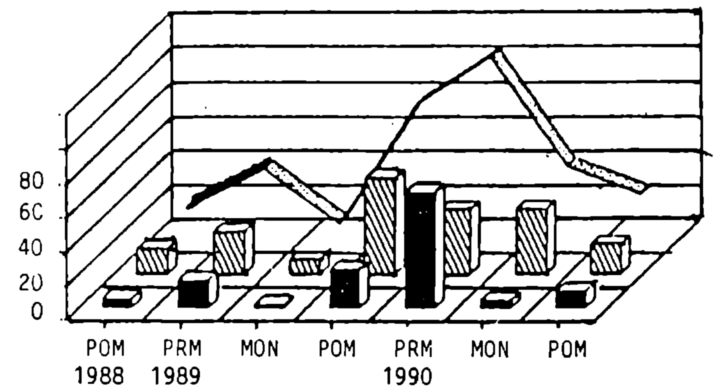

Fig. 60

Station 9

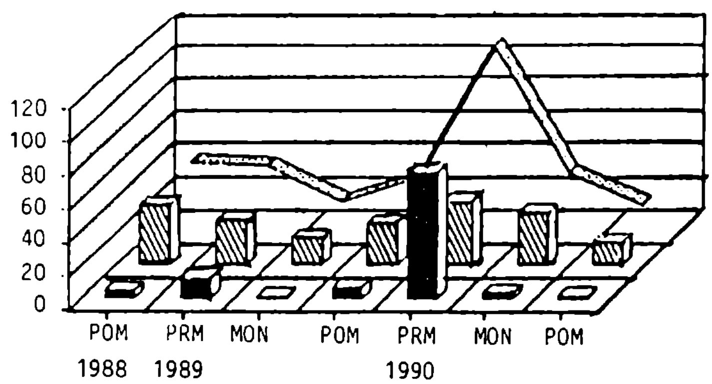

Fig. 61

PRM: Premonsoon, MON: Monsoon, POM: Postmonsoon

Meiobenthic biomass
Macrobenthic biomass
Metabolic Index

5.5 PRAWN PRODUCTION

Detailed data on prawn production was collected from the perennial pond at Edavanakkad (Station 1) and the seasonal field at Cherai (Station 6). Metapenaeus dobsoni was the dominant species followed by Penaeus indicus and M. monoceros.

The prawn and fish production data of the perennial pond is given in Table 23. The total production at this pond was 4434 Kg during 1989-1990 period. During 1989, a total of 2239.5 Kg including prawns and fishes was realised at this station. Prawn formed 91% (2038 Kg) and finfishes formed 9% (201.5% Kg). M. dobsoni constituted 1318.5 Kg (64.7%) of the total prawn catch. P. indicus was the next important species forming 31.5% (641 Kg), followed by M. monoceros with 3.8% (78.5 Kg). The prawn harvest was the highest during premonsoon period and the least during the monsoon period. The catch of M. monoceros did not show any wide fluctuations as exhibited by the other two species.

The finfish catch also showed a similar pattern, being the highest in the premonsoon period (81.5 Kg) and the lowest in the monsoon season (56 Kg).

During 1990, the total catch from this pond was 2195 Kg of which prawns formed 86.9% (1908 Kg) and fishes formed 13.18% (287 Kg). M. dobsoni dominated the catch forming 64.5% (1231 Kg). P. indicus was the next dominant species with 577 Kg (30.3%) followed by M. monoceros with 100 Kg (5%). The highest catch was recorded during the premonsoon period (41% of the total). Almost equal quantities of prawn were harvested during monsoon and postmonsoon periods.

Table 23

Prawn Production at the Perennial Pond (Kg) at Edavanakkad (Station 1)

	1989				1990			
	PRM	MON	POM	TOTAL	PRM	MON	POM	TOTAL
P. indicus	275.05	145.5	220	641	338	54	185	577 (144.3)
M. dobsoni	552.5	148	618	1318.5 (329.6)	465	430	336	1231 (307.8)
M. monoceros	23.5	28	27	78.5 (19.6)	20	59	21	100 (25)
Total Prawn Production	851.5	321.5	865	2038 (509.5)	823	543	542	908 (477)
Fish Production	81.5	56	64	201.5 (50.4)	96	88	103	287 (71.8)
Total Production	933	377.5	929	2239.5 (559.8	919 (229.8)	631 (157.8)	645 (161.3)	2195 (548.8)

PRM - Premonsoon; MON - Monsoon; POM - Postmonsoon

Production (Kg/ha) is given in parenthesis.

The rate of prawn production during 1989 and 1990 was 509.5 Kg/ha and 477 Kg/ha respectively. The total catch including prawn and fish, during these two years were 559.8 Kg/ha and 548.8 Kg/ha respectively.

The fish fauna of this pond included Oreochromis mossabmica, Etroplus suratensis, E. maculatus, Liza macrolepis. L. parsia and Ambassis sp. They were mainly caught in the castnets in small numbers.

The catch data of the seasonal field (Station 6) is given in Table 24. In the seasonal fields the prawn culture operation lasted only for 6-7 months and hence, seasonal data on production could not be collected. The total production during the period of investigation was 2953 Kg. During 1989, a total production of 1509 Kg was obtained of which prawns formed 83.8% (1264 Kg) and fishes, 16% (245 Kg). M. dobsoni was the most dominant species forming 46.8% (591 Kg) followed by P. indicus (43.3%), and M. monoceros (7.9%).

During 1990, the total production from this field was 1444 Kg of which prawns formed 81.7% (1174 Kg). M. dobsoni dominated the prawn catch forming 50.6% (594 Kg), followed by P. indicus (41.3%) and M. monoceros (81.5%). The quantity of prawn harvested was higher during the premonsoon season. The rate of prawn production during 1989 and 1990 was 632 Kg/ha and 587 Kg/ha respectively.

Table 24

Prawn Production at the Seasonal Field (Kg) at Cherai (Station 6)

	1989			1990		
	PRM	POM	TOTAL	PRM	POM	TOTAL
P. indicus	321	251	572 (286)	327	158	485 (242.5)
M. dobsoni	354	237	591 (295.5)	403	191	594 (297)
M. monoceros	57	44	101 (50.5)	58	37	95 (47.5)
Total Prawn Production	732	532	1264 (632)	788	386	1174 (587)
Fish production	122	123	245 (122.5)	149	121	270 (135)
Total Production	854 (427)	665 (321.5)	1509 (754.5)	937 (468.5)	507 (253.5)	1444 (722)

PRM - Premonsoon, POM - Postmonsoon

Production (kg/ha) is given in parenthesis.

The fish fauna of this field included O. mossambica, E. suratensis, E. maculatus, L. macrolepis, L. parsia, Ambassis sp., Tachysurus maculatus and Gerres filamentosus. The catch of fish was 245 Kg (122.5 Kg/ha) and 270 Kg (135 Kg/ha) in 1989 and 1990 respectively.

The data on prawn/fish catch from the perennial pond at Edavanakkad (Station 1) show that 509.5 Kg/ha and 477 Kg/ha were the total quantity of prawns harvested during 1989 and 1990 respectively. The earlier reports on the prawn production from perennial ponds at Edavanakkad region showed a range of 741-881 Kg/ha (George, 1974), 485 Kg/ha (Nair et al., 1988), 455-936 Kg/ha (Nasser and Noble, 1991) and 270-1143 Kg/ha (Sheeba, 1992). In the present study it could be seen that the harvest of prawns was high during 1989, when the overall benthic productivity of this pond also was high. Application of cow-dung and ground nut oil cake as manures also could have augmented the production during 1989.

In the seasonal field at Cherai (station 6) the prawn harvest ranged from 560 to 549 Kg/ha during 1989 and 1990 respectively. The different production figures from seasonal fields given by earlier workers were 764 Kg/ha (Nair et al., 1988) and 739 Kg/ha (Nasser and Noble, 1991). Sathyadas et al. (1989) reported that the yield from the prawn culture fields in Vyppin island decreased from 1000 Kg/ha in the fifties to 700 kg/ha in the seventies. But Sheeba (1992) reported a high prawn production value of 2640-2932 Kg/ha from seasonal fields. This high production has been attributed to the higher organic carbon content of soil. In the present study though the organic carbon content was very high in the seasonal field, a corresponding increase in prawn production was not observed. Various parameters like primary productivity and recruitment of juvenile prawns (George, 1974) and fluctuations in salinity (Nair *et al*., 1988) have been reported to affect prawn production in the culture systems. During 1990 the prawn production showed a slight decline in the perennial and seasonal fields. This could be attributed to the decline in the overall benthic productivity.

At all the stations, along with prawns, fishes belonging to various genera were also caught. The periodic harvests included many species of fish. They entered the culture systems as seeds or juveniles when water was let in during the high tide period. Prawn farming ponds in other countries have also been found to contain diverse fish communities (Terazaki *et al*., 1980). Parker *et al*. (1972), noted that mullet was abundant in prawn farming ponds and Tang (1961), and Terazaki *et al*., (1980) suggested that various species of mullet compete with prawns for food in ponds. Maguire and Bell (1981) demonstrated in their experiments that juvenile *Mugil cephalus* had no apparent effect on the growth and survival of prawns in pens.

It is apparent that a variety of fishes entered and survived in tidally flushed prawn farming ponds. In longer farming operations as in the perennial systems, the potential exists for fish to grow large enough to be serious predators as well as competitors for food with the prawns. Shigueno (1975) found that predation by fish was the major cause of mortality in Japanese prawn farming ponds. In the present study no adverse effect on prawn production was caused by the presence of fish.

One reason could be that the fishes were caught when they were still small in size and hence they did not pose a threat to the prawns by way of becoming predators or competitors. The fishes were removed periodcally by using castnets. The presence of jellyfish in large number at station 4 was reported by the farmers to be the reason for poor harvest of prawns. The farmers had experienced the damage caused by jellyfish infestation in the previous years also.

CHAPTER VI

DISCUSSION

6.1 BOTTOM FAUNA

The distribution and composition of benthic fauna of Cochin backwaters were studied in detail by Kurian (1953, 1967), Kurian et al. (1975), Pillai (1978) and Batcha (1984). Srinivasan (1982), Sugunan (1983) Sinhababu et al. (1984), Sing (1987) and Aravindakshan et al. (1992) made short-term studies on the hydrography and benthos of prawn culture systems. In the present study the number of species recorded were less than that recorded by the previous workers. A similar observation has been made by Singh (1987) who compared the benthos of the backwater and the prawn culture systems.

According to Willems et al. (1984), the explanations for variable abundances of benthic invertebrates included (1) differentially successful and sequential recruitment by larvae of various species; (2) predation; and (3) habitat complexity. Since species composition and abundance are influenced by the presence of larvae in the given localities, variations in larval recruitment and reproductive periodicity may provide an explanation for some of the density differences observed among the species that were collected. Not enough information is available on the life history strategies and larval recruitment of most of the infaunal organisms of this area to substantiate this view.

Maurer et al. (1984) reported that tropical estuaries in developing countries commonly have few restrictions on the use of these bodies of water as receptacles for sewage and industrial waste or on the exploitation of their biological resources. They related the low species composition to pollution of water. It is true in the case of Cochin backwaters which receives a large amount of industrial wastes. Coconut retting in some parts of the backwaters adds to the considerably high pollution. Singh (1987) also correlated the low species diversity to pollution of the Cochin backwaters.

Rees (1984) reported that a possible source of error could be the ability of the grab to penetrate bottom sediments to sufficient depths to catch the deeper fauna. In the present study care was taken while sampling to make sure that the grab was closed tightly and was full and as the sampling stations had soft substrata the grab could easily penetrate to sufficient depths.

Pinkster and Goris (1984) and Vincent (1986) reported variations in macrobenthic communities. Pinkster and Goris (1984) suggested that in the monthly samples not more than 25-40% of those species that occur throughout a year can be found. They recommended that two sampling periods (April-June and September/October) would give the best representation (upto 60%) of the species that occur throughout the year. In the present study as the observations were made for 24 consecutive months, it can be assumed that all the species were sampled.

A categorisation of macrofauna into marine, brackishwater or freshwater forms was not possible as (1) all the stations except station 4 were in the northern side of the barmouth and had similar salinity profiles and (2) most of the species were recorded in all the seasons making it difficult to group them based on their salinity preferences. Though station 4 was situated interior, the tidal influx is greatly felt here. Truely marine species like Histrio histrio recorded from the feeder canals adjacent to this station show the incursion of high saline water.

Remane and Schlieper (1958) reported that species richness is usually low in brackishwater and the species found are mostly characteristic for environments with a fluctuating salinity. The occurrence of the benthic organisms in almost all seasons suggests that these species are tolerant to changes in salinity and are true estuarine forms. A few species like Paracondylactis sp. (Coelenterata) and Notophygos sp. (Polychaeta) can be grouped as marine migrants based on their occurrence only during high saline conditions. Bhat and Neelakantan (1984) reported the occurrence of Paracondylactis sp. during high saline months in Kali estuary, West Coast of India. Almost all other macrobenthos can be regarded as resident groups within the Cochin backwaters based on their distribution and occurrence in all seasons, though not at all stations. The important resident groups were amphipods, tanaids, caprellids and polychaetes.

The variations in composition and abundance of macrobenthos has been mainly related to the changing environmental conditions (Eagle, 1981; Nichols, 1985), interspecific competition for space (Mc Auliffe, 1984), food resources (Kemp, 1988 and Kemp and Boynton 1985) and substrate composition (Bussarawich et al., 1984; Campbell, et al., 1986; Cano and Garcia, 1982; Colella and Geronino, 1987; Eckman, 1983 and

Ferencz, 1974). Thomson (1982) reported that depth and location are better predictors of community compostion. Nelson-Smith and Case (1984) and Dermott (1984) also showed depth to have an important bearing on species composition. Campbell et al. (1986) also related the variations in species distribution to depth at each station. Depth can not be regarded as a major factor determining the benthic abundance as the stations covered under the present study were shallow water bodies.

Wiltse et al. (1981) studied the effect of nutrient additions and predator exclosure on benthic associations and found that fertilizers had no effect on total density of benthos. But they observed that the algal-microbial mats could influence species composition. But in the present study algal mats were not found to have an impact on species composition. Culp and Davies (1985) while studying the responses of benthic macro-invertebrates to manipulation of interstitial detritus in Carnation Creek, British Columbia, found that the source and quantity of detritus influenced the species composition. In the present study it was observed that the perennial and seasonal fields were rich in detritus. The detritus in the seasonal fields is of plant origin, the main source being the paddy stem and hay left to decay and rot in the field after the harvest of paddy. But in the perennial ponds the detritus is mainly of animal origin, since the vegetation along the banks of the pond could not have contributed to detritus in considerable quantities. The organic matter carried into these culture systems by water during high tide is the same in both the field and the pond as the water is received from the same water body.

The pelagic larval stage of many macrobenthic organisms (Thorson, 1957), is important in determining the distribution of species. Gage (1974) suggested that the fluctuating temperature and salinity values at the surface operate as a stress condition with the result that only a limited number of larval species survive. In the present study wide fluctuations in surface temperature and salinity were observed and this could have lead to the mortality of many larval species. Campbell et al. (1986) observed that the larval recruitment is chiefly controlled by velocity with which water flows. Though the present study was carried out in enclosed water bodies, the velocity of water in the backwater can exert a stress condition and have an impact on larval distributiton and settlement, inturn affecting the species composition.

Predation has been found to be a major factor affecting benthic populations (Sikora and Sikora, 1985). Post and Cusin (1984) hypothesized that fishes remove large numbers of small crustaceans such as cumaceans and amphipods from benthic assemblages. Stephenson (1980) worked out the relationship of macrobenthos of Moreton Bay to prawns and reported that these two were inversely related. Predation on benthos can also be expected to alter species composition, resulting in greater abundance of those species having higher intrinsic rates of population increase (Slobodkin, 1962). In the present investigation a few species of fish also were caught along with prawn during the harvest from many stations. As these were prawn culture systems, care was taken to remove the presence of any other species that could pose a threat to the growth of prawns. Castnet operations were made frequently to remove the fish species. Many of them were recorded only in a few numbers during the two year study. Hence a detailed investigation on their gut content was not attempted. The effect of predation by prawns on the meio- and macrobenthic fauna is dealt with in the section on Trophic Relationship.

The distribution and abundance of meiofauna showed wide fluctuations. Emberton (1981) observed that the variation in meiofaunal populations of Cape Cod Bay depended on season and depth. Seasonal changes in the number of meiofauna were noticed in the present study but as mentioned earlier, as the depth is low it can not be considered to affect distribution and compostiion of meiofauna. Water flow has been demonstrated to be important to meiofaunal ecology (Boaden, 1968; Fegley, 1987 and Riedl and Machan, 1972) but the effects due to water flow on meiobenthos is of only minor importance as the present study was carried out in enclosed water bodies. During this study, the meiofaunal population was found to vary with the different sediment types. Disturbances on sediment surface has been reported to affect the meiofaunal distribution (Hague, 1982). Herman and Heip (1986) observed that in a brackishwater pond, the meiofaunal population was affected by large temperature fluctuations and long term trend in salintiy. Hines and Comotis (1985) stressed the importance of vertical distribution of infaunal invertebrates in sediments. The meiofauna of two layers of sediment (0-5 cm and 5-10 cm layers) were sampled during the present study.

In the present investigation the meiofauna comprised mainly nematodes, harpacticoids and polychaetes. Oligochaetes, ostracods, bivalve spat, tanaids and amphipods also were recorded in very small numbers. It was observed that meiofauna was the most abundant at the 0-5cm layer. About 80% of the total meiofauna was recorded in this layer of sediment. A similar observation was made by Ansari et al. (1977) on the meiobenthos of Goa coast. The concentration of fauna reported from other studies were 91% in the top 5 cm layer (Coull, 1970) and 80% in the top 12mm layer (McIntyre and Murison, 1973). Hirakawa and Kumada (1986) observed that in Mikawa Bay, the maximum abundance of meiofauna was in the 0-5 cm layer. Ganapathi and Raman (1973) have reported interstitial fauna to be more concentrated below the 5 cm layer on a tropical beach in India. McIntyre (1969) considered the availability of oxygen and food to be the main factors for the concentration of the meiofauna in the top layers of the sediment. In the present study the occurrence of meiofauna below 5 cm was very low and was composed of nematodes and harpacticoids.

Nematodes were the major component of the meiofauna forming 80% of total. Anadon (1982) reported that nematodes formed 82% of the total meiobenthic population in La Foz estuary, Spain. Ansari and Ingole (1983) found nematodes to form 53.7% of the interstitial fauna of the sandy beaches of Andaman Island. Nematodes were the most abundant meiofauna forming 80% of the total in the present study. Kurian (1974) while working on the benthos of Vembanad lake reported that nematodes were the most dominant meiobenthos. Srinivasan (1982) also made a similar observation in the prawn culture systems of Cochin. Harpacticoids formed 13% and polychaetes, 2.7% of the total meiobenthic count in the present study. The highest degree of occurrence of meiobenthic polychaetes was recorded at station 4 and this station also abounded in macrobenthic polychaetes, mainly Dendronereis aestuarina. Oligochaetes, ostracods, bivalve, tanaids and amphipods together formed only about 0.3% of the total meiobenthic population. All these groups were found in the 0-5 cm layer. Bivalve was collected from station 9, where the bivalve Villorita cyprinoides occurred in very large numbers.

According to Sanders (1968) the underlying cause of high diversity was the persistence of stable environmental conditions over a long period of time. Based on his 'stability - time hypothesis', the communities in constant conditions become 'biologically accomodated' and the biological stress between species such as intense competition or non-equilibrium in predator-prey relationships become progressively reduced over a long period of time. Johnson (1974) postulated that shallow water infaunal species diversity is influenced by food-resource diversity. In the present study, the abundance of meiofauna which form the natural food source of macrobenthic organisms, was found to be low in these culture systems. However, this can not be taken as a major reason for the low species diversity.

While the details of the mechanisms giving rise to high and low diversity are still a matter of debate, it has become clear that, benthic communities at greater depths experience relatively constant conditions and under these circumstances develop a high species diversity. Shallow-water communities, by comparison, have a lower species diversity and are likely to show marked fluctuations. One of the reasons for the low species diversity in the present investigation, could be the shallowness of the systems. The benthic fauna are subjected to natural environmental changes like salinity fluctuations and rainfall during southwest monsoon which constantly modify the ecological conditions and affect the settlement and accomodation of new species.

In the present study it was noticed that the biomass, though exhibiting seasonal fluctuations, did not vary always corresponding to the population count. High biomass values did not show a direct relationship with the numerical abundance. Harkantra and Parulekar (1981) suggested that biomass depended on the size of the animal and not on the numerical abundance. This suggestion holds good in the present study also. The caprellids which occurred in large numbers at stations 1, 4, 7, 8 and 9 contributed only negligibly to the biomass. At stations 8 and 9 the black clam, V. cyprinoides, was the major contributor to the biomass though their numerical abundance was not high.

6.2 HYDROGRAPHY AND BOTTOM FAUNA

The southwest monsoon represents regular and unique annual climatological phenomena markedly influencing the hydrobiological features of estuarine and coastal ecosystems. Jones (1950) stated that temperature, salinity and bottom deposit were the major factors influencing the distribution of bottom fauna. Panickar (1966) advocated the concept of partial or complete destruction of tropical estuarine fauna during the southwest monsoon followed by an annual repopulation of estuaries and backwaters during the postmonsoon season for the west coast of India. Such cyclic changes are ascribed to lowering of salinity due to heavy freshwater runoff during the monsoon and subsequent increase in salinity during postmonsoon period. The effect of salinity on marine and brackishwater invertebrates and fishes has been studied by Beadle (1957), Robertson (1957) Nicol (1960) Prosser and Brown (1961) and Lockwood (1962). Kinne (1966) suggested that salinity is the 'ecological master factor' controlling the life of estuarine animals. McLusky (1968) studied the effect of salinity on the distribution of Corophium volutator and indicated that 2 ppt is the critical minimum salinity controlling distribution.

Desai and Krishnankutty (1969), Patnaik (1971), Kurian (1973), Parulekar (1974 and 1984)), Parulekar and Dwivedi (1974 & 1975), Ansari et al. (1977), Sivakumar (1980) Varshney (1985) reported that salinity fluctuations had a strong bearing on the distribution of the benthic fauna. In the present study, copious rains during the southwest monsoon depleted the benthic fauna in certain stations. But their number remained high at stations 1, 2, 4, 5, 7 and 9 during the same period. Kurian (1967) reported that in spite of the high variation in salinity at the bottom, in most of the places at Cochin Harbour area, the intensity of benthic biomass was high. According to Patnaik (1971) and Murugan et al. (1980) salinity does not directly affect biomass. Qasim et al. (1969) showed an inversely proportional correlation between population count and salinity. The increasing number of benthic organisms during premonsoon is an indication of recolonization. A similar view has been expressed by Parulekar (1984) who stated that the greater environmental stress prevailing in an estuarine environment results in distinct seasonal changes in the distribution of dominant species, characterised by a total depletion during southwest monsoon and initial colonisation, growth and structural development of benthic communities in the premonsoon season. Due to rainfall and freshwater runoff, wide temporal and spatial variations in salinity was observed which resulted in considerable decrease in the qualitative and quantitative distribution of the macrobenthic fauna. All the meiobenthic groups also showed a drastic decline in their number with the onset of monsoon.

It is interesting to note that in 1989, Nassarius sp. formed 83% of the total benthic population count at station 5. Their highest number 17,006/m^2 occurred in the first fortnight of July 1989. Thereafter there was a reduction in number and it reached 48/m^2 in January 1990. This species was totally absent during the rest of the period. In July 1989, very small sized shells of Nassarius sp. also were collected in large numbers. But in the following months the percentage of the small sized shells became low. In August and September the salinity values at this station decreased to 1.7 ppt and 1.2 ppt respectively. This lowering of salinity values could have resulted in a large scale mortality of the young ones which will be more susceptible to changes in the environment, thus preventing recruitment. In August and September 1989, there was a slight increase in the temperature of the overlying water. This also could be a reason for the sudden decline of small sized gastropods at this station.

Dissolved oxygen is another important factor limiting benthic abundance. During this study the variation in dissolved oxygen was from 2.03 to 8.80 ml/l and in general it remained well above 3 ml/l, the minimum concentration recommended for culture ponds (Spotte, 1979). The observation made by Kurian (1967) that in shallow waters dissolved oxygen may not be a limiting factor for benthic fauna due to constant flushing and shallow nature of the water column holds good in the case of the prawn culture systems also. Similar observations have also been made by Parulekar and Dwivedi (1975) in Mandovi and Zuari estuaries, Srinivasan (1982) in prawn culture systems near Cochin and Chandran (1987) in Vellar estuary. At station 5, dissolved oxygen concentration was comparatively low during October to December. This period coincides with the minimum species density at this station. The species recorded were Nassarius sp. and Apseudes chilkensis. The absence of the other species could be related to the low oxygen levels over a prolonged period of three months. Earlier workers have shown that many benthic organisms can tide over periods of anaerobic conditions and better so, at low temperatures. But in the present study during October-December, temperature remained above 28 ^{o}C. Low oxygen at relatively high temperature could have resulted in the absence of other benthic organisms. It can also be inferred that A. chilkensis and Nassarius sp. can tolerate low oxygen levels. The ability of molluscs to withstand anaerobic conditions has been studied by Moore (1931), Dales (1958) and Karandeeva (1959). In general, dissovled oxygen was not found to be a factor limiting benthic abundance and distribution. Damodaran (1973) observed that a decrease in total biomass could not be attributed to poorly oxygenated conditions.

Temperature seldom exerts significant influence on the ecology of organisms in tropical estuaries as the annual variations of temperature normally does not exceed 5 to 7 ^{o}C. (Chandran, 1987). In the present study the range in temperature was from 24 to 36 ^{o}C. This variation in temperature was not found to have a profound effect on the distribution and abundance of benthic organisms. The higher temperature was recorded during premonsoon period and this period registered high abundance of many species.

The other parameters like pH, alkalinity and nutrients did not appear to have any profound influence on the distribution and abundance of benthic organisms.

6.3 SUBSTRATUM AND BOTTOM FAUNA

It has been well established that the qualitative and quantitative distribution of bottom fauna has a direct relationship with the type of bottom deposits (Thorson 1957, 1958; Sanders, 1958; Jonasson, 1984; Bloom et al., 1972).

The composition of the sediment showed considerable variation from station to station. Based on the texture of sediment the prawn culture systems covered under this study can be grouped into 2 major sedimentological divisions: 1) silty sand-stations 1, 2, 3, 4, 6, 7, 8 and 9 and 2) silty clay - station 5.

Analysis of the data on the qualitative and quantitative distribution of benthic fauna revealed that there exists a strong relationship between the benthic populations and the nature of the substratum. In general the population density, species diversity and biomass values were higher in ponds where the substratum was predominantly sandy. The only exception to this was station 5, seasonal field with a clayey substratum (88.79% to 91.73% of clay), where the highest population density of 25,169 numbers of Nassarius sp. per m^2 was recorded. The other seasonal fields (stations 6 and 7) with clay content 4.21 to 19.96% and 13.11 to 15.16% respectively, supported only poor benthic populations.

In environments characterised by almost identical temperature and salinity regimes, sediment characteristics might play an important role in the distribution of benthic organisms (Sanders, 1958; Kurian, 1973; Damodaran, 1973; Pillai 1978, Chandran, 1987). In the present study, texture of the sediment was found to play a role in governing species composition and abundance. Abundance and diversity of benthic organisms were relatively lower in ponds with clayey substratum than in ponds with sandy substratum. This is in agreement with the observations of Pillai (1978), Harkantra et al. (1982) Harkantra and Parulekar (1981 and 1986), Parulekar et al. (1982). Jagadeesan and Ayyakkannu (1992) while studying the benthos of Coleroon estuary, recorded poor benthic faunal abundance in fine clayey sand. In the Cochin backwaters Pillai (1978) observed that the higher biomass was associated with a substratum having a higher percentage of fine sand with small percentage of silt, followed by silty bottom and the minimum biomass was found in clayey substratum. Although a clayey substratum may be nutritionally rich, it may not favour colonization due to its soft nature. Locomotion also is difficult both over and in the soft sediment and the fine particles of silt and clay may clog the respiratory and feeding mechanisms.

Though polychaetes occurred in all stations, they showed a preference for sandy substratum with moderate amounts of silt. Maximum number of polychaete species was recorded from station 4, a perennial pond where the sand fraction varied from 73.16 to 77.65% and silt from 13.50 to 21.84%. Wilson (1952) observed that polychaete larvae critically examined the substratum before settling and postponed their metamorphosis until a suitable substratum is found.

The crustacean fauna was represented mainly by amphipods and tanaids. These two groups occurred at all stations irrespective of the type of substratum. Neymann (1971) stated that benthic crustaceans being detritophages, their distribution is dependent on the availability of detritus than on the nature of sediment (Savich, 1972). The lack of substratum preference by crustaceans were reported earlier by Pillai (1978) in the Cochin backwaters and Parulekar and Dwivedi (1975) in the estuaries of Goa. Based on the observations in the course of the present study, it could be seen that caprellids showed a preference for sandy substratum as they were abundant at stations 8 and 9 where the sand content ranged between 74.11 and 87.69%.

Among molluscs bivalves were abundant at stations 1, 2, 4 and 9 showing a preference for a sandy substratum with moderate amounts of silt. Nuculana mauritiana was the most dominant bivalve recorded followed by Villorita cyprinoides. Studies on benthos of Long Island (Sanders, 1958, 1960) and of Cochin backwaters (Pillai, 1978) have revealed that suspension feeders constituted the major fauna in coarser sediments, whereas selective and non-selective deposit feeders dominated the fine sediments. The observations made during the present study conform to the result of the above works. Gastropods were abundant in the seasonal fields. Nassarius sp. occurred in very large numbers at station 5 where the substratum was predominantly clayey. Bivalves were the least represented at this station. The only bivalve recorded was Nuculana mauritiana which occurred only twice during the study. Driscol (1967) attributed the reduction in density of suspension feeders in fine deposits to the reduced amounts of suspended food on silty clay, unfavourable to suspension feeders and thereby allowing deposit feeders a competitive advantage.

During the present study, the texture of the sediments of the ponds did not show a wide and distinct seasonal fluctuations but the faunal composition and abundance varied greatly between seasons and between stations. Such uneven distribution on similar deposits had been reported earlier by Ansari et al. (1977) and Ansari et al. (1984). Kurian (1967) observed that the type of sediment alone can not be considered a master ecological factor determining the distribution and abundance of the benthic macrofauna. The level of organic carbon in sediment is reported to be a reliable index of productivity of a water body and Kurian (1973) attributed the high productivity of benthos in the Cochin estuary to high percentage of organic content. Harkantra et al. (1982) reported organic carbon in the benthic zone along the west coast of India to be a limiting factor controlling distribution and abundance of benthic populations. The organic carbon content of the present study ranged from 0.89 to 4.9% in the perennial ponds, 1.9 to 7.2% in the seasonal fields and from 0.5 to 4.1% in the canals. The highest percentage, 7.2% was recorded at station 6. At this station tanaids and the gastropod, Littorina sp. occurred in very large numbers. In the seasonal fields an increase in organic carbon content was noticed after the harvest of paddy. In October-November period, the organic carbon content was high (7.2%). But it could be observed that during this period the benthic population count was low. Bader (1954) reported a decrease in the number of bivalves at ponds with above 3% organic carbon. According to Ganapathi and Raman (1973) organic carbon above 6% is anoxic to the marine life. Among the perennial ponds, station 4 had the lowest range of organic carbon (0.83 to 2.63%). The polychaete, Dendronereis aestuarina, occurred in very large numbers at this station. D. aestuarina was abundant at stations 1, 4, 8 and 9 where the sediment contained more than 60% sand and 9-15% silt, and the organic carbon ranged between 0.53 to 4.9%. Sarma and Rao (1982) while studying the distributiton of D. arborifera in Vasishta-Godavari estuary reported total absence of this species in coarse sandy substratum as well as those with 90% silt-clay fraction. They observed an increase in abundance with increasing organic carbon. In the present study such a relationship could not be observed. In the perennial ponds the organic carbon ranged from 0.83 to 4.11% which was low compared to that of seasonal fields (1.96 to 7.23%). But there was no corresponding increase in abundance of polychaete in the seasonal fields. A probable reason could be the high content of clay in the sediment of these fields. It could be stated that the texture of sediment is an important factor in the distribution of *D. aestuarina*. Harkantra *et al.* (1982) reported that polychaetes were abundant in silty-sand.

The numerical abundance and biomass of tanaids were high at station 3. This station received domestic sewage in considerable quantities and hence had high organic enrichment. Stations 5 and 6 also had high organic matter content and here also tanaids occurred in large numbers. It leads to a conclusion that tanaids showed a preference for sites with high organic enrichment. Predominance of crustceans which feed by browsing on detritus has been found to be related to the availability of detritus rather than the nature of substratum. Higher density of crustaceans in organically enriched sediments has been reported by Chandran (1987).

The meiofauna was more abundant in the perennial prawn culture ponds. The highest degree of abundance was recorded at station 1. The stations 1, 2 and 4, where the meiofaunal count was the highest, had a predominantly sandy substratum with a good silt content. The percentage of sand varied from 60 to 78 and the silt from 15 to 29. The canal systems, stations 8 and 9, also had similar substrata but the meiofaunal content was low. The canals had a large amount of decaying vegetation which leaves the sediment - water interface deficient in oxygen. This could be the reason for the poor meiofaunal content at these stations, though they had a substratum similar to those of the perennial ponds. The meiofauna were the least represented at the seasonal fields. This could be attributed to the high clay content, which has been reported earlier by many workers to have very poor fauna.

6.4 SEASONAL VARIATIONS OF BENTHIC FAUNA

The species-wise distribution of macrobenthic fauna at different stations is given in Tables 1 to 9.

An analysis of data on macrobenthos showed that southwest monsoon caused a marked change in species composition. The lowering of salinity during the monsoon season had a strong bearing on the distribution and composition of extuarine fauna. The increasing quantities of freshwater inflow and the copious rains during monsoon, may result in an almost freshwater condition in many parts of the COchin backwaters. Salinity steadily increases during the postmonsoon as the monsoon recedes, and reaches peak values in premonsoon. The benthic fauna was affected by this cyclic change in salinity. The benthic organisms which depleted during monsoon, recolonized during postmonsoon and a rich bottom fauna was observed during post and premonsoon periods. Such a cyclic pattern in the distribution of benthic fauna of Cochin backwaters has been described by Pillai (1978) and Batcha (1984).

The important benthic groups recorded during the post and premonsoon periods were polychaetes, amphipods, tanaids and bivalves. About 80% of the species registered their peak abundance during the premonsoon or postmonsoon periods. The benthic fauna showed wide fluctuations in their number during the different seasons. A few species occurred during the monsoon season also, exhibiting adaptive mechanisms to the wide variations in salinity which is a characteristic of true estuarine species.

In the perennial ponds, tanaids and caprellids occurred in fairly good numbers during monsoon. At station 1, Apseudes chilkensis appeared in large numbers ($3492/m^2$) in September 1990. Melita zeylanica was absent during June-August 1990, but occurred in September ($2381/m^2$). Corophium triaenonyx showed a reduction in number at all the 4 perennial stations. Caprellids occurred in large numbers at stations 3 and 4 during monsoon. At station 4, polychaetes (mainly Dendronereis aestuarina) was the most abundant during monsoon season. Starting with $45/m^2$ in May, their number reached upto $3295/m^2$ in August, 1989 and from $204/m^2$ in January to $3401/m^2$ in September, 1990. Bivalves occurred during monsoon only at stations 1 and 4.

Among the seasonal fields, the population density was the highest at station 6. Tanaid, A. chilkensis was recorded during monsoon at station 5. There was a drastic decline in their number from $3535/m^2$ in April to $68/m^2$ in August 1989, and from $1655/m^2$ in June to $499/m^2$ August 1990. A. gymnophobia which had a high abundance upto the middle of monsoon season ($5447/m^2$ in July) showed a sharp drop to $91/m^2$ in the first fortnight of August. At stations 6 and 7, polychaetes also showed a decreasing trend as the monsoon advanced. At station 5, the gastropod, Nassarius sp. showed an increase from $181/m^2$ in December, 1988 to 25, $169/m^2$ in June 1989, and then started declining. The number of small sized shells of Nassarius sp. were less in the samples from July onwards. This could be due to the narrow tolerance range of the young gastropods to salinity. Paracondylactis sp. (Coelenterata) was recorded in late monsoon of 1990 at station 6.

In the canals, all the species except caprellids showed a reduction in their numbers during monsoon. Though caprellids were not present throughout the year, their highest abundance was observed during monsoon. In 1990, polychaetes showed a reduction in number to $68/m^2$ in July, but from August onwards there was an increasing trend at station 8. A similar observation was made at station 9 also. Coelenterate, Paracondylactis sp. occurred in large numbers from August (1990) onwards.

The meiobenthic organisms were greatly affected by the salinity changes during monsoon. At all stations they totally perished in monsoon and recolonized during postmonsoon. A decline in meiofaunal population during the southwest monsoon has been reported by Ganapathi and Raman (1973), Kurian (1973), and Srinivasan (1982). Suresh et al. (1992) studied the ecology of interstitial meiofauna at Kalpakkom on the east coast of India and reported a reduction in meiofaunal density during premonsoon reaching the lowest in monsoon.

The species diversity was low during the southwest monsoon period, when the environmental stress on the community was very high. The fluctuating and unpredictable physical conditions resulted in decreasing numbers of species. As a result, the interspecific competition between the few species which were able to withstand the stress was of relatively minor importance and they became abundant. Generally, during the premonsoon period there exists a relatively stable environmental condition and biotic interactions like competition for food become factors controlling diversity and abundance of the different species.

A well marked seasonal pattern was noticed in the biomass also. Biomass was high during the pre- and postmonsoon periods. A reduction in values was found during the monsoon season. Polychaetes, crustaceans and molluscs were the major contributors to the biomass.

Biomass values were high during the premonsoon period at stations 1, 3, 5, 7, 8 and 9. During monsoon season high biomass was recorded at station 4 and 6 and during postmonsoon at station 2. At station 1, the major contributor to the biomass was polychaetes eventhough the high numerical abundance was due to caprellids. But in 1990, higher biomass was recorded during premonsoon season owing to the abundance of tanaids. Large numbers of polychaetes and crustaceans resulted in high biomass in the monsoon season at station 2. Crustaceans occurred in large numbers during monsoon period at station 3, accounting for a higher biomass value. At station 4, the mjaor contributor to biomass was polychaete fauna.

In six out of nine stations increase in biomass was observed during the premonsoon. The change in salinity condition in the postmonsoon season which was moderate, steadily shifted to a stable condition during the premonsoon period. Recolonization of many benthic organisms which started in the postmonsoon period reached its maximum level. This accounted for the increase in biomass during premonsoon.

The decrease in biomass during monsoon noticed at a few stations, could be ascribed to the lowering of salinity resulting in poor abundance. Desai and Krishnankutty (1969), Ansari (1974), and Harkantra (1984) reported a sharp decline in biomass during the southwest monsoon in the different estuarine systems. Pillai (1978) and Batcha (1984) also have reported a similar trend in benthic biomass in the Cochin backwaters. Parulekar et al., (1982) and Harkantra and Parulekar (1981) observed an increase in benthic biomass in estuaries of Goa during premonsoon periods.

The results of the present study reveal the effect of two major factors, salinity and texture of sediment, on the distribution, composition and abundance of benthic fauna in the prawn culture systems. Pillai (1978) while studying the macrobenthos of Cochin backwaters, pointed out the above parameters to have a profound influence on benthic populations and singled out salinity as an "ecological master factor" (Kinne, 1966). It could be observed that changes in salinity caused wide fluctuations in the abundance of benthic organisms while the texture of the sediment played a key role in determining the species composition at each station.

6.5 TROPHIC RELATIONSHIP

Trophic ecology involves all the biotic and abiotic components of the ecosystem and the energy transfer between them. The biotic factors mainly comprises organisms with different feeding habit like browsing, rasping, foraging, scavenging, filter and deposit feeding, preying and parasiting. It also means that organism with any type of feeding habit may find trophic support in resourceful ecosystem like an estuary.

Benthic production is mainly by organisms that depend upon bottom deposit, nutritious, suspensions and some smaller metazoans. The benthos produce a biomass on the estuarine bed with several biotic and abiotic relationships. Detritus is one source of energy for the benthic organisms. The microbial organisms colonising over detritus, faeces and sediment, supply energy to many of them and so does the organic matter concealed in silt, clay and oozes. Apart from all these, many smaller organisms are fed upon by the larger ones. So the benthic existence itself reflects the cycle of energy more or less in a complete manner connoting that benthos forms an absolute ecosystem instead of being a part of one.

The functional role of benthos in the food chain of the sea bed has been studied by many research workers (Teal (1962), Odum (1980), Winberg (1971), Warwick and Price (1975), Cederwall (1977), Heinle et al. (1977), Rosenberg et al. (1977), Waters (1979), Tenore et al. (1982). Assimilation rates of benthos (Conover, 1977), transfer efficiencies in the food chain(Pomeroy, 1974) and mechanism of energy transfer (Holme and Mc Intyre, 1971; Riedel, 1972) are some of the major studies in this field. Specific trophic interactions of benthos have been studied by Peer (1970), Hargrave (1971 and 1972), Klein et al. (1975), Alongi and Tietjan (1980) and Wildish et al. (1989).

An important group in the trophic network of benthic environment is meiobenthos. the role of meiofauna in benthic production and supply of energy to higher trophic levels has been hypothesized by McIntyre (1964, 1969 & 1971), Tietjan (1969), Giere (1975), Lasserre et al. (1975), Mc Lachlan (1977) and Tenore et al. (1977) who suggested that the function of meiofauna in benthic community is either nutrient remineralization or competition with macrofauna. Gerlach (1971) and Thiel (1975) found that in mudflats, estuaries and deep seas, the meiobenthos - macrobenthos standing crop rate is approximated at one, which suggests a more significant role of meiofauna in benthic energetics.

Flint and Rabalais (1981) developed a theoretical food web for shrimp populations, focussing on transfer of carbon. The results indicated that the majority of primary production (approximately 80%) was divereted to benthos. Further, it appeared that the secondary production of benthos was not sufficient to support the shrimp populations. They concluded that at least a part of their nutrition was derived from the detritus pool.

A key question about shrimp production concerns the components of the benthic community from which prawns derive their nutrition. Several studies have been attempted to determine the role of benthic infauna as a food source for commercially important demersal species. Observations such as those of Mc Intyre et al. (1970), Arntz (1980) and Gaston, et al. (1988) implicate the benthos as important food items for species of prawns.

An attempt was made to identify the major food items of prawns. For this, about 100 prawns were collected and their guts analysed. The gut contents were mostly a semi-digested matter. In a few cases polychaete segments, crustacean appendages and diatoms were noticed. Nematodes were also present in about 8% of the stomachs analysed. The crustacean or polychaete species could not be identified. The nematodes that were present in about 8% of the guts indicate the trophic chain involving meiobenthos. One possibility is the direct feeding of prawn on the meiobenthic fauna. But an interesting observation was that, although station 4 had higher abundance of nematodes (about 80% of the total meiobenthic count), their abundance in prawn guts was neglitible. A rapid digestion of nematodes cannot be the cause of this phenomenon as the resistant chitinous integument of the nematodes is not easily digested. The nematodes could have reached the prawn gut also through other macrobenthic organisms, which in turn feed on nematodes. McIntyre (1969) has reported that nematodes appear to pass intact through the stomachs of flatfish. Alheit and Scheibel (1982) also have reported that nematodes were not easily digested, as many specimens in good condition were removed from the posterior parts of fish intestines.

Based on the theoretical food web for prawn production put forward by Flint and Rabalais (1981) an attempt has been made to assess the production and the potential for trophic coupling. They used a conversion factor of 4.5 to convert the production figures to annual production and 6% conversion between wet weight and carbon of metazoans to get carbon equivalents.

The trophic web has been worked out for the perennial pond at Edavanakkad (station 1) and the seasonal field at Cherai (station 6). The total prawn production from these culture systems was converted to carbon equivalents, to make a comparison between the trophic levels possible. The carbon equivalents of prawn production at station 1 was estimated to be 22.62gC/m^3 and 10.53 gC/m^3 during 1989 and 1990 respectively. Similarly at station 6, the corresponding values were

14.65 and 13.61gC/m^3 in 1989 and 1990 respectively. Assuming 10% transfer efficiency to support so much prawn production, the production at the macrobenthic level should have been 226.2 and 105.3gC/m^3 at station 1 and 146.5 and 136.1 gC/m^3 at station 6.

But the actual figures of macrobenthic biomass (net weight) converted to carbon equivalents were 4.02 and 3.20gC/m^3 at station 1 (in 1989 and 1990 respectively) and 4.73 and 2.42 gC/m^3 at station 6, which are far below the expected values. The meiobenthic biomass values were very low. It could be seen that even after considering the meiofauna to be five times more metabolically active than the macrofauna (Elmgren, 1975), the meiofauna biomass added only negligibly to the total benthic production in these prawn culture systems.

Theoretically, if the macrobenthic production supported the tertiary production (in this case prawn production), with 10% transfer efficiency, the prawn production figures would be much smaller than the figures obtained. It shows that if the prawns had depended only on benthic production for their nutritional supply, their production would not have reached the current dimensions. This suggests that in addition to the benthic production, prawns depended on other sources potentially rich in energy, for their nutrition. The two possible sources of energy are benthic algal production and detritus. The former can not be taken as an important source providing energy because they were poorly represented at these two stations. This leaves only detritus for consideration as the additional source of energy. The presence of detritus in the guts of prawns indicated that it could act as a potential source of energy and provided evidence for another means of prawn gaining nutrition. This is strongly supported by the presence of detritus in 81% of the guts analysed (Table 25).

Cook and Linder (1970) Caillouet et al. (1976) and Peckarsky (1980) observed that shrimp rely upon food provided by the marine detritus pool for at least some of their nutrition. Condrey et al. (1972) observed that brown shrimp ate dead diatoms and algal mat material in an estuarine habitat. In the present study, detritus was an important component in the gut contents. Maguire and Bell (1981), in their experiments observed that prawn production was higher in a pond which contained high levels of detritus. They also recorded that the stomachs of prawns from the ponds contained much more drtritus than macrobenthos. Hence the dependence of the prawn populations on the detritus pool is a reasonable conclusion.

The shallowness of the culture systems allows direct transport of primary production to the bottom. It also enhances processes related to benthic-pelagic coupling. The primary production of the prawn culture systems around Cochin backwaters has been studied by Sheeba (1992). According to that study, the primary production in the perennial ponds ranged from 156 to 9186 mgC/m^3/day, and in the seasonal fields from 390 to 6378 mgC/m^3/day, and in the canals from 100 to 3340 mgC/m^3/day. In perennial ponds in Edavanakkad region she has reported the annual primary production to be 156-2184 gC/m^2/day (average 1170). Based on this value, it could be seen that the average benthic production, 3.61gC/m^2 per year utilized 3.09% of the primary production. Likewise,

Table 25

Number of prawns (%) showing the presence of different food items.

Food Items	*P. indicus*	*M. dobsoni*	*M. monceros*
Nematodes	10	8	14
Crustacean appendages	3	14	11
Polychaete segments	13	9	8
Diatoms	27	21	17
Bivalve	-	2	-
Detritus	78	81	83

in the seasonal field the average primary production was $3384 gC/m^2$ per year, of which the benthic production ($3.57 gC/m^2$ per year) utilized 1.06%. Assuming 10% transfer efficiency of primary production to the secondary levels, the expected production should have been 117 and $338.4 gC/m^2$ per year in the perennial and seasonal fields respectively. Sheeba (1992) has reported the utilization of zooplankton in the secondary level to be 5.87% (perennial pond) and 8.98% (seasonal field). It can be seen that the benthos and zooplankton together utilizes only a small percentage of the available primary production and that a large quantity of primary production is not accounted for in the secondary levels.

Qasim (1970) reported that primary production is inefficiently utilized in the Cochin estuary. The apparent wastefulness of the primary production can be explained in terms of alternate pathways in food chain. In the culture systems the possibility of one such pathway could be established directly with mullets (Liza parsia, and L. macrolepis) which are herbivorous fishes. A substantial quantity of the basic food sinks to the bottom and is used directly by sedentary animal communities. Gopinathan et al. (1982) reported high quantities of suspended detritus in Cochin estuary and connected prawn culture systems.

It could be seen that the primary production, however, was not adequate to satisfy the requirements of the tertiary production involving benthic food chains although it supported production at the secondary levels. Alternative pathways supporting tertiary production have been suggested by Qasim (1970). In the present investigation it could be observed that in addition to the link between benthic infauna and prawns, there existed an alternative direct pathway between detritus and prawns supplementing the energy requirements of the prawns.

Comparing the three types of culture systems it could be seen that the perennial ponds were more productive when their nutrient profile and secondary (benthic) production were taken into account. But prawn production in these ponds were lower than that in the seasonal fields. Though the very high content of organic carbon and the clayey substratum resulted in poor benthic production, the prawn production was higher in the seasonal fields. The gut content analysis showed that detritus was the major source of energy in 80% prawns and the higher prawn production at the seasonal fields could be related to the rich detrital matter present in these culture systems. The canals, in the present conditions, are not suitable for prawn culture as the water is stagnant and hardly any attention is given to the maintenance and management of these systems. The utilization of energy derived from natural sources of food such as benthic production and detritus, by prawns is of great importance in these traditional prawn culture systems, where supplementary feeding is not practised. Selective stocking and scientific management could augment prawn production in these culture systems.

SUMMARY

In the traditional prawn culture systems which are characterised by the lack of any input towards selective stocking and supplementary feeding, the prawns depend on natural productivity for their nutrition and, to a large extent the quality and quantity of benthos decide the benthic productivity of these systems. The present investigation on the "Benthic ecology of selected prawn culture fields and ponds near Cochin" was taken up with a view to provide information on the qualitative and quantitative distribution of benthos and their relationships to prawn production of different culture ecosystems and to the physico-chemical parameters influencing their production. A two-year observation was carried out in nine selected prawn culture systems including perennial ponds (stations 1 to 4) seasonal fields (stations 5 to 7) and contiguous canals (stations 8 and 9) during December 1988 to November 1989.

All macro- and meiobenthic organisms contributing to the fauna were identified and their abundance, distribution, diversity, biomass and trophic relationships between benthos and prawns were studied. The environmental variables studied were temperature pH, salinity, dissolved oxygen, alkalinity, nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen, phosphate and silicate of bottom water and organic carbon and texture of the soil.

Water temperature ranged between 25.2 to 36 ^{o}C in perennial and seasonal systems and 24 to 34 ^{o}C in the canals. Temperature showed a clear seasonal fluctuation with high values in premonsoon. pH of water varied from 6.4 to 8.5 in perennial ponds, 5.6 to 8.5 in seasonal fields and 6.1 to 8.1 in canals. Salinity of the culture systems showed wide fluctuations reaching almost freshwater conditions during monsoon period. The range in salinity were 0.26 to 28.12 ppt in perennial ponds, 0.27 to 27.85 ppt in seasonal fields and 1.38 to 20.33 ppt in canals. Dissolved oxygen concentration was generally higher in the perennial ponds with a range of 2.03 to 8.8 ml/l. In the seasonal fields the range was from 1.27 to 6.6 ml/l and in the canals, 1.59 to 4.77 ml/l. Alkalinity values showed wide fluctuations ranging from 10 to 108 (perennial ponds) 14 to 154 (seasonal fields) and 19 to 194 mg/l (canals).

A distinct seasonal pattern in fluctuation of nutrients was not discernible in these culture systems, but generally higher values were recorded during monsoon. The perennial ponds, had higher nutrient profile than the other two culture systems. The range of nutrients in the perennial ponds was, 0.001 to 2.56 µg at/l (nitrite), 0.07 to 23.15 µg at/l (nitrate), 0.09 to 89.25 µg at/l (ammonia) 0.001 to 15.6 µg at/l (phosphate) and 3 to 129 µg at/l (silicate); in the seasonal fields the range was 0.01 to 2.25 µg at/l (nitrite), 0.03 to 19.75 µg at/l (nitrate), 1.41 to 89.16 µg at/l (ammonia), 0.01 to 11.8 µg at/l (phosphate) and 7 to 90 µg at/l (silicate); and in the canals, 0.003 to 2.05 µg at/l(nitrite),0.93 to 20.8 µg at/l (nitrate), 3.4 to 99.96 µg at/l (ammonia), 0.01 to 19.03 µg at/l (phosphate) and 10 to 115 µg at/l (silicate).

There was a noticeable difference in the texture of the sediment between the stations and a marginal increase in silt and clay fractions could be observed towards the end of monsoon and in postmonsoon. The substratum of perennial ponds was primarily silty - sand type. The sand fraction ranged from 53.28 to 77.65%; silt from 13.5 to 32.95%, and clay from 1.5 to 21.96%. Among the seasonal fields, station 5 had a very high clay content ranging from 88.79 to 91.73%. The ranges in sand, silt and clay fractions in seasonal fields were 1.07 to 68.34%, 6.72 to 30.61% and 4.21 to 91.73% respectively. In the canals the range was 67.11 to 87.88% (sand), 9.18 to 23.54% (silt) and 2.35 to 10.86% (clay).

Organic carbon showed wide fluctuations between the stations. In the perennial ponds the organic carbon content fluctuated between 0.83 and 4.9%. The seasonal fields had higher organic carbon content which could be attributed to the decay of paddy stumps and straw left in the field after the harvest. Moreover, seasonal fields had higher clay content which is known to trap a high proportion of organic matter. The range of organic carbon in the seasonal fields was from 1.96 to 7.23% and in the canals, 0.53 to 4.11% with higher values in August - September.

The important macrobenthic groups were polychaetes, crustaceans and molluscs. Altogether, 1 species of coelenterate, 9 species of polychaetes, 8 species of molluscs, 18 species of crustaceans and 2 species of fishes were recorded. Paracondylactis sp. was the only coelenterate recorded. Among polychaetes, Dendronereis aestuarina was the most widely distributed species followed by Prionospio polybranchiata. The other species, Perinereis cavifrons, Notophygos, Ancystrocyllis constricta, Lumbriconereis simplex, Paraheteromastus tenuis, Nereis chilkensis, Nephthys oligobranchia were limited in distribution.

Molluscs were represented by 4 species each of bivalves and gastropods. Nuculana mauritiana was the most abundant bivalve followed by Villorita cyprinoides. Modiolus sp. and Meretrix meretrix occurred only at a few stations. Gastropods formed about 18.56% of the total macrobenthic population. Littorina littorina was the abundant form, with a wide distribution. Nassarius sp. was collected only from station 5, where it formed 67% of the total benthic fauna in the first year of study. Starting with $181/m^2$ in December 1988, they reached upto 25, $169/m^2$ in July 1989. Shells of Nassarius sp. varying in size from 0.30 mm to 17mm were recorded. Nerita sp. occurred only at station 3 and Cerethidia fluviatilis at station 1.

The crustacean fauna was represented by 18 species, and was widely distributed. Crustaceans formed 73.2% in the perennial ponds, 43.3% in seasonal fields and 74.5% in the canals. Amphipods were the most dominant crustaceans. The species recorded were Corophium triaenonyx, Melita zeylanica and Quadrivisso bengalensis. Tanaids were represented by Apseudes chilkensis and A. gymnophobia. They occurred in fairly good numbers during the monsoon also. Caprellids were the most abundant in the canals. The other groups such as isopods (Cirolana sp.), harpacticoids, ostracods, cumaceans (Camylaspis sp.) and mysids (Mysis sp.) had only stray occurrences. Decapods included Penaeus indicus, Metapenaeus dobsoni, M. monoceros. One specimen each of Scylla serrata and Matuta sp. were also recorded. Chironomus larvae were abundant and they occurred in large numbers at stations 4, 8 and 9. Gobiid larvae and an elver of Anguilla sp. were collect during the study.

Species diversity of polychaetes and crustaceans were high during premonsoon periods and the lowest was recorded during monsoon. The highest diversity for crustaceans (1.707) and for polychaetes (1.509) were recorded at station 2.

The biomass was constituted mainly by polychaetes,tanaids and bivalves in the perennial ponds, by polychaetes in seasonal fields and by bivalves and coelenterates in the canals. The decrease in biomass value during monsoon could be attributed to the lowering of salinity resulting in poor macrofaunal abundance. But biomass did not always vary corresponding to the population count. The metabolic index of the different seasons and stations were compared. The perennial ponds and canals had higher metabolic index than the seasonal fields. The indices were found to be high during premonsoon corresponding to the increase in benthic biomass.

The important meiobenthic organisms were nematodes and harpacticoids. The 0-5 cm column harboured 79.5% of the total meiobenthic fauna. The perennial ponds had the highest abundance of meiobenthos followed by canals and seasonal fields. Nematodes formed 79.6% of the total and were recorded at all stations, whereas harpacticoids formed 13.4%. Higher abundance of meiobenthos was observed during premonsoon. The distribution of polychaetes was restricted to the 0.5 cm layer and they occurred only in postmonsoon.

The other groups like tanaids, amphipods, bivalves, ostracods and oligochaetes had only stray occurrences.

The pattern of abundance of both macro-and meiobenthos clearly indicated that environmental variables played an important role in modifying the benthic assemblages. Though there was a reduction in the benthic populations during south west monsoon, many species were recorded during monsoon also suggesting that these organisms are well adapted to the wide fluctuations in salinity. Organisms such as Paracondylactis sp. (Coelenterata) and Notophygos sp. (Polychaeta) can be grouped as marine migrants based on their occurrence only during the high saline conditions of postmonsoon period. All other species can be regarded as resident groups within the Cochin estuary as they were present in all the seasons though not at all stations.

The quality and quantity of benthos was found to have a direct relationship with the type of substratum. Abundance and diversity was low in ponds with clayey substratum than in ponds with sandy substratum. Organic carbon also has been found to be an important factor limiting abundance and distribution. It could be seen that when the organic carbon was very high (7.2% at station 5) there was a reduction in benthic population. It can be suggested that after a particular limit, the increase in organic carbon does not result in enhanced benthic production. It might be due to the fact that as more and more decomposition takes place, the overlying water becomes deficient in oxygen leading to a reduction in benthic populations.

The prawn production data from station 1 (perennial pond at Edavanakkad) showed that Metapenaeus dobsoni formed 65%, Penaeus indicus

30.5% and M. monoceros 4.5% of the total prawn production. The production figures for the years 1989 and 1990 were 2038 kg (509.5 kg/ha) and 1908 kg (477 kg/ha) respectively. At station 6 (seasonal field at Cherai), the production was 1264 kg (632 kg/ha) in 1989 and 1174 kg (587 kg/ha) in 1990. M. dobsoni formed 49%, P. indicus 43% and M. monoceros 8%. This shows that the seasonal field supports a better prawn production which is in agreement with the previous reports on prawn production of this area.

An attempt has been made to compare the benthic production with the primary and secondary productions reported from the same area by earlier workers. Based on the hypothetical food web proposed by Flint and Rabalais (1981), the trophic web has been worked out at stations 1 and 6. The total benthic biomass was converted to carbon equivalent of 4.02 and 3.203 gC/m^2 in the perennial pond (station 1) and 4.725 and 2.418 gC/m^2 in the seasonal field (station 6) in 1989 and 1990 respectively. The carbon equivalents of prawn production for these years were 23.62 and 10.53 gC/m^2 at station 1 and 14.65 and 13.61 gC/m^2 at station 6. Assuming 10% transfer efficiency, it could be seen that the benthic production alone was not sufficient to support the prawn production at the tertiary level. This implies that there is an additional source of food from which prawns derive energy. The presence of detritus in the guts of prawns examined indicates that it could act as a potential source of energy. Based on these observations it could be assumed that in addition to the direct links between the benthic fauna and prawns, there existed an alternate direct pathway of energy transfer from detritus to prawns. The utilization of energy derived from benthic production and detritus by prawns could be of great importance in the traditional culture practices in the low-lying areas around Cochin backwaters. In addition to this, selective stocking, supplementary feeding and better scientific management could augment prawn production in these traditional culture systems.

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