STUDIES ON THE HYDROBIOLOGY AND POLLUTION OF THE VEMBANAD LAKE AND ADJACENT WATERS

THESIS SUBMITTED TO

THE COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

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OF

DOCTOR OF PHILOSOPHY

By

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COCHIN-682 031

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DECLARATION

I hereby declare that the thesis entitled "Studies on the Hydrobiology and pollution of the Vembanad Lake and adjacent waters" is an authentic record of research carried out by me under the supervision and guidance of Dr. P.V. Ramachandran Nair in partial fulfilment of the requirements of the Ph.D Degree in the Faculty of Marine Science of the Cochin University of Science and Technology and that no part of it has previously formed the basis of the award of any degree, diploma or associateship in any University.

Cochin - 31

September, 1991.

V· KUNJUKRISHNA PILLAI

CERTIFICATE

This is to certify that this thesis is an authentic record of the research work carried out by Mr. V. Kunjukrishna Pillai in the Central Marine Fisheries Research Institute, Cochin under my supervision in partial fulfilment of the requirements for the Degree of Doctor of Philosophy of the Cochin University of Science and Technology, and that no part thereof has been presented before for any other degree.

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September, 1991

Dr. P.V. RAMACHANDRAN NAIR
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CONTENTS

PREFACE

The candidate joined Central Marine Fisheries Research Institute in 1963. His work was mainly in the Fisheries Environment Management Division. During the past several years he has been engaged in various aspects of environmental problems in the coastal waters of Arabian Sea, Cochin estuary, Vembanad Lake and adjacent waters. During these years he has undertaken several field trips on board large Research Vessels as well as smaller boats collecting data from different types of ecosystems. During the course of his research career he has been associated in various projects as Associate as well as Project Leader and he has published fifty research papers on topics related to hydrobiology and water pollution.

The topic of the thesis is actually a consolidated work on the Vembanad lake and adjacent waters. In order to give a composite picture on the ecological changes in this ecosystem, the data collected through several years representing various periods and seasons have been discussed to give a comprehensive picture of the ecosystem. The candidate has taken considerable effort in standardising the methods applied and making the results as precise and accurate as possible.

In this connection he had the rare opportunity of working in U.K. (1978-79) and U.S.A. (1984). He worked with Prof. J.D. Burton who is an eminent estuarine Chemist and Oceanographer in the Department of Oceanography, University of Southampton, U.K. and the association with him gave an opportunity to sharpen his skill in analytical techniques and to obtain

necessary expertise especially in the analysis of nutrients and heavy metals using Atomic Absorption Spectrophotometer.

On an FAO Fellowship at the Department of Fisheries, Auburn University, Alabama, U.S.A. worked with Prof. C.E. Boyd, an international expert on Water Quality in aquaculture which enabled him to acquire the necessary expertise in the management of water quality in aquaculture. The experience gained from these two laboratories have gone a long way in attaining a high standard of precision and accuracy in the collection and analyses of the data. In addition, joining the intercalibration exercise in metal analyses organised by Dr. R. Sen Gupta of National Institute of Oceanography, Goa has also been of immense help in improving the accuracy of certain estimations.

I express my deep sense of gratitude to Dr.P.V. Ramachandran Nair, Retired Principal Scientist and Supervising teacher for suggesting the problem, his continued guidance, supervision and constant encouragement throughout the course of this investigation.

The work presented here was initiated under the guidance and supervision of Dr. E.G. Silas, former Director of Central Marine Fisheries Research Institute and the present Vice-Chancellor, Kerala Agricultural University. I wish to record my sincere thanks to him for his guidance, help and inspiration.

Dr. P.S.B.R. James, the present Director, Central Marine Fisheries Research Institute has always been a source of encouragement. His active guidance and suggestions helped the candidate to co-author two papers related to the topic which are appended here. I express my sincere thanks to him for all his help, and kind permission for completing this study.

Dr. P. Vedavyasa Rao, Principal Scientist, was always a source of encouragement. His friendly advice and suggestions were always helpful in completing this work. I am thankful to him for his help and advice.

The data presented is subjected to some detailed statistical analysis which was possible with the help of my colleagues in the respective discipline. I wish to record my sincere thanks to Dr. A.K. Kesavan Nair, Senior Scientist (CIFT), Shri. M. Srinath, Senior Scientist and Shri. T.V. Satyanandan, Scientists of CMFRI for their help in carrying out the statistical analysis. A special thanks to Dr. K.S. Scariah, Senior Scientist for the help in drawing some of the figures using the computer. I am also thankful to the Director, CMFRI for permitting me to use the computer facility in the Institute.

For the last several years the author received sincere and valuable technical help from Mrs. K.K. Valsala, Technical Assistant, in analysing almost all the samples for various parameters from which data are presented here. I wish to record my sincere thanks to her for all the help and assistance received.

A number of my colleagues with whom I had associated at one time or other had helped me to a great extent in my work. I take pleasure in recording my sincere thanks to my colleagues, Dr. K.J. Joseph (Reader in Department of Marine Sciences, Cochin University of Science and Technology), Shri. V.K. Balachandran, Technical Officer, CMFRI, Dr. C. Suceelan, Senior Scientist, Shri. (Late) I. David Raj, Scientist, Dr. A.G. Ponniah, Senior Scientist, Fish Genetics Bureau, Allahabad, Dr. P.K. Krishnakumar, Scientist, C.M.F.R.I., and Shri. Sankar V. Alavandi, Scientist (CIBA, Madras).

Prof. C.V. Kurian, my respected teacher was kind enough to go through the manuscript and offer many valuable suggestions to improve the presentation. I am indebted to him for his suggestions and sincere advices.

INTRODUCTION

1. INTRODUCTION

The large expanse of waters on the west coast of India extending from Alleppey to Crangannore separated from the Arabian Sea by a narrow strip of land is a backwater system of lakes and lagoons which is connected to the sea at Cochin and Azhicode. The portion of this system that extends from Alleppey to Cochin is generally known as the Vembanad Lake.

A number of scientific reports are available dealing with varied aspects of the ecology of the Vembanad Lake such as hydrography, nutrients, primary productivity, plankton, benthic fauna, crustacean and molluscan fishery resources. The hydrography of this lake has been studied by a number of workers (Balakrishnan, 1957; Ramamritham and Jayaraman, 1963; George and Kartha, 1963; Cheriyan, 1967; Josanto, 1972; Shynamma and Balakrishnan, 1973; Balakrishnan and Shynamma, 1967; Sankaranarayanan and Qasim, 1969). The physico-chemical characteristics of this dynamic estuarine system shows significant changes in time and space in the annual cycle since it is influenced to a large extent by the tidal flow from the sea as well as from the fresh water discharge by the rivers into the lake. Seasonal changes in temperature are not much pronounced in the estuary although the surface water often shows extreme variations than the bottom waters. Due to warm weather and maximum solar radiation during the summer period the temperature remains uniform throughout the water column. Thermal stratification is not distinct during the summer season, but during monsoon season from May onwards a sharp thermal gradient develops in the estuary.

It has been estimated that a total quantity of 11,000 million cubic metres of water is drained through this lake into the Arabian Sea annually by the rivers. Varying degrees of salinity, from fresh water to seawater exist in the lake and the backwater system, depending upon the amount of fresh water discharged by the various river systems. When the streams are in flood, the lake and the inland channels are filled with fresh water which is found far down to the Cochin channel during the period of the year. The dissolved oxygen normally ranges between 3.5 to 6 ml/l. At deeper layers a rapid lowering of the levels have been reported during the monsoon months.

From the information available it is noticed that a cycle of events leading to the fluctuations in the physico-chemical factors in Vembanad lake is fairly regular, and year by year can be divided into three seasons of four months each: (1) pre-monsoon season (Jan-April) of stable hydrographic parameters showing typical marine conditions, (2) a monsoon season (May-Sept) associated with pronounced changes in environmental features, and (3) a post-monsoon period of recovery (Oct-Dec) when the marine component begins to develop in the estuarine system.

As the Vembanad Lake is known to have a rich fishery resource, considerable work has been carried out on the biology and fisheries of both fin fishes and shell fishes of these waters. Some of the contributions are those of Menon and Raman (1961); George (1962); Kuttyamma and Antony (1975); and Kathirvel et. al., (1976). A detailed study of the limeshell fishery was reported by Rasalam and Sebastian (1976). The significant reports on the fishery resource include the pioneering work of Shetty (1965) and the recent studies by Samuel (1969) and Kurup (1982).

The total production of fish and other related resources of the Lake is reported to be about 5825 tonnes, of which prawns constituted more than 30 percent. Apart from this, there is a substantial lime shell fishery which is contributed by both live clams as well as sub-soil deposits of white shells.

The composition of fish and prawn catches from these waters is as follows: Prawns (Metapenaeus dobsoni, M. monoceros, M. affinis, Penaeus indicus, Macrobrachium rosenbergii) 60-70%; Mullets (M. cephalus, M. macrolepis, M. cunnesius, M. parsia, M. seheli) 11%; pearl spots (Etroplus suratensis and E. maculatus) 10%; cat fishes 9% and others 1% (Jhingran, 1982). Post larvae of different species of prawns exhibit considerable fluctuations in abundance. Those of M. dobsoni, M. monoceros, P. indicus are present almost throughout the year, the largest numbers were found during March-June and October-December. The prawn fishery of Cochin backwaters is mainly contributed by the juveniles of M. dobsoni (30-95 mm), P. indicus (45-140 mm) and M. monoceros (35-120 mm). The fishery is abundant throughout the year though the catches are heavier during the monsoon and post-monsoon period than in the pre-monsoon period.

Regarding the qualitative abundance of the fishery resources, one of the earlier reports available is by Shetty (1963). His study indicated that the major commercially important forms are: prawns (M. dobsoni, M. monoceros and P. indicus) and fishes (M. cephalus, M. cunnesius, M. parsia, M. macrolepis and M. waigiensis) in the upper half of the backwaters and Lates calcarifer, Chanos chanos and Etroplus suratensis in the lower half. In addition to these, the Sciaenids (Sciaena coiter) the perch (Lutianus argentimaculatus) and the cat fishes (Tachysurus spp) are found in good numbers in the backwaters. Shetty reported 120 species of fishes including crustaceans and crabs. However, in a recent study, Kurup (1982) reported 150 species of fishes belonging to 100 genera and 56 families from the Vembanad Lake. The fish species which are inhabiting the different zones of the estuary are grouped by Kurup and Samuel (1987) as follows: (1) 23 species of oligohaline fishes, (2) 38 species of true estuarine fishes of which (a) 10 species are inhabiting all zones irrespective of salinity distribution, (b) 16 species confined to high saline areas and (c) 12 species which are observed in the transition zone, (3) 89 species of marine fishes of which 41 species are euryhaline and 48 are stenohaline in their habitat.

Apart from the fin and shell fish fishery, the Vembanad Lake is a major source of lime-shell fishery. The clams that contribute to the fishery are: Villorita cyprinoides (Gray); V. cyprinoides var. cochinensis (Hanley); V.cyprinoides var. delicatula (Preston); V. cornucopia Prashad; Meretrix meretrix (Linnaeus) and M. casta var. ovum (Hanley). Villorita contribute to more than 90 percent of the clams of this lake.

The clams which get an ideal habitat for growth are yearly subjected to the south-west and north-east monsoon rains. During monsoon, flood waters from the rivers carry large quantities of mud and silt into the lake which settle on the clam beds. It is presumed that larger clams which do not exhibit much locomotor effort to escape are buried and perish. This process and natural mortality might have contributed over the centuries to the acretion of a wealth of lime shell deposits in the Lake. The lime shell that contribute to the fishery is broadly known as 'white shells' and 'black shells'. The white shells are found as sub-soil deposits and are known to extend at places upto several feet below the surface of the soil. The shells of the Villorita species are black in colour and that of Meretrix varies from distinct or pale yellow or even brown. The live clams found on the bottom of the lake are collected, boiled and their flesh is separated and marketed. Rasalam and Sebastian (1976) reported that during 1968, the shell fish catch was 1,01,312 tonnes. The lime shell fishery in the lake continues to support a large number of fishermen population living on the banks of Vembanad Lake.

Owing to the high productivity and extremely favourable physical and biological conditions for growth and propagation, the animals associated with these brackish water environments are rich and varied. The prawn resources of the lake form an important resource from the commercial point of view. It is already known that the prawns temporarily utilise the biotic niche for completing their life cycle. The question arises as to what will happen if the estuary dependent prawns are deprived of the environment and whether the resource can adjust to the new conditions brought by changes in the environment. These are questions still to be answered. But all indications are that the fertile estuarine environment plays a major role in the life and survival of the prawns, and it is essential that the environment is not disturbed for continued high productivity of the resources.

Among the more important physical features of the estuarine system, the wind generated and tidal currents causing the circulation of the water form the master factor which play an important role in making these waters a highly complex environment. It is the water circulation patterns which govern factors like distribution of other chemical components of the water in addition to salt content, physical properties such as temperature, suspended matter and biological populations, especially of those species with planktonic stages in their life history. It must be emphasised that all the above factors play complex interactive roles in determining the distribution, survival and growth of young fishes and prawns during their sojourn in the lake. The mechanisms involved and the extent to which changes in these factors influence the productivity of the fishery resources remain to be fully elucidated. However, it is only reasonable to assume that any interference which will upset the balance of the natural equilibrium prevailing in this dynamic ecosystem will have its own adverse effect on the resources.

During the peak monsoon period the fresh water discharge from the southern rivers exceeds 1500 m^3/sec. During this period the tidal influx is observed upto 11 km. During dry season the tides of Cochin are of a mixed semidiurnal type with an average range of about 0.9 m with the highest known tide of 1.75 m. The salinity of the lake gradually reduces from the north towards south ranging from near sea water conditions to traces. However, during the summer months, from the month of December through May, when the flow of the river systems dwindle, on account of tidal action and density, converts the waters in the lake and the inland channels down to 80 km from Cochin becomes saline. The Vembanad Lake and the backwater system exert considerable influence on the ecology of the surrounding areas.

One of the major hazards to the cultivation of paddy in the agricultural fields lying adjacent to the Vembanad Lake is the incursion of saline water through tidal flow, especially during the summer months. To prevent salt water incursion and to promote a double crop of paddy in about 50,000 ha of low lying fields in the area, it was decided to construct a 1463 metre long barrage rising 92 cm above the level of high tide at Thanneermukkom in the Vembanad Lake at an estimated cost of Rs.485 lakhs. The barrage started regular functioning from the summer of 1976 and since then this has resulted in some ecological changes in the lake in general and in the area south of the barrage in particular.

The pollution caused by the discharge of partially treated or untreated wastes from the factories, sewage and chemicals from agricultural operations (both fertilizers and pesticides) finding their way into the water bodies are the main factors contributing to the water pollution problems in these waters (cf. Appendix 1 & 2). In recent years there have been a number of reports about fish kills due to water pollution in the backwaters around Cochin, which included the Periyar river near the industrial area at Eloor and also the Chitra-puzha near Ambalamedu, another industrial suburb of Cochin. The quantity of effluents discharged into the rivers from this area together is estimated around 200 million litres per day (Nair, 1982). Several instances of fish kills have been reported from this area (Silas and Pillai, 1976; Nair et. al., 1981). When the impact of pesticides on the ecosystem is considered, the main aspects of the problem are their effects on non-target organisms, their ability to persist in the environment and also their tendency to bioaccumulate in various trophic levels. It is reported that the total quantity of pesticides used annually in Kerala State is about 1000 tonnes, of which more than 250 tonnes are used in the paddy fields of Kuttanad region situated adjacent to Vembanad Lake.

Of late, there have been reports of fish kills as well as significant reduction in the catch of some of the important fishery resource from this lake system. One of the reasons attributed to the same is degradation of water quality due to various pollutants including industrial and agricultural wastes. Human interference such as construction of barrage and land reclamation adds to the environmental degradation and ecological imbalance resulting mainly in the reduction of total available area or by change in the chemical composition of the ambient water.

These investigations cover a crucial period when human interference in this sensitive ecosystem has considerably influenced the ecology. Unlike other investigations which are centred mainly in the Cochin backwater, the present study deals with the entire estuarine system in totality on several parameters related to hydrography, ecology of biota, productivity and also the effects of pollution. The objective of this study has been thus to review the systems physical, chemical and biological features through varying periods of time at locations where human interference is high so that an overall assessment of the changing ecology could be made so as to impress on the scientific community whether remedial measures could be undertaken in sensitive areas. It is also the objective of this study to point out thrust areas where concerted efforts from a larger body of scientists and administrators who can sit together and chalk out programmes for a co-operative endeavour in monitoring the most sensitive areas and also suggest ways and means to exploit the rich and diverse resources at optimum levels with emphasis on conservation and protection from environmental degradation resulting in depletion of resources. Areas also have been identified which are potentially more productive where aquaculture could be intensified.

MATERIALS AND METHODS

2. MATERIALSAND METHODS

Data presented in this work covers a wide spectrum of environmental and ecological parameters such as hydrography, plankton, fish biomass, pollution and ecology. A total of twenty two stations have been sampled covering the different zones of the lake system during different time frames in order to include all the cycle of events that follow the monsoon, the preceeding and succeeding periods and also the tidal incursions from the marine environment. Data on hydrography, primary production and zooplankton were collected from seven stations (Fig. 1A) covering Azhicode to Alleppey region. Six stations from Cochin to Muhamma were covered for hydrography and fish resource (Fig. 1B). Data on hydrography, primary production, zooplankton and fish resource were collected from six stations in the Cochin-Eloor grid (Fig. 1C). For metal levels in bivalves, samples were collected from four stations in the Cochin estuarine system (Fig. 1C). Fish kills were investigated at the respective periods of occurrence. Regular samplings had been carried out earlier during the seventies (before the construction of the Thanneermukkom barrage). After the commissioning of the barrage in 1976 data were also collected from the area for a comparative study. The picture presented here are from average values obtained from a number of observations from the lake system as a whole which enabled an evaluation of the changing ecology with reference to man-made changes including that of pollution.

Standard methods relevant to each aspect of sampling and analysis have been carried out with emphasis to precision and accuracy in chemical analysis. Water samples were analysed following the method of Strickland and Parsons (1968 and 1972). Nutrients were analysed using a UV/VIS (PYE

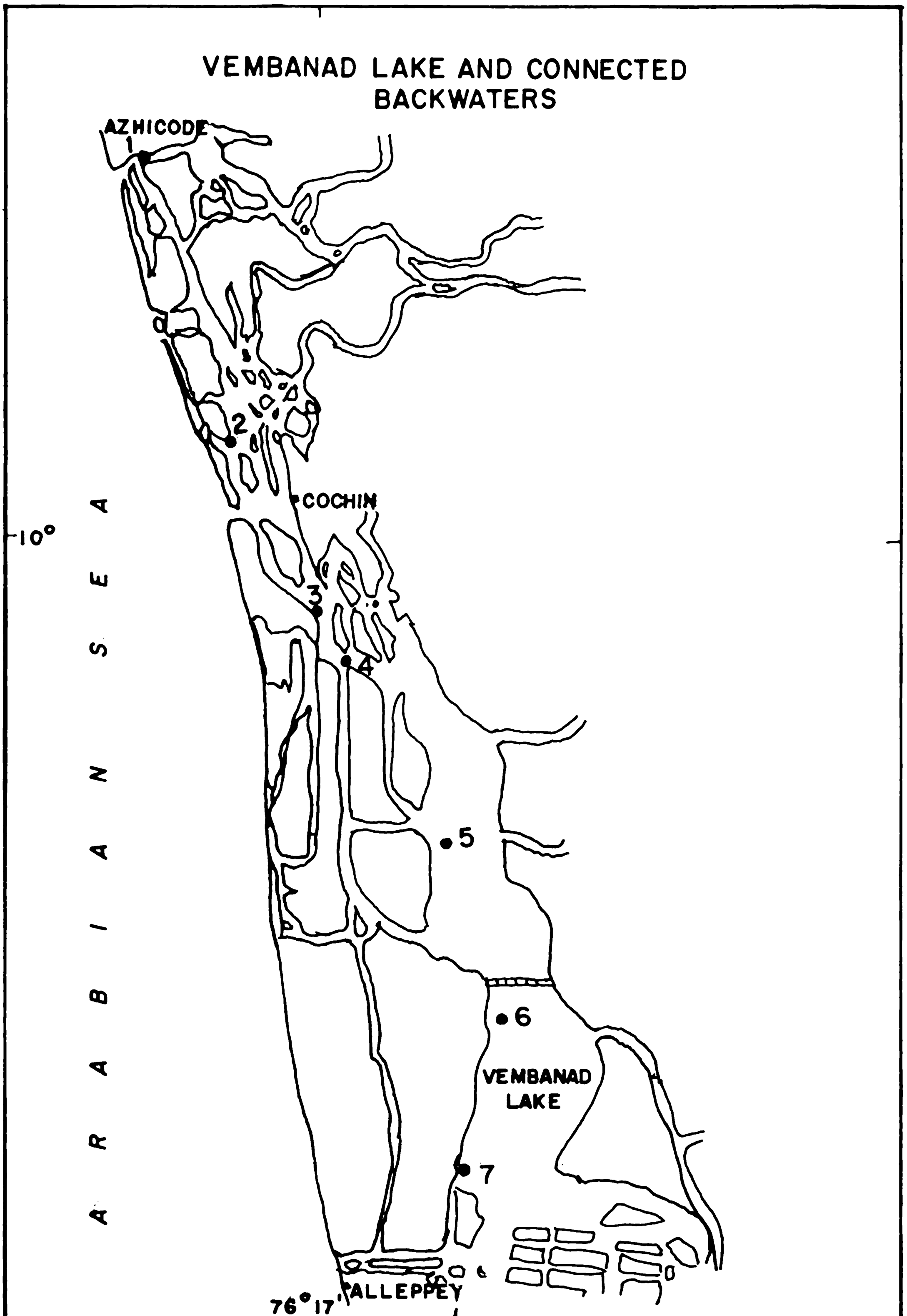


Fig. 1-A. Map showing station positions

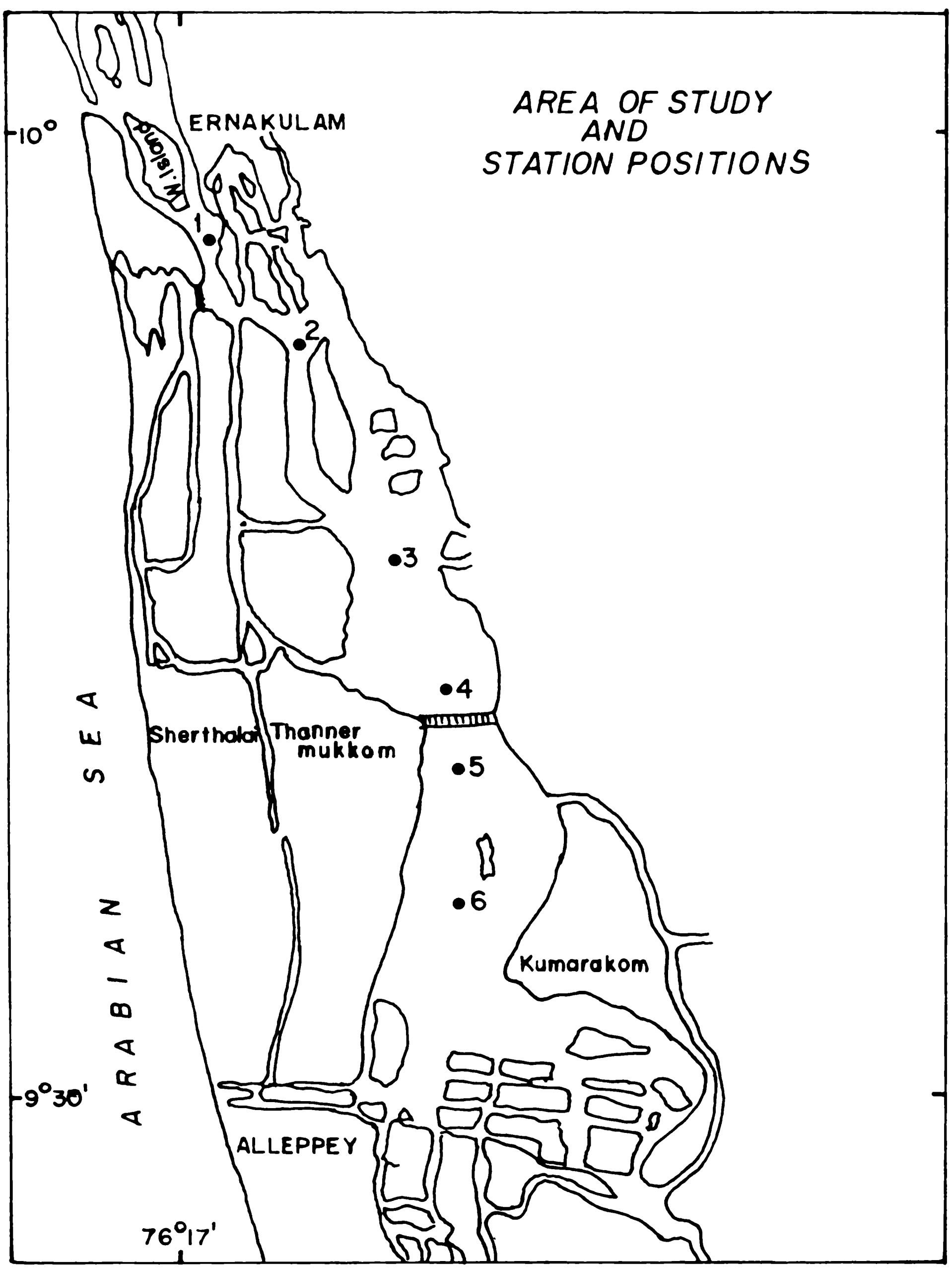


Fig. 1 B. Map showing station positions.

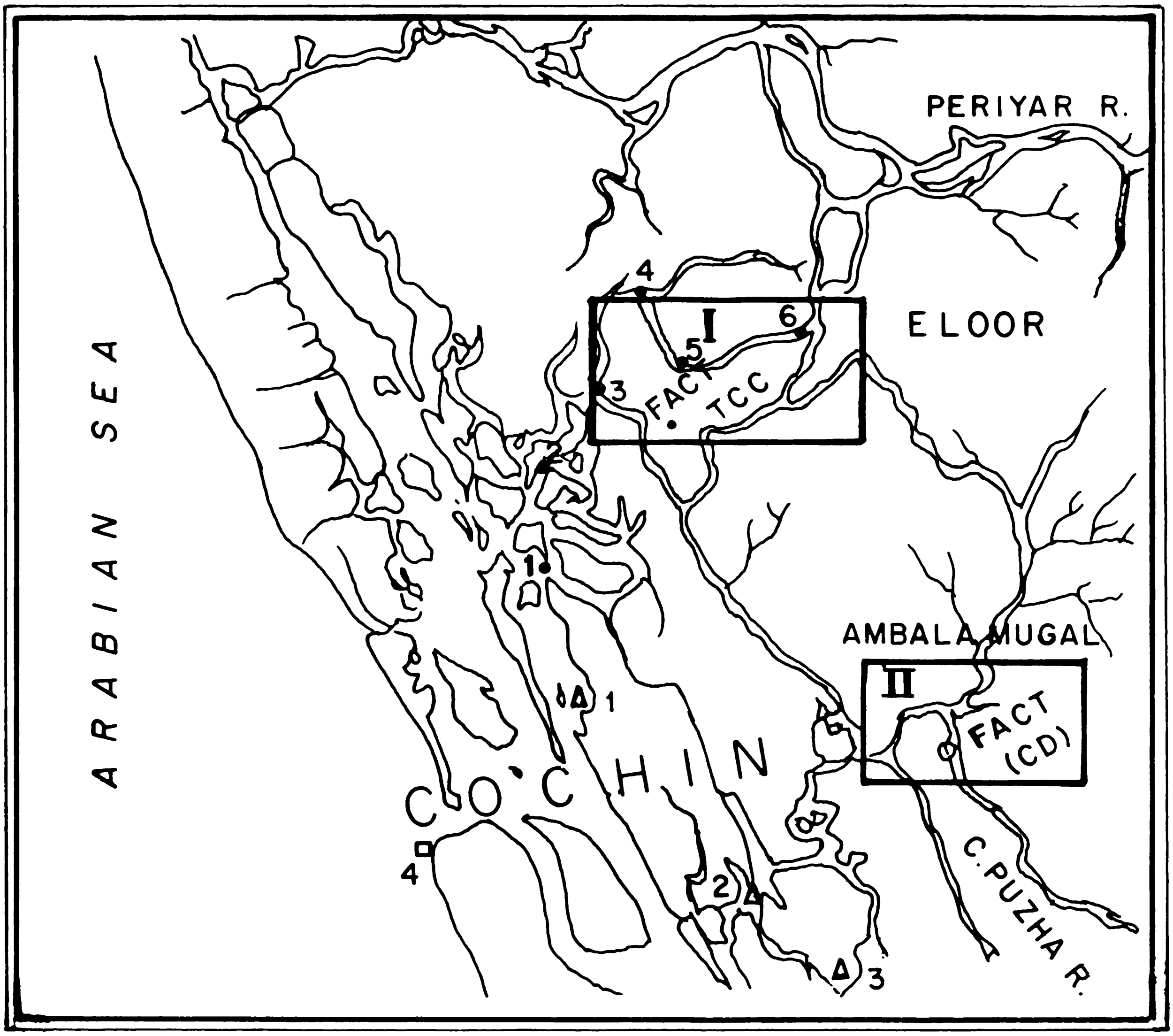


Fig.1C. Map showing locations of case studies.

I II Locations of fish mortalities.

1 – 6 Stations monitored for ecological investigations.

Δ Stations from which *Villoritta* sp. were collected.

□ Stations from which *Sunetta scripta* were collected for metal analysis

UNICAM) Spectrophotometer. Productivity data were collected by C^{14} technique. Zooplankton samples were taken from surface using a ½ metre diameter nylon net (mesh size 0.34 mm) operating for 15 minutes at 3 knots from a 30' boat. The total numbers of zooplankton were calculated for 1000 m^3. For the collection of fish samples a specially designed experimental trawl net (length: 4 m, head and foot rope: 5.4 m and mesh size: 8 mm) was operated and each haul was of 30 minutes duration. Statistical analyses were carried out wherever necessary to correlate the level of variations as well as interrelationships.

Details of the methodology followed for important parameters as well as experiments carried out to ascertain precision and accuracy are given below.

2.1 Standardisation and intercalibration of methods

2.1.1 Water analysis

As part of the standardisation programme of the methodology for nutrient analysis, detailed analyses were carried out to determine the suitability of two methods for the estimation of total phosphorus in water.

For total phosphorus analysis of water, all organic phosphorus must be converted to inorganic orthophosphate so that it may be measured. Digestion and oxidation are employed to release phosphorus from organic combination. The American Public Health Association (1980) recommended three digestion procedures; persulfate digestion, sulfuric acid-nitric acid digestion and perchloric acid digestion. The persulfate digestion technique is much easier to conduct than the other two procedures, so it was decided to determine if the persulfate

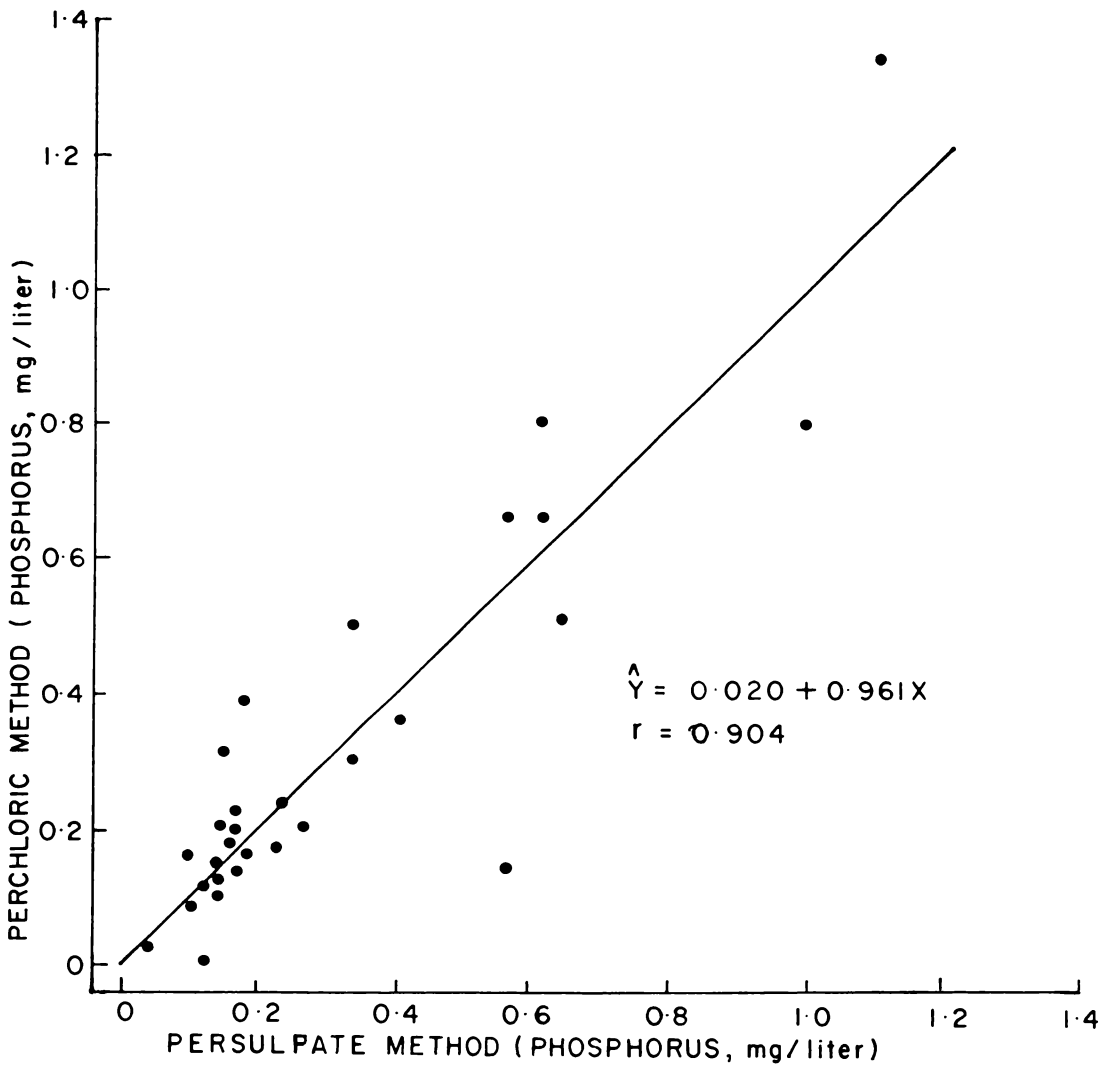


Fig. 1f. Comparison of perchloric and persulphate methods.

digestion method compared favourably to the perchloric acid procedure for analysing water samples for total phosphorus. Phosphate concentrations in the digested solutions were determined by the ascorbic acid method (APHA, 1980). The precision of each method was estimated by making seven replicate determinations on each of three samples which represented low, intermediate, and high total phosphorus concentrations (Analytical Quality Control Laboratory, 1972). Next, total phosphorus analyses were made by each method on a series of 29 water samples, and the regression equation was computed (Fig.1f). Finally, total phosphorus concentrations were measured for three samples. Portions of these samples were then spiked with 0.1 mg/L of inorganic phosphorus, and total phosphorus was determined again. The percentage recovery, which is an estimate of accuracy was estimated by the following equation:

$$\% \text{ recovery} = \left(\frac{F}{I + S}\right) 100$$

where F = the final total phosphorus concentration, I = the initial total phosphorus concentration; and S = concentration of phosphorus in spike. Details of the comparison between the two methods and results of the spike recovery estimations are given in tables I and II respectively.

Table 1. Comparison of means and precision for total phosphorus concentrations (mg/L) obtained by the perchloric acid method and the persulfate method. Each sample was analysed seven times by each method.

Sample No.	Perchloric method			Persulfate method				
	Mean	SD	CV	Mean	SD	CV	F	t
1	0.070	0.077	111.0	0.089	0.011	12.4	48.7"	0.65
2	0.159	0.009	5.7	0.152	0.029	19.1	10.4"	0.60
3	0.662	0.007	1.5	0.505	0.026	5.1	14.2"	0.39"

"Significant at 1% level probability. A significant F value means that variances were not homogeneous; a significant t value indicates that means differed significantly.

Table II. Spike recovery estimates for total phosphorus analysis by the perchloric acid method and the persulfate method. Each estimate is based on triplicate analyses.

Sample No.	Phosphorus	Recovery %	
		Perchloric method	Persulfate method
1	0.178	91.8	89.2
2	0.384	95.8	100.0
3	1.358	102.0	99.4

2.1.2 **Estimation of ammonia in water**

Although a number of methods are available for the estimation of ammonia in seawater, difficulties are still encountered in the routine laboratory analysis in obtaining reproducible results owing to interference of high blank values. However, the indophenol blue method is still accepted as the standard method for ammonia in seawater. Certain detailed investigations in the method of Solarzano (1969) with various modifications were carried out of which the following gave satisfactory results.

To a 50 ml sample add 2 ml of phenol-methanol reagent (by substituting ethanol with methanol blank value could be reduced substantially but without affecting the reaction)followed by 2 ml nitropruside reagent and cover the flasks with aluminium foil allowing the minimum exposure to light while adding the reagents and keep the samples away from light. After one hour the absorbance is measured at 640 nm. (With 10 cm cuvettes the blank absorbance was 0.07 - 0.09. Beers law was obeyed in the concentration range 0.1 to 10 ug at NH_3N/L and the factor relating to absorbance/Concentration is 6.5 for sea water) (Fig.1e).

Among the various methods available for the estimation of ammonia in sea water, the methods of Solarzano (1969); Truesdale (1971); Harwood and Kuhn (1970) and Liddicot et. al., (1974); were tried. Considering the simplicity, the method of Solarzano appeared to be preferable.

2.1.3 **Mercury analysis in water**

Sample preparation and analysis

The method consists of two steps, viz.,

(1) Wet oxidation for the conversion of all mercury into divalent mercury and, (2) determination of mercury by cold vapour atomic absorption technique (Hatch and Ott, 1968) using ECIL Mercury Analyser.

About one litre of the sample is collected in acid-cleaned glass bottles. It is acidified by adding 2-3 ml concentrated nitric acid. A suitable aliquot of the sample containing not more than 1.0 ug of mercury is taken in a 150 ml beaker and diluted to 80 ml if necessary. 10 ml of sulphuric acid (1:1) and 3 ml of conc. nitric acid are added while stirring. 10 ml lots of potassium permanganate solution (5% v/v) are added until the colour persists for at least few minutes.

10 ml of freshly prepared potassium persulphate solution (5% v/v) is added and kept on a water bath for 2 hrs. It is cooled then to room temperature, transferred and made upto 100 ml in a volumetric flask. Blanks and

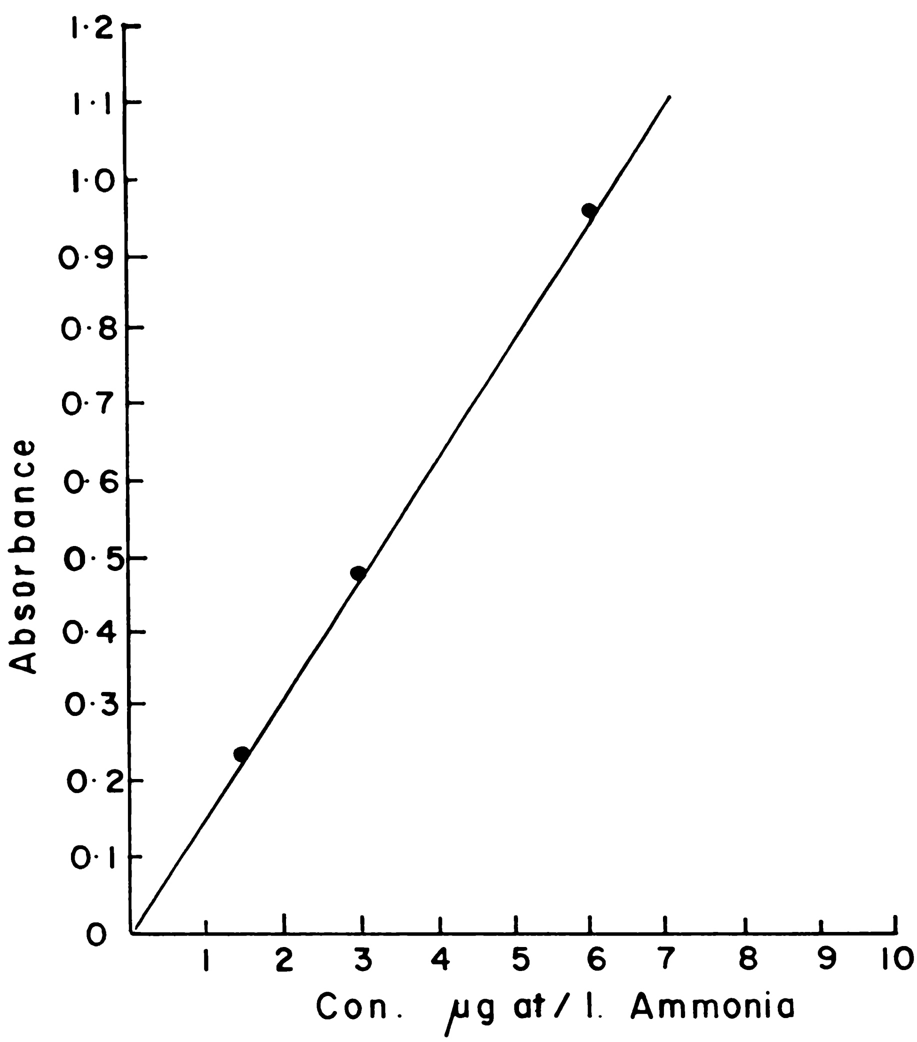


Fig.1e. Standard graph for Ammonia

standards, containing 0.1 to 1.0 µg of mercury through the procedure are also run. About 20 ml of the solution is taken in the reaction vessel (R2) and the vapour is generated by operating the instrument. The absorbance of the vapour produced is measured. (Excess potassium permanganate is reduced with a few drops of 10% W/v hydrozyl amine hydrochloride in 12% (w/v) sodium chloride solution). The mercury content in the aliquot was calculated as follows:

$$\text{Mercury content in water} = \frac{\text{Mercury content in aliquot (ng) x 5}}{\text{Volume of sample taken (ml)}}$$

Preparation of standard

1 ml of mg/ml H_gNO_3 (1000 µg/ml) was diluted to 100 ml. From this solution 1 ml (10 µg) was diluted to 100 ml to give 100 ug/ml working solution. From this working standard 0.2 ml, 0.4 ml, 0.6 ml (i.e. 20 ng, 40 ng, 60 ng respectively) were taken for drawing the calibration graph (Fig. 1g).

The average percentage recovery of total mercury from water was 84.5% and the minimum detection limit was 0.2 ng/ml.

2.1.4 Analysis of metals in biological samples

Samples were analysed after wet digestion following the method of Daziel and Baker (1983). The digested samples were analysed on a Perkin Elmer AAS (Model 2380) in an air acetylene flame.

For obtaining reliable data in the sample analysis, especially in metal analysis, it is essential to have high accuracy and precision in the analysis, which invariably depend on the experience of the person, the method followed as well as the infrastructure available. However, to assess the accuracy and precision it is essential to participate in intercalibration exercises and also

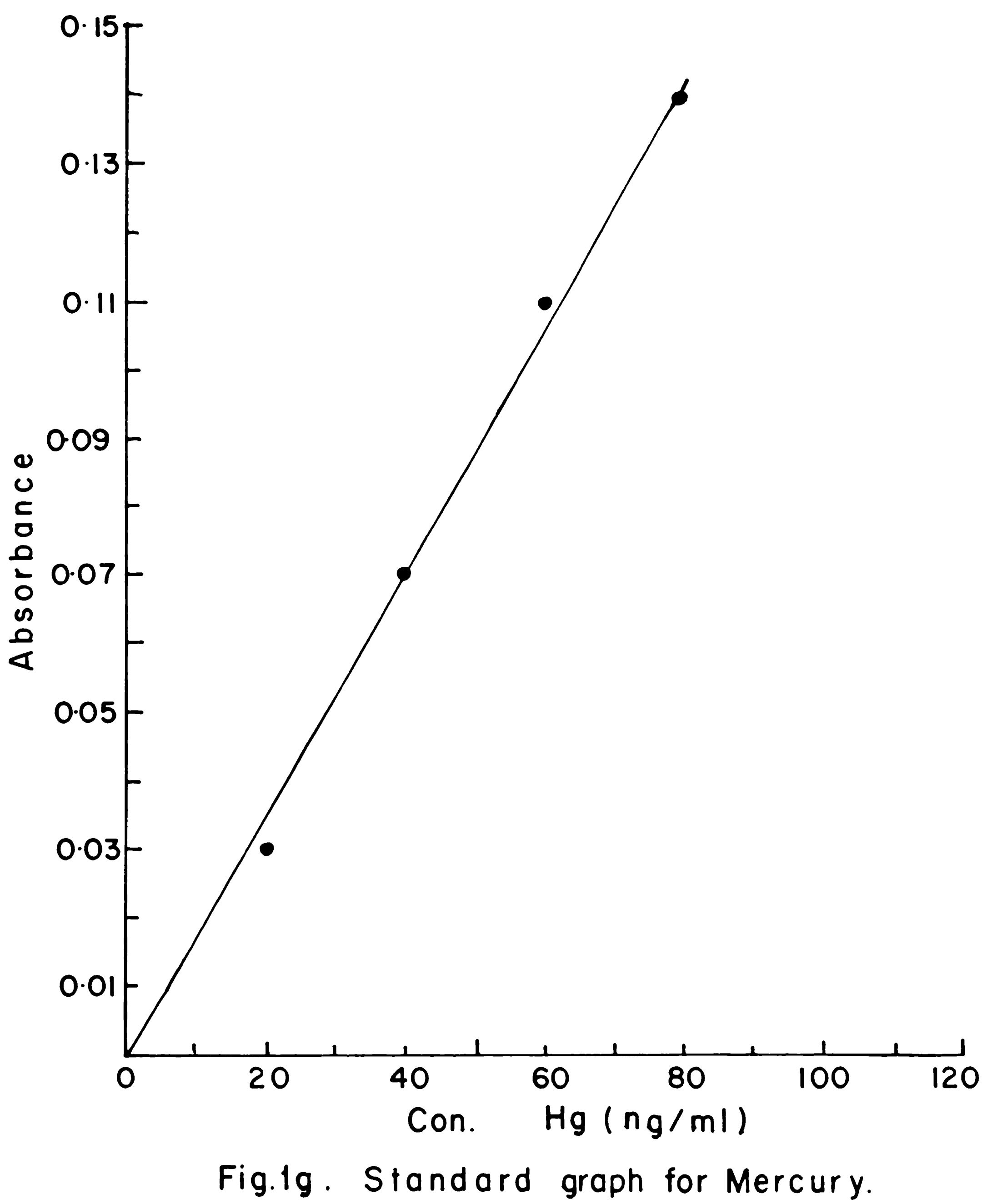


Fig.1g. Standard graph for Mercury.

by doing percentage recovery estimations. With this objective, a number of analyses have been carried out by joining in intercalibration programme as well as by doing percentage recovery estimations (Table 1).

2.1.5 **Intercalibration with NIO, Goa (October, 1989) biological sample**

Metal	% deviation from true value
Cd	- 2.9%
pb	- 11%

2. Material No.9 Sargasso, NIES Japan (1990)

Metal	Present value ug/g	NIES value ug/g	Accuracy %	Precision
Cu	4.65	4.90	- 5.1	4.8
Zn	15.75	15.60	+ 1.0	7.2

Calculation:

1. Accuracy $= \frac{\text{Difference between present value and NIES value}}{\text{Certified value}} \times 100$

2. Precision $= \frac{\text{Standard deviation}}{\text{Mean}} \times 100$

Table 1. Details of percentage recovery estimations

% Recovery test for Trace Metals

Date	Copper (Cu)	Zinc (Zn)	Lead (pb)	Cadmium (Cd)
10.3.89 (Triplicate) 4.0 ug/g to 10g tissue	89.64% C.Mean : 6.48 S.D. : 0.671 S.Mean : 8.05 S.D. : 0.167	96.19% C.Mean : 11.13 S.D. : 0.50 S.Mean : 12.64 S.D. : 0.276	92.4% C.Mean : 0.0875 S.D. : 0.018 S.Mean : 3.76 S.D. : 0.139	100.38% C.Mean : 0.037 S.D. : 0.004 S.Mean : 4.053 S.D. : 0.483
15.5.89 (5 replicates) 25 ug/g to 10g tissue	86.04% C.Mean : 4.39 S.D. : 0.135 S.Mean : 25.27 S.D. : 1.724	83.07% C.Mean : 0.71 S.D. : 0.853 S.Mean : 28.85 S.D. : 1.62	91.26% C.Mean : 0.237 S.D. : 0.088 S.Mean : 22.96 S.D. : 0.465	88.11% C.Mean : 0.117 S.D. : 0.052 S.Mean : 22.14 S.D. : 2.45
17.5.89 -do-	89.11% C.Mean : 5.562 S.D. : 0.742 S.Mean : 26.34 S.D. : 0.923	101.4% C.Mean : 8.75 S.D. : 0.736 S.Mean : 34.23 S.D. : 0.493	97.03% C.Mean : 0.265 S.D. : 0.048 S.Mean : 24.52 S.D. : 0.402	98.61% C.Mean : 0.058 S.D. : 0.014 S.Mean : 24.71 S.D. : 0.251
Average	88.26%	93.55%	93.56%	95.70%

1. Instrument used : Perkin Elmer (2380) using an Air-Acetylene Flame at standard conditions - Sensitivity check carried out before each set of analysis. B.G. correction applied wherever applicable.

2. Standard used : SPECTROSOL (BDH-England) 1 ml = 1.0 mg was used with appropriate dilutions.

3. Method followed : Dalziel, Jad Baker, C (1983). Analytical methods for measuring metals by atomic absorption Spectrophotometery. FAO Fish Tech. Pap. 212: 14-20.

4. Material used : Tissue. Soft parts of P. indicus 10 g digested with 1:1 Nitric Acid + Hydrogen Peroxide - diluted to 25 ml. C. - Control; S. spiked.

5. Procedure : 10 gm of homogenised, weighed sample was taken in 100 ml acid washed glass beaker. To this, 10 ml of freshly prepared solution of 1:1 v/v hydrogen peroxide/nitric acid was added and allowed to stand for one hour. The beaker was then kept on a sand bath and heated to 160°C. The boiling was continued for 2 hrs till the reaction is over and the volume reduced to about 2-5 ml. The digested solution was allowed to cool, then transferred to a volumetric flask and diluted to 25 ml (filtered on GFC paper if required). Blanks were also run through the same procedure. The samples were then analysed on AAS against appropriate standard calibration.

ENVIRONMENT

3. THE ENVIRONMENT

The Vembanad Lake, now a typical brackish water system is believed to have attained its present configuration in the 4th Century A.D. according to the historical information available (Anon., 1973). It is said that most of the present day lake system was primarily a marine environment, bounded by an alluvial bar parallel to the coastline and interrupted by Arabian Sea at intervals. As a result of a catastrophic deluge which took place in 1341 A.D., parts of the Alleppey and Ernakulam Districts including a number of islands arose thus separating a distinct water body from the sea. (Menon, 1913). Due to the same reason, River Periyar deviated from its original course and entered the sea through Cochin harbour which altered the ecology of the northern portion considerably. This transformation of originally marine environment into an estuarine system is evidenced by the occurrence of large quantities of typically marine shells deposited in many locations in the Vembanad Lake (Preston, 1916).

The Vembanad Lake is the largest brackish water lake system situated between latitudes 9°28' and 10°10'N and longitudes 76°13' and 76°31'E. It has a length of about 90 km and extends from Alleppey to Azhicode. The total area is about 256 sq.km. The depth of Cochin navigation channel varies from 8-12 m and the depth of other parts of the lake is 1-5 m. The width of the lake varies from a few hundred metres to about 8 km. The main sources of fresh water for the lake are two large rivers, Periyar in the north and Pamba in the south. Four other rivers, viz: Achancoil, Manimala, Meenachil and Moovattupuzha also empty into the lake. During the southwest monsoon the lake receives an average rainfall of 3300 mm and is virtually converted into fresh water basin.

The Vembanad lake and connected backwater system exert considerable influence on the socio-economics of the surrounding areas as the living resources available in the lake plays an important role for the people living on its shore. The most important variable which controls the distribution, survival and growth of plants and animals in this ecosystem is salinity. The wide spectrum of divergence in salinity from almost freshwater to seawater enables the sustenance of a variety of aquatic life both plant and animal, in the lake. An ecological balance has been evolved over the period of its evolution by the biota surviving in this dynamic ecosystem.

The Vembanad lake and adjacent backwaters are more affected by the monsoon. This results in pronounced seasonal variations in the environmental parameters that affect the primary and secondary productions. Changes in the environmental parameters and production rates are also caused by the tidal influx, nutrients distribution, incident solar radiation, nature of the medium and species composition of the primary and secondary producers.

The seasonal variability of the nutrients in the lake demands an understanding of the fresh water discharge into the system, which is chiefly controlled by the spectacular regime of the rainfall during the monsoon months. This provides a general mechanism underlying not only the nutrient distribution but also the other environmental features. The area under study remains marine dominated for about six months, and then, rather suddenly, becomes fresh water dominated for the rest of the year. The far reaches of the estuary both at the northern and southern ends, close to the river basins, remain almost fresh water dominated throughout the year except for a brief period just before the monsoon, when the level of rivers, especially in the Periyar, decreases considerably and the salt water penetrates into the river basins. The other feature of importance is the short term changes brought about by tidal oscillations, but these remain reasonably constant throughout the year, except perhaps during extraordinary changes in metereological conditions.

HYDROBIOLOGY AND FISHERY OF THE VEMBANAD LAKE

4. HYDROBIOLOGY AND FISHERY OF THE VEMBANAD LAKE

4.1 Hydrography

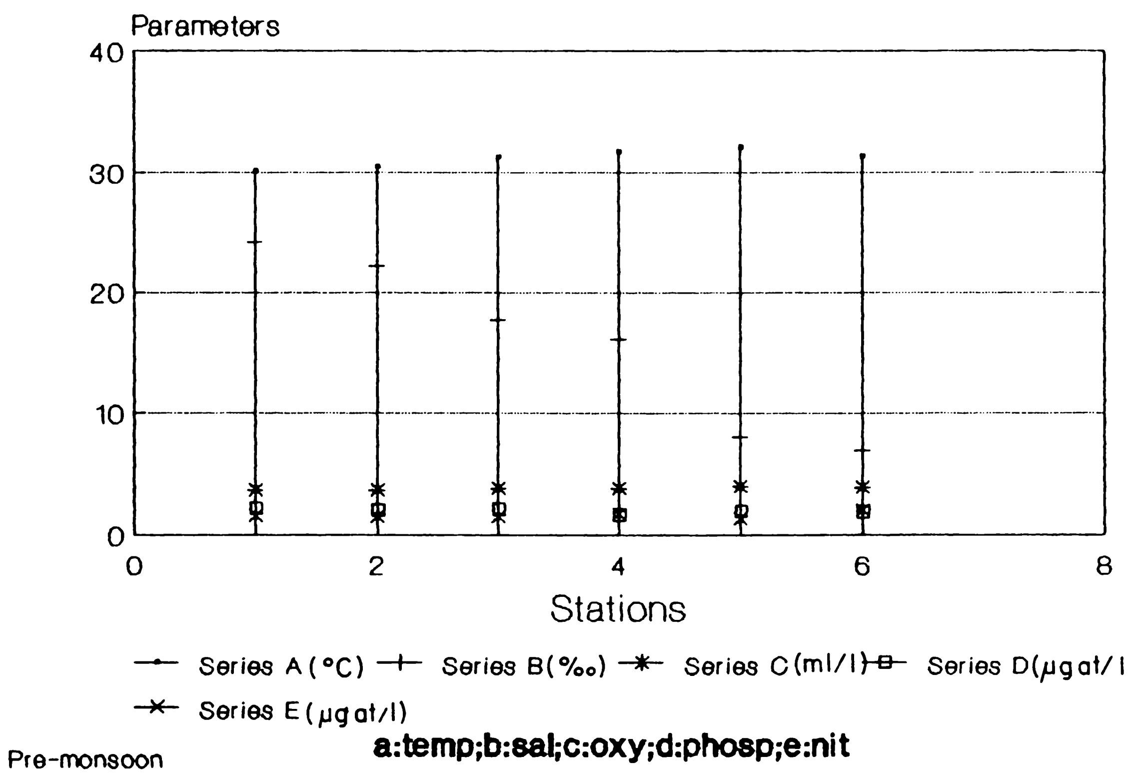
Since the environment dealt with includes estuarine, brackish water and fresh water regimes, the hydrography is influenced to a great extent by the above characteristics. The influence exerted through seasonal changes during pre-monsoon, monsoon and post-monsoon also is apparent in certain parameters such as temperature and salinity. Details of the data are given in Figs: 2-4 and 5-10.

4.1.1 Water temperature

The variations in different seasons in water temperature are very clear. Temperature during pre-monsoon period was always much higher than what was recorded during the other seasons. The maximum temperature recorded is 32°C during pre-monsoon at Stn.5, while at the same station during monsoon season the temperature recorded is only 29.3°C. The water temperature appears to be more stable during the post-monsoon period.

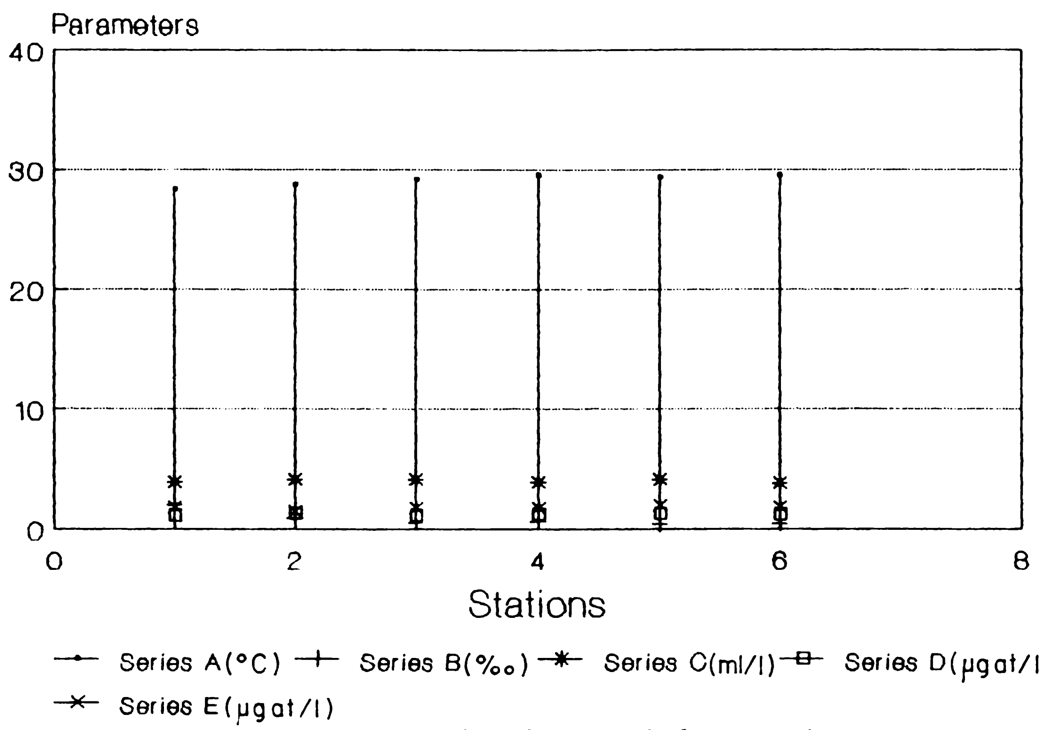
According to Haridas et. al., (1977) the temperature usually decreased with depth. But at stations having shallow water, the temperature did not exhibit much difference between surface and bottom layers. Sometimes pockets of higher temperature were found to occur in the bottom layers at stations near the mouth. But these occurred only in the pre-monsoon period in December. However, Sankaranarayanan and Qasim (1969) states that in the Cochin backwater during the pre-monsoon months when the water is highly saline no thermal stratification exists. The temperature during this period (Jan-April) remains

Fig. 2 Hydrobiology of Vembanad Lake
Hydrography



a:temp;b:sal;c:oxy;d:phosp;e:nit

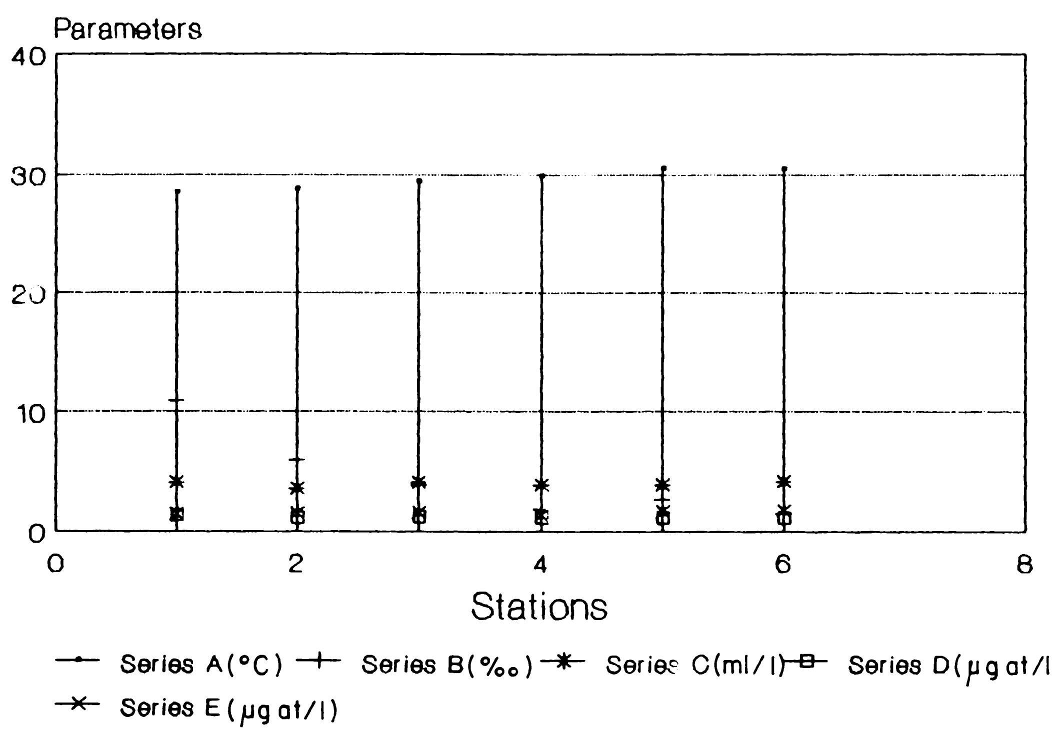
Fig. 3 Hydrobiology of Vembanad Lake
Hydrography



Monsoon

a:temp;b:sal;c:oxy;d:phosp;e:nit

Fig. 4 **Hydrobiology of Vembanad Lake**
Hydrography



post-monsoon **a:temp;b:sal;c:oxy;d:phosp;e:nit** uniform throughout the water column and records its maximum. From May onwards with the onset of the monsoon, the changes in the water temperature become apparent. These are accompanied by a gradual fall at the surface and a very rapid fall at deeper layers during July and August. Thus from June onwards a sharp thermal gradient develops in the estuary which continues with varying degrees till about September-October. They also observed that the changes in the depth profile of temperature clearly indicate that the fresh water discharge alone is not responsible for the changes in temperature, since the variations in deeper layers are far more pronounced and rapid than at the surface. Such a rapid change at the bottom cannot occur unless there is an intrusion of a tongue of cold water from the sea into the estuary. In the present study also, similar trend of stratification, especially during monsoon months was observed in stations located nearer to Cochin bar mouth.

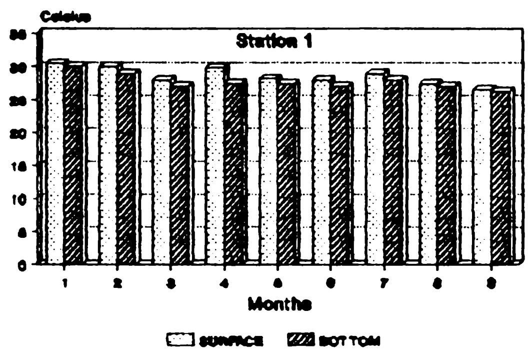
4.1.2 **Salinity**

Among the hydrographic parameters, salinity exhibited extreme variations from almost fresh water condition during monsoon season to relatively high salinity conditions during the pre-monsoon period. The highest salinity recorded at the northern zone during pre-monsoon period is 24.14‰ and the lowest at the southernmost region is 6.88‰ thus showing estuarine characteristics. Towards the north there is a marked increase in the salinity approximating marine conditions. During the monsoon season salinity values were very low especially at the surface indicating the effect of large volumes of fresh water discharge by the rivers into the lake (range: 1.97‰ to 0.47‰). In the zone adjacent to the bar mouth there is certain amount of stratification because of the incursion of shelf waters which remains at the bottom. During the post-monsoon, brackish water condition exists along the greater part of the lake system. A pronounced gradient in the salinity continues for some period during the post-monsoon also. However, distribution pattern of salinity reveals a zonation of estuarine to brackish water conditions which is more apparent during pre and post-monsoon periods.

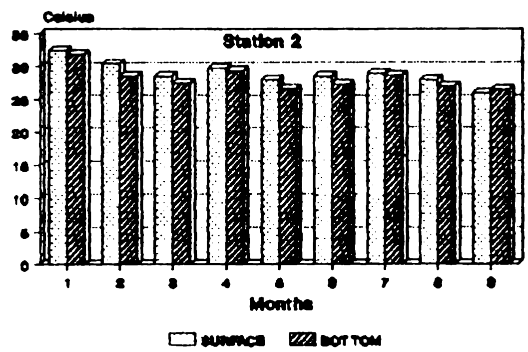
Haridas et. al., (1977) states that an analysis of the distribution along the longitudinal axis showed that the salinity values always fell sharply after Stn.3 (nearer to the present Stn.3 at Thevara) at the surface as well as in the bottom layers during summer. This suggests a more pronounced influence of sea water upto this station, and conversely that of the fresh water beyond this station. During monsoon the area of fluctuation oscillated more towards the mouth of the estuary. This is because the strong fresh water flow pushed back the high saline sea water and the penetration of sea water was restricted to the bottom layers. They also stated that the salinity in general decreases from the mouth of the estuary towards the head. The extent of incursion of saline water depend on the strength of the tidal influx and the fresh water efflux which differ with seasons. The salinity always increases towards the bottom indicating a two layered flow. During summer distinct stratified layers are absent because of well mixed condition enhanced by the strong tidal currents.

According to Sankaranarayanan and Qasim (1969), concurrent with fresh water discharge from the Cochin backwater during the monsoon months, there

Fig. 5 Hydrography and nutrients of Vembanad Lake
Temperature



Temperature



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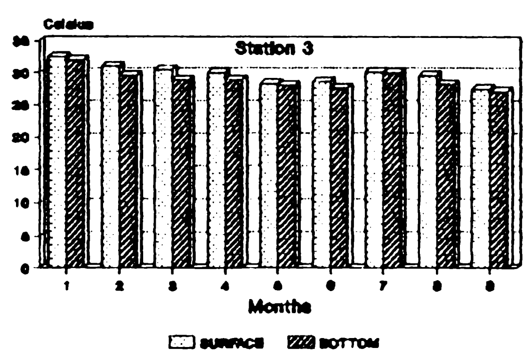
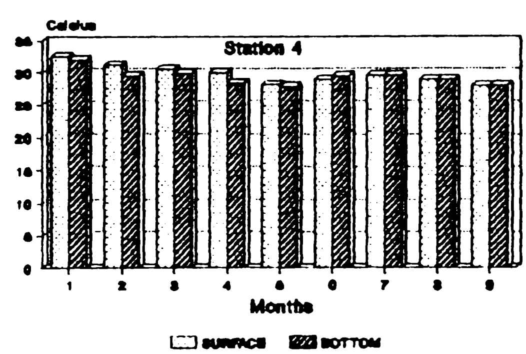
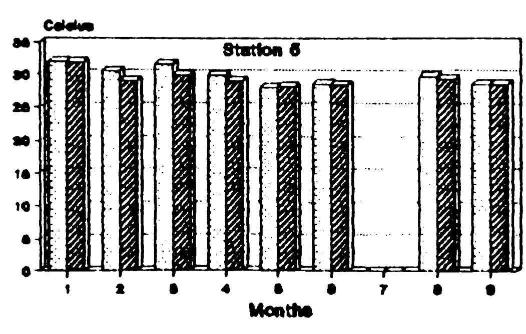


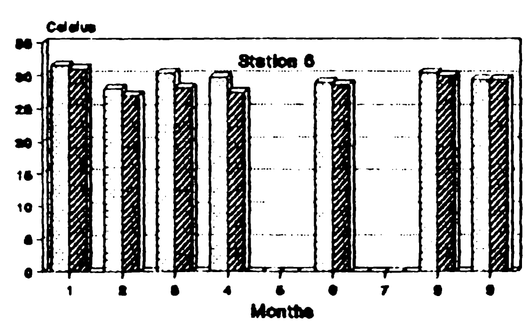
Temperature



Temperature



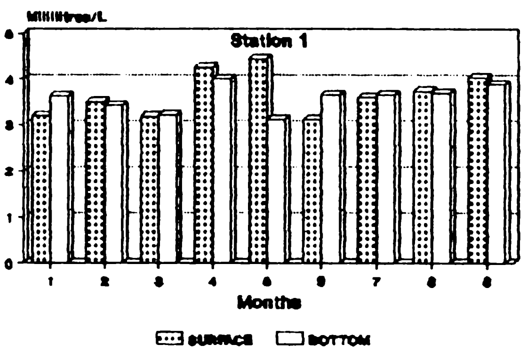
Temperature



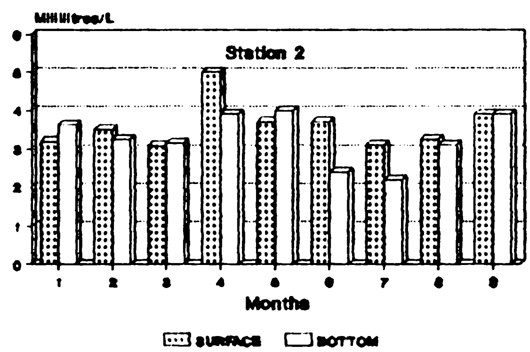
Temperature

Months: April-Dec.

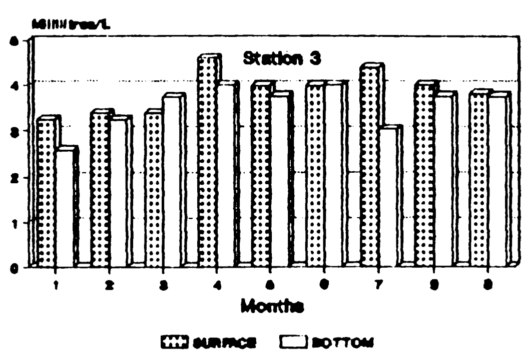
Fig.6 Hyydrography and nutrients of Vembanad Lake
Dissolved oxygen



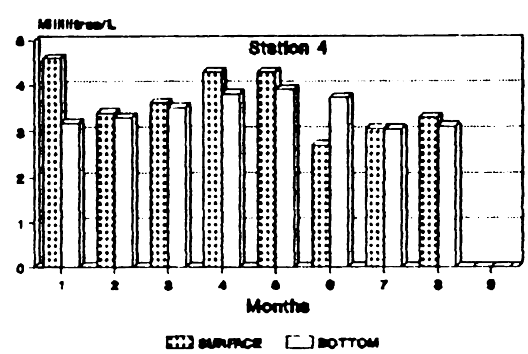
Dissolved oxygen



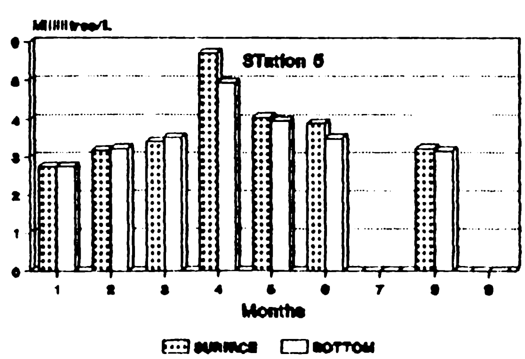
Dissolved oxygen



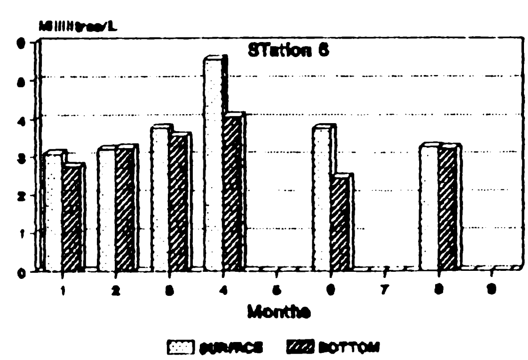
Dissolved oxygen



Dissolved oxygen



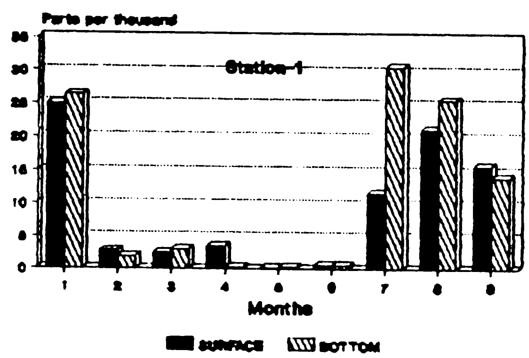
Dissolved oxygen



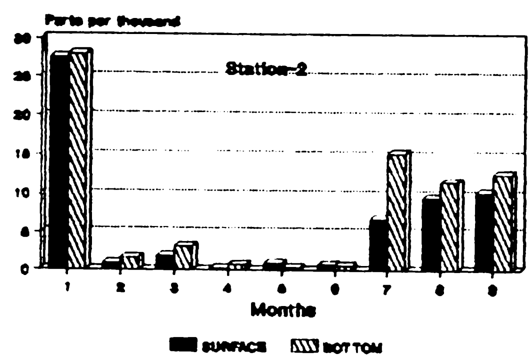
Dissolved oxygen

Months: April - Dec.

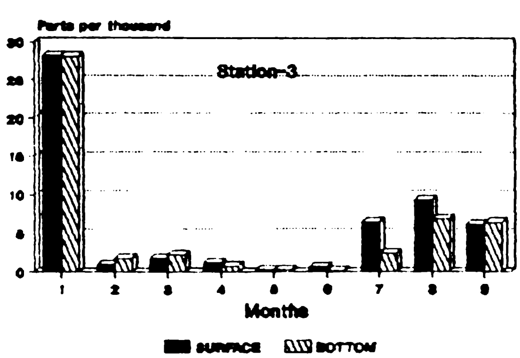
Fig. 7 Hydrography and nutrients of Vembanad Lake
Salinity



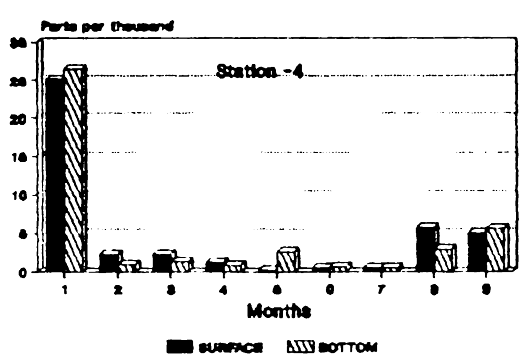
Salinity



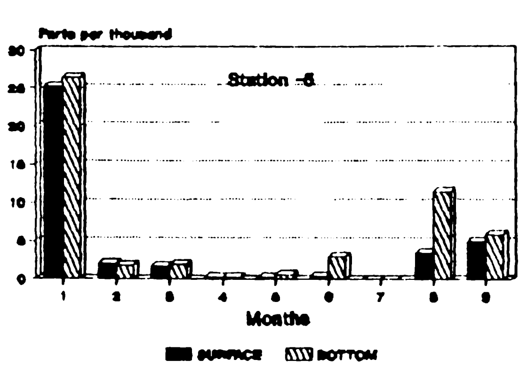
Salinity



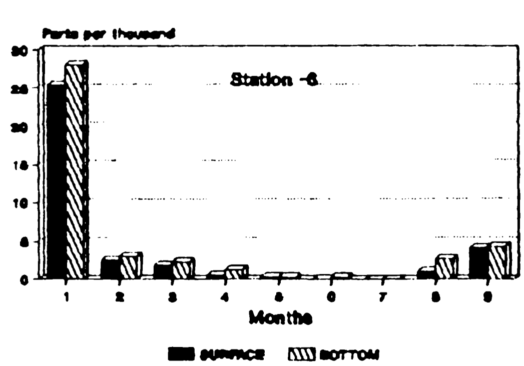
Salinity



Salinity



Salinity



Salinity

Months: April - Dec.

is an incursion of cold saline water from the Arabian Sea into the backwater. This water becomes particularly noticeable at the bottom and has been recognised by earlier workers (Ramamritham and Jayaraman, 1963) as upwelled water from the Arabian Sea which finds its way into the backwater through the main channel.

In a recent study (1990) the author observed that at a typical estuarine station inside the bar mouth in the month of July, while the surface value showed a salinity of only 0.31%, the bottom value was 35.57% . The data collected on an year round basis indicate the same trend as that reported by the earlier workers from Cochin backwater. Invariably, the bottom salinity was always higher than that of the surface.

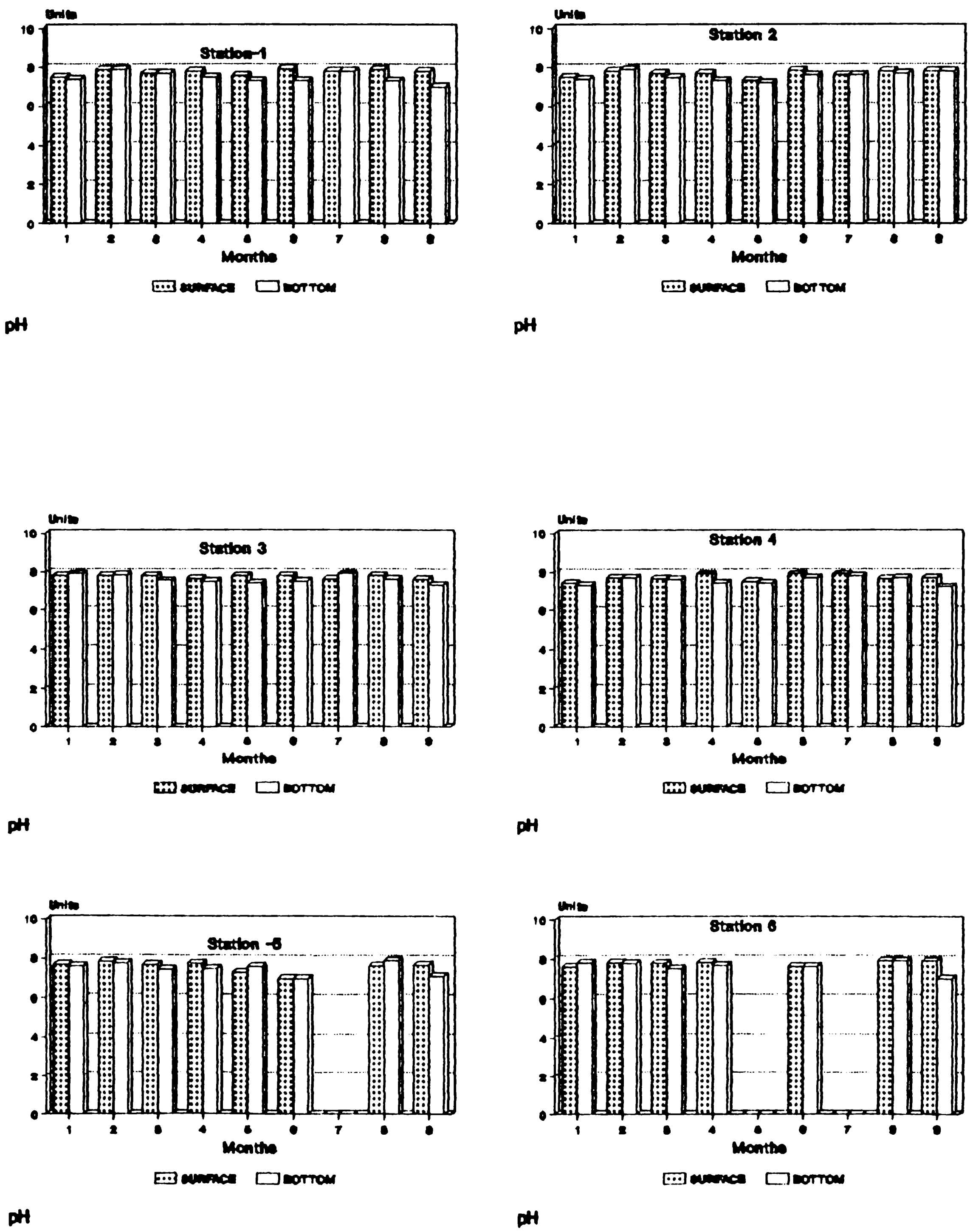
4.1.3 Hydrogen ion Concentration (pH)

The pH distribution did not show much variation in the surface and bottom layers of the water column. However, a certain amount of reduction in pH was noticed in the southern zone, especially during the monsoon season (Fig.8). Higher levels were recorded during September-December period. Earlier observations by Sankaranarayanan and Qasim (1969) showed that maximum values were recorded from October to March and during the period of fresh water discharge the values at all depths decreased reaching a minimum during July and August.

4.1.4 Dissolved oxygen

Dissolved oxygen values do not reveal any significant variations during different seasons which may be due to the flow of water as well as tidal

Fig.8 Hydrohraphy and nutrients of Vembanad Lake
pH



Months: April–Dec.

mixing and wind action. However, comparatively higher concentrations were frequent during monsoon seasons. The range of dissolved levels during different seasons were: (1) Pre-monsoon: 3.58 to 3.9 ml/L; (2) Monsoon: 3.9 to 4.1 ml/L; and (3) Post-monsoon: 3.57 to 4.16 ml/L respectively. Details of the oxygen values are given in Fig.6. Haridas et. al., (1973) also observed the same type of phenomena in the lake system, especially during the monsoon period. Qasim et. al., (1969) stated that the higher oxygen concentration during this period can be due to the higher primary production consequent on a better utilization of the nutrient availability occurring in the surface layers during the monsoon season. In general, higher levels of oxygen was recorded during monsoon period, the lowest during pre-monsoon season. The post-monsoon period appeared to be more stable pronouncing relatively lesser variations.

4.1.5 **Inorganic phosphate**

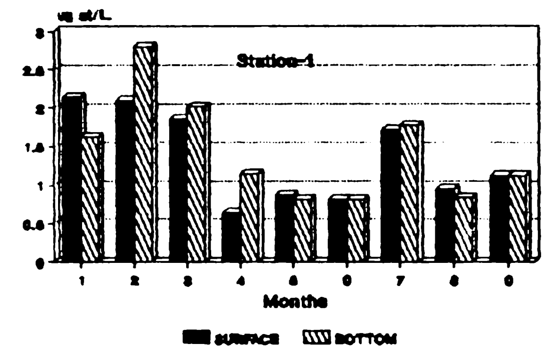
As a limiting nutrient in the brackish water ecosystem, inorganic phosphate plays a vital role in the productivity of water in the Lake. The seasonal trend of distribution of inorganic phosphate is given in Fig.9. It is apparent that when the lake is taken into consideration in totality, the variations in inorganic phosphate shows a distinctly higher level during the pre-monsoon period, compared to the other two seasons when the values are moderate. However, it is interesting to note that in the southern zone during the monsoon period, the phosphate value is higher (1.22 to 1.27 µg at/L) which may be due to the fresh water discharge from the paddy fields. The phosphate levels in this region has to be considered in the light of large scale fertilizer application in the surrounding paddy fields practiced every year. It is almost certain that large quantities of phosphate which is unutilised may finally end up in the estuarine sediment which serve as store house for the excess nutrients. Meanwhile, the increased levels of phosphate recorded at stations situated in the Cochin bar mouth area (Stns. 1 & 2) may be due to the land run off as well as sewage discharge into the estuarine area.

According to Sankaranarayanan and Qasim (1969) in the Cochin back-water during the period when homogenous conditions prevail, i.e. from January to April, phosphorous values are low and there is very little difference in the values at various depths. Towards May and June, when the pre-monsoon and monsoon showers set in, the phosphorus values attain their first peak. The values increase from the surface to the bottom. This probably indicates that the phosphorus contribution of the estuary is largely dependent upon external sources such as land drainage and fresh water run off. They state that 'a correlation between the distributions of organic and inorganic phosphorus exists at deeper layers, where the water remains stagnant and an aerobic condition develops into inorganic phosphorus and the fresh water discharge, may be due to silt loaded influx of water containing large quantities of dissolved and particulate organic matter, whose ultimate decomposition probably occurs at the bottom.

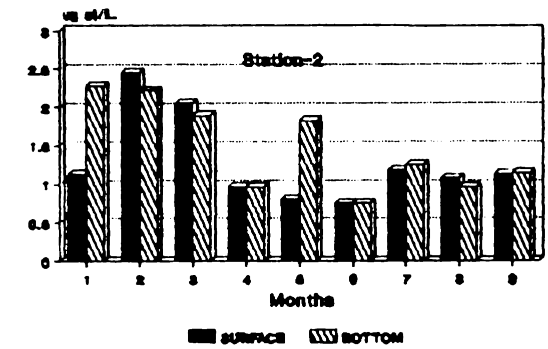
4.1.6 Nitrite nitrogen

Unlike the inorganic phosphate, nitrite levels show an entirely different pattern, maximum levels being recorded during the monsoon season. There is also no definite pattern of this nutrient distribution in any of the zones in the lake system. In the overall distribution pattern, nitrite shows opposing

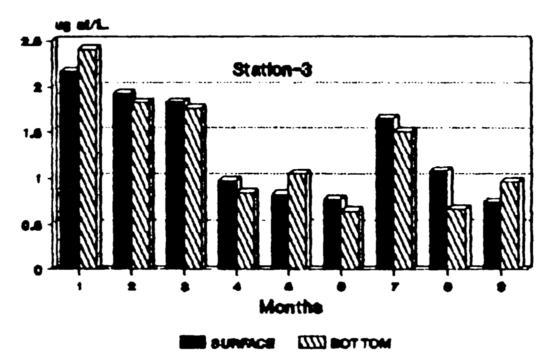
Fig.9 Hydrography and nutrients of Vembanad Lake
Phosphate (Po4-P)



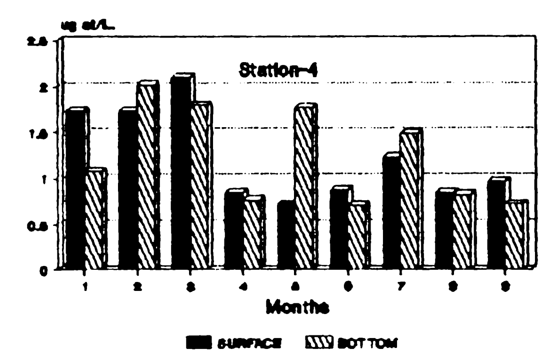
Phosphate (Po4-P)



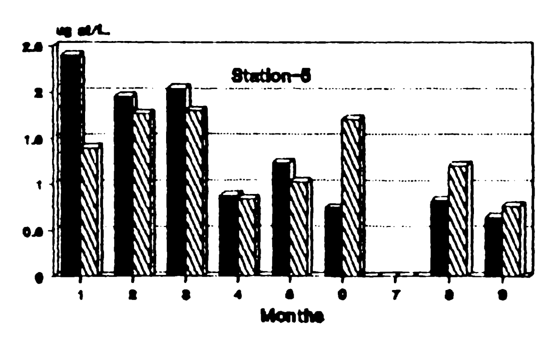
Phosphate (Po4-P)



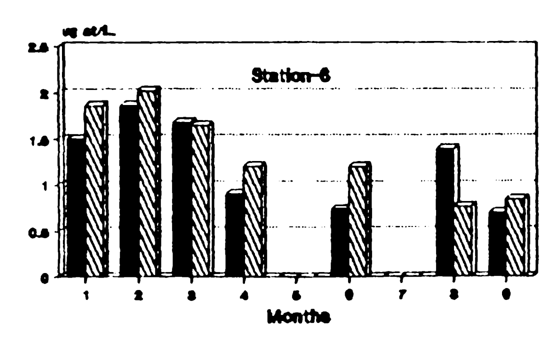
Phosphate (Po4-P)



Phosphate (Po4-P)



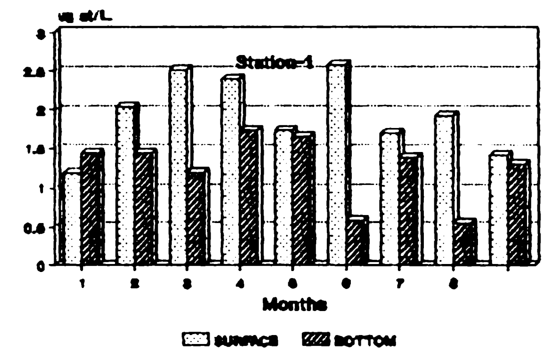
Phosphate (Po4-P)



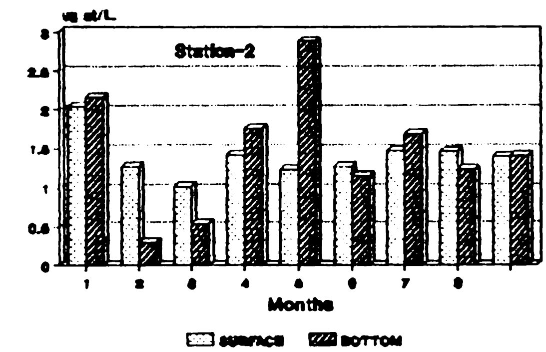
Phosphate (Po4-P)

Months: April - Dec.

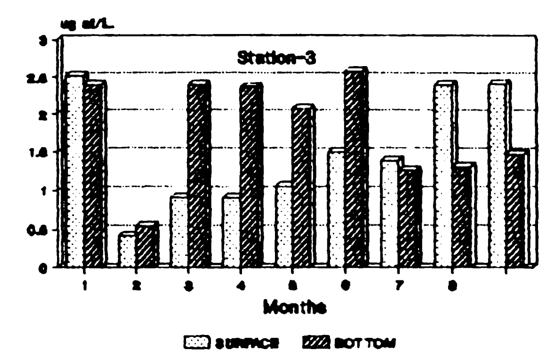
Fig.10 Hydrography and nutrients of Vembanad Lake
Nitrite (No^{2}-N)



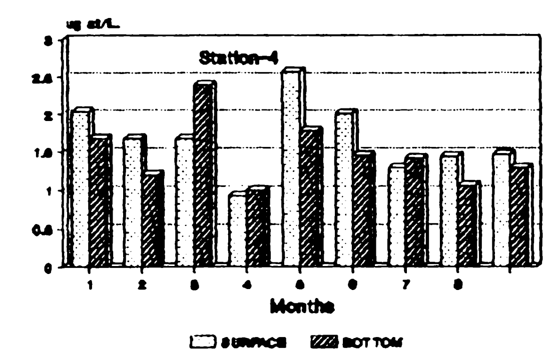
Nitrite (No2-N)



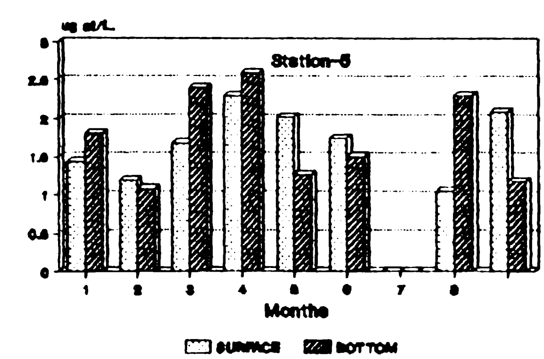
Nitrite (No2-N)



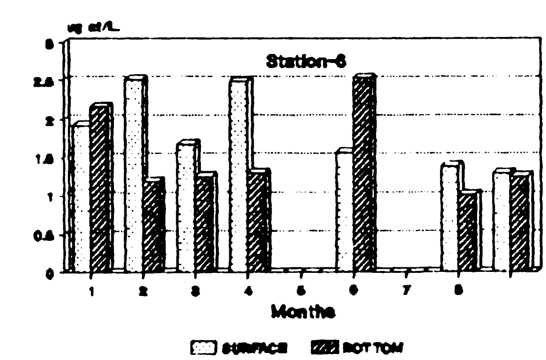
Nitrite (No2-N)



Nitrite (No2-N)



Nitrite (No2-N)



Nitrite (No2-N)

Months: April–Dec.

trends compared to phosphate levels. Data on inorganic phosphate and nitrite collected for a period of about nine months from the surface and bottom from six stations from the Cochin-Alleppey sector of the Vembanad Lake indicate that differing trends in their levels were high at the surface, but nitrite showed an opposing trend, being higher at the bottom. But during the monsoon season, the trend in phosphate levels reversed showing higher levels at the bottom. This higher levels of phosphate at the bottom can be attributed to two reasons, (1) due to the large quantity of silt brought down by the rivers and (2) due to the churning up of bottom sediment due to the increased flow of fresh water towards the estuary. However, nitrite levels did not show such a trend during monsoon season. In the post-monsoon season, both the nutrients showed higher levels at the surface throughout the study area.

Qasim et. al., (1969) stated that while there is a close correlation between the cycles of phosphorus and organic production in the backwater, the nitrogen cycle is completely unconnected with productivity rhythm, for most of the year, there is little or no Nitrite-N in the water. Sankaranarayanan and Qasim (1969) observed that there seems no firm basis, for believing that the instantaneous concentration of nutrients as inorganic salts in the estuary provide a significant source of phytoplankton bloom.

Studies conducted recently by the author (1990) on nutrient levels for twelve months from a typical estuarine station near Cochin (Fig. 1C); (Table 2) showed that inorganic phosphate levels were comparatively high during pre-monsoon season. However, the highest value (15.11 µg at/L) was recorded in July. While nitrite levels were low or negligible, Nitrate and Ammonia

Table 2. Levels of nutrients in a typical estuarine station near Cochin
(Unit/µg at/l)

Month	Phosphate	Nitrite	Nitrate	Ammonia
January 1990	2.16	1.26	Nil	7.12
February	2.02	0.21	-	5.49
March	4.32	0.35	98.48	7.82
April	11.42	1.28	11.52	25.09
May	3.94	3.9	7.16	30.82
June	5.43	1.55	16.19	21.80
July	15.11	1.15	33.25	15.96
August	1.96	0.23	6.59	5.63
September	1.52	1.08	2.99	4.02
October	1.57	0.10	0.91	Nil
November	0.83	0.34	4.88	0.27
December	0.83	0.23	Nil	Nil

were high during pre-monsoon as well as in early monsoon period. During post-monsoon period the levels were rather low.

Sankaranarayanan and Qasim (1969) stated that generally, the amount of nitrite in the sea is small as compared to that of nitrate and ammonia, although in temperate waters it shows a slight increase in winter. In the backwater both these forms of nitrogen appear at the bottom, probably as a result of decomposition of organic nitrogen within the sediment. Regarding the general trend this may be true, but observing the levels of ammonia, it is possible that some additional source such as sewage and industrial effluents also may be contributing to the input of ammonia at least in the area around Cochin harbour.

4.1.7 Primary Production

Primary production measured by 14C shows wide fluctuations from station to station as well as from season to season. Unlike the inshore environment on the west coast where maximum production occurs during the monsoon period, in the Vembanad Lake relatively higher rates of production are observed during the other periods. The rate of production is uniformly high in almost all the stations exceeding 10 $mgC/m^3/hr$. Considering the magnitude of production, the area north of Cochin harbour stands out to be the most productive area in the backwater region, with an average daily rate of 1200 $mgC/m^2/day$. It was not possible to measure the extinction coefficient and depth of the euphotic zone and conduct experiments for the entire water column. However, assuming that the light penetration and depth of the euphotic zone is same as in Cochin backwaters it may be taken as 3 m in monsoon and 4 m in pre and post-monsoon. The Seechi disc visibility readings (1 to 1.5 m) also confirms this. Hence the rate of production in the water column may be assumed to be 1.5 to 2 gC/m^2/day. This would amount almost twice the rate of production obtained in the Cochin backwater (Qasim et. al., 1969). The measurements by 14C further confirm the spatial variability in the Vembanad Lake as observed in the standing crop. For comparison, one of the least productive station on the southern side of the lake can be taken (Stn.6). The average rate of production amounts to 200 mgC/m^3/day. The column production for euphotic zone is a little less than 0.5 gC/m^2/day. Hence an annual gross production of ca. 150 gC/m^2 seems to be the minimum rate of primary production in the Vembanad Lake. Likewise at the northern station (Stn.1) the annual gross production is a little over 500 gC/m^2. This rate of production is high but not unusual for such euphotic areas in marine environments (Strickland, 1965).

The northern most region (Azhicode) is just about moderately productive. There is considerable admixture of inshore water through the bar mouth into this area except during the monsoon floods. During this period the rate of organic production drops to the lowest point. However, due to the moderately high rates during the rest of the season a gross annual production of nearly 200 gC/m^2 is estimated. This is considerably lower than the nearshore values recorded by Nair et. al., (1968). Inspite of seasonal and spatial variations the annual gross production for the entire Vembanad Lake comprising about 300 sq.km. is calculated as about 1,00,000 tonnes of carbon(Nair et. al., (1975).

4.1.8 **Secondary Production**

The trend in secondary production rates showed two peaks, one during pre-monsoon and the other during post-monsoon period. Earlier observations of George (1958); Nair and Tranter (1971) and Haridas et. al., (1973) showed almost the same sequence of zooplankton distribution. As in the case of primary production the maximum amount of zooplankton biomass is recorded in the same station located north of Cochin harbour. However, in the middle region of the Lake, fairly large quantities of zooplankters, especially larval forms were met with especially during pre-monsoon season indicating the influence of increased salinity in the area. But during the monsoon season, the zooplankters were practically scarce in the lake except in the middle zone where a few numbers were encountered. The large quantities of Salvinia weeds brought down by the fresh water influx from the southern half to the estuarine area might have considerably affected the abundance and distribution of the planktonic organisms to a great extent. Information on the quantitative distribution of zooplankton as well as the influence of hydrographic parameters on their abundance are discussed below.

The zooplankton population was represented by sixteen groups of organisms in the plankton; viz: copepods, decapod larvae, crab zoea, lucifers, jelly fishes, hydromedusae, amphipods, cladocerans, isopods, cirripid nauplius, oikepluera, chaetognaths, mysids, cumaceans and copepodites. Invariably, copepods and decapod larvae were dominant in the plankton. Fish eggs and larvae were abundant during the pre-monsoon season.

The trend in the zooplankton biomass shows two peaks, one in March-April and the other during October-January. The second peak is less prominent. The peak is high at stations situated in the middle portion of the lake. During the monsoon season (July-September) there is complete change in their abundance showing very low values in the entire lake, both in the total biomass as well as in the nummber of groups represented.

The zooplankton data for six months and representing fifteen groups were used for the analysis of variance which was applied to examine the difference in counts from place to place, from time to time and from group to group and also to see whether there were any significant interactions between two of the three factors: space, time and groups. To stabilize the variance, the counts were converted to the logarithmic scale. To tackle '0' counts '1' was added to each count before taking the logarithm. The results of this analysis are given in Table 3.

Table 3. Analysis of variance of logarithm of Zooplankton counts

Source	S.S.	D.F.	M.S.
Total	1,519,2093	629	
Between stations	8.7704	6	1.4617+
Between months	57.4028	5	11.4806**
Between groups	798.9474	14	57.0677**
Station x month	34.3350	30	1.1445*
Station x group	58.8950	84	0.7011
Month x group	277.7680	70	3.9681**
Residual	283.0907	420	0.6740

*Significant at 5% level

** Significant at 1% level

+ More or less equal to the tabulated value of F at 5% level

The monthly variation in the counts is found to be highly significant (at 1% level). So also is the variation between groups. Further observations are required to conclude whether the variation in the counts between stations is significant or not because the tabulated values are more or less equal. However, compared with the monthly variation the spatial variation is low. As the interaction between stations and months is significant, it appears that the pattern of seasonal variation in the counts differs from place to place. The interaction between months and groups is found to be highly significant which shows that the different groups do not have any particular preference for any particular station as the interaction between stations and groups is not significant. Thus, the months, the groups and the interaction between these two appears to account for a good amount of variation in the counts. The group-wise mean monthly counts is given in Table 4.

From the results discussed above, it is evident that variation over time is significant in zooplankton abundance. To determine the extent of influence of the environmental factors of the estuary on secondary producers, the correlation coefficients were calculated. The influence of salinity on zooplankton production is evident from the highly significant value of the partial coefficient of correlation Log zooplankton and Log salinity, Zs.T. Pillai et. al., (1973) did not find any significant correlation between zooplankton biomass and salinity for the Cochin backwater. But they observed significant coefficients of correlation between copepod species and salinity. However, their sampling stations were restricted to Cochin harbour area and the present study covers the entire lake system. Haridas et. al., (1977) observed that the zooplankton biomass values fluctuate seasonally in correlation with hydrographical conditions prevailing in the estuary. The zooplankton populations reached their abundance along with the peak of the summer. The higher biomass values, always encountered at the areas in proximity to the mouth after the establishment of high salinity regime, suggest a more stable environment in this area unlike the mouth which is affected more by the mixing of the tides and turbulance. The linear decrease in the biomass towards the head of the estuary is correlated with that of salinity.

The significance of correlation between salinity and zooplankton in the present study suggests that the groups constituting the zooplankton population and predominant in the estuary prefer high salinity. It is thus possible that a large part of variation of zooplankton abundance in space and time is brought about by the variation in salinity.

Rank correlation coefficients (Table 5) showed high correlations of temperature and salinity on zooplankton in all the stations except Stn.3 for temperature. Primary production was not found to be a limiting factor except for Stn.1 as judged from rank correlation of zooplankton on primary production.

Table 5. Rank correlation coefficients

Station	Zooplankton/ Temperature	Zooplankton Salinity	Zooplankton/ Prim. production
I	0.634	0.750	0.904
II	0.657	0.642	0.166
III	- 120	0.881	0.047
IV	0.421	0.718	0.030
V	0.452	0.297	- 0.285
VI	0.473	0.783	0.392
VII	0.475	0.737	0.166

Table 4. Group-wise means of monthly counts of zooplankton

Zooplankton	Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Copepods	27869	3329	1097	48	490	1148	11359	646	2335	724	25029
Decapod larva	880	765	3052	9	200	197	344	396	963	231	12549
Crab zoea	31209	4165	18	2	0	0	0	0	0	0	0
Lucifers	334	845	2245	0	0	0	4	0	5	27	77
Jelly fishes	0	1	0	0	0	0	0	0	0	0	0
Hydromedusa	12	8	12	0	0	0	0	0	0	0	0
Amphipods	0	0	0	0	1	21	0	13	8	31	295
Cladocerans	0	0	0	0	0	0	84	13	45	0	0
lsopods	0	0	0	0	0	0	1	0	0	4	2
Cirriped nauplius	34	2	0	0	0	0	0	0	0	2	0
Oikopluera	32	2	14	0	0	0	0	0	2	2	0
Chaetognaths	0	0	0	0	0	0	0	0	0	9	2
Ctenophores	4	0	0	0	0	0	0	0	0	0	0
Mysids	0	0	2	0	0	0	0	0	0	0	0
Cumaceans	0	0	0	0	0	1	2	18	0	0	0
Copepodites	0	0	0	0	0	0	4	0	0	0	0

4.2 Fish resource of Vembanad Lake

The Vembanad Lake is well known to support a rich variety of living resource which include fin and shell fishes. The total estimated area of the lake is about 30,000 ha and the total production is estimated to be about 6,000 tonnes. Apart from this a substantial quantity of clam fishery (both live as well as semifossilised white shells) also exists in the lake. Due to limitations in sampling and coverage, the lime shell fishery is not dealt with in detail in this study. Crustaceans, especially prawns form a major component (about 30%) of the fish landings. The fishery resource, in general, is represented by a mixed group, which includes pelagic as well as demersal forms. The details of production, number of craft and gears, number of fishermen etc. are given in Table 6.

Table 6. Production Details of Vembanad Lake (1980-81)

	Area (ha)	Prod. in M.T.			Prod. per ha (Kg)		
V. Lake	30,000	Fish	Prawn	Total	Fish	Prawn	Total
		3845	1980	5825	128.17	66.00	199.17

Number of Villages	:	32
Active Fishermen	:	9380
Boats	:	5200
Gears		
Stake nets	:	3654
Chinese nets	:	990
Free nets	:	14950

Source: Inland Fish Marketing in India (6) (Srivastava, 1983)

Due to the multivarious groups involved, a representative sampling is difficult to obtain for quantitative estimations. In the present study, the data were collected using a specially designed trawl net operated in each station for 30 minutes and the sample thus obtained is analysed. In spite of inherent limitations, it can be stated that data by experimental trawling is the first attempt from the Vembanad Lake. The area covered for sampling is from Arookutty in the north to Muhamma in the south with six stations which virtually covered the Vembanad Lake proper.

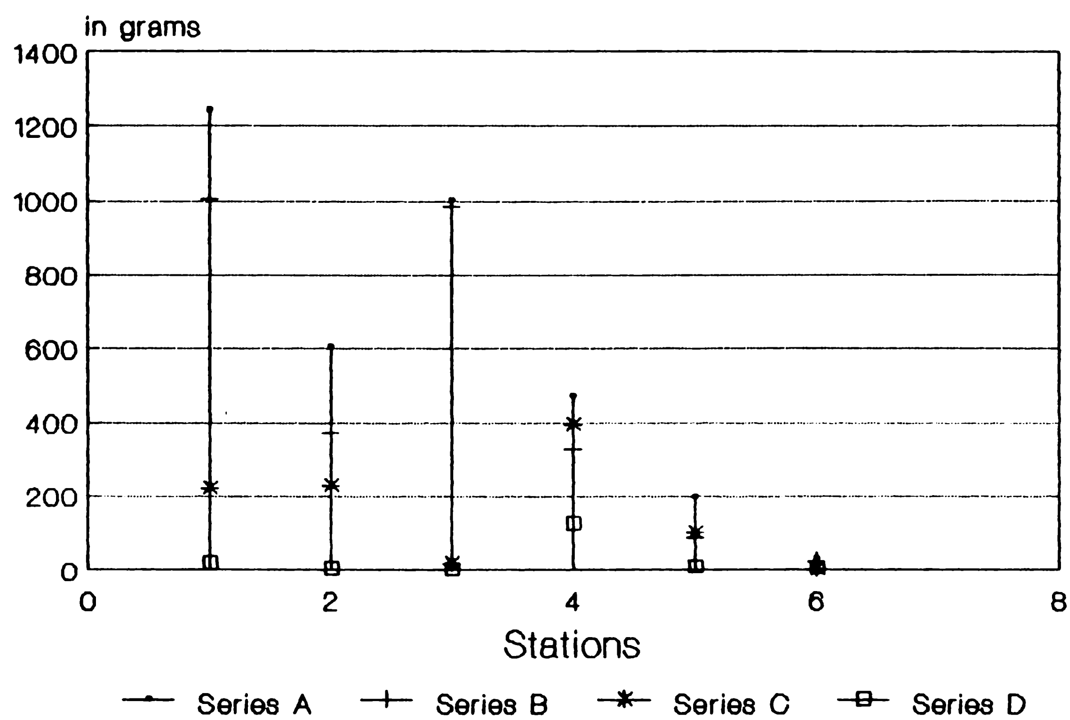
4.2.1 General trend in the resource pattern

As the seasonal trend is apparent in the sampling, the data are presented accordingly. The quantitative estimation reveals that the post-monsoon period is more productive compared to pre-monsoon and monsoon seasons. While in the northern zone pre-monsoon landing was almost equal to post-monsoon season, in the middle zone, the post-monsoon peak is very clearly visible. The maximum quantity obtained was 1.24 kg. in Stn.1. But in the southern zone, the resource was practically negligible when compared to northern zone probably because of the fresh water dominance except during the pre-monsoon period. Details of the data are given in Tables 7 & 8 and Figs. 11 & 13.

4.2.2 Percentage composition

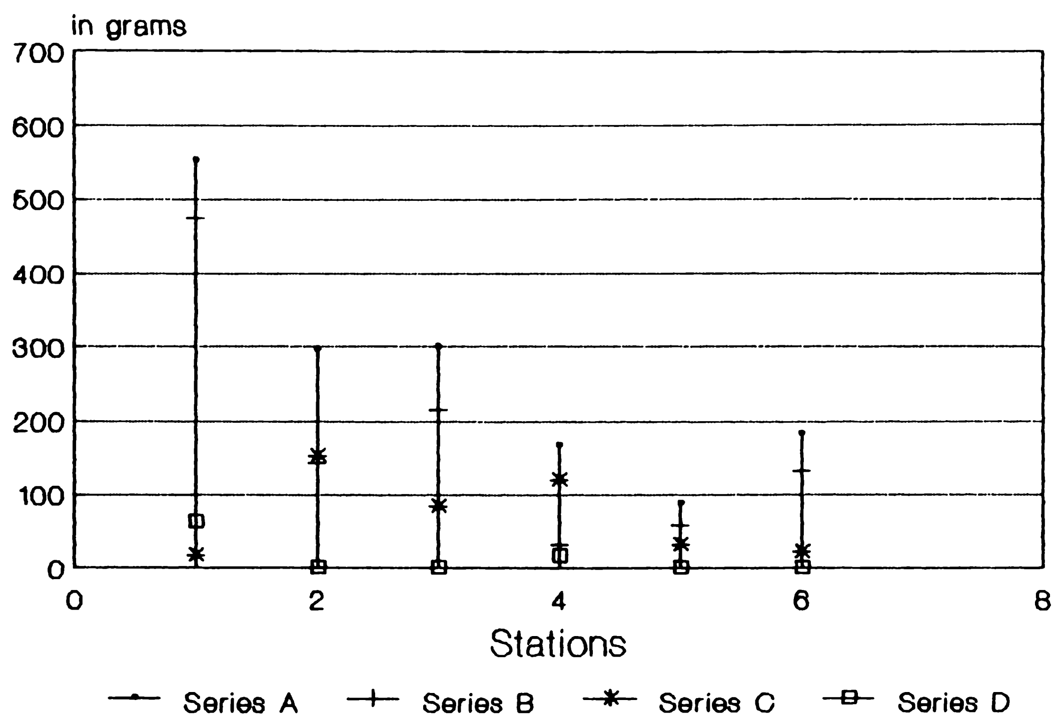
The fishery resource samples obtained were mainly represented by fin fishes, prawns and crabs. The percentage composition analysed with respect to each station samples reveals that while fin fishes invariably dominated the other two groups, in the middle zone prawns were equally abundant as fin fishes which indicates the favourable ecological conditions prevailing in the zone, especially for the prawns. Crabs, represented by *Neptunus* sp and *Scylla serrata* were present only in the northern zone, obviously due to the higher salinity gradient. The maximum catch represented 32% in Stn.2 (Fig.11).

Fig. 11 Hyrdobiology of Vembanad Lake
Trend of fish catch (gms)



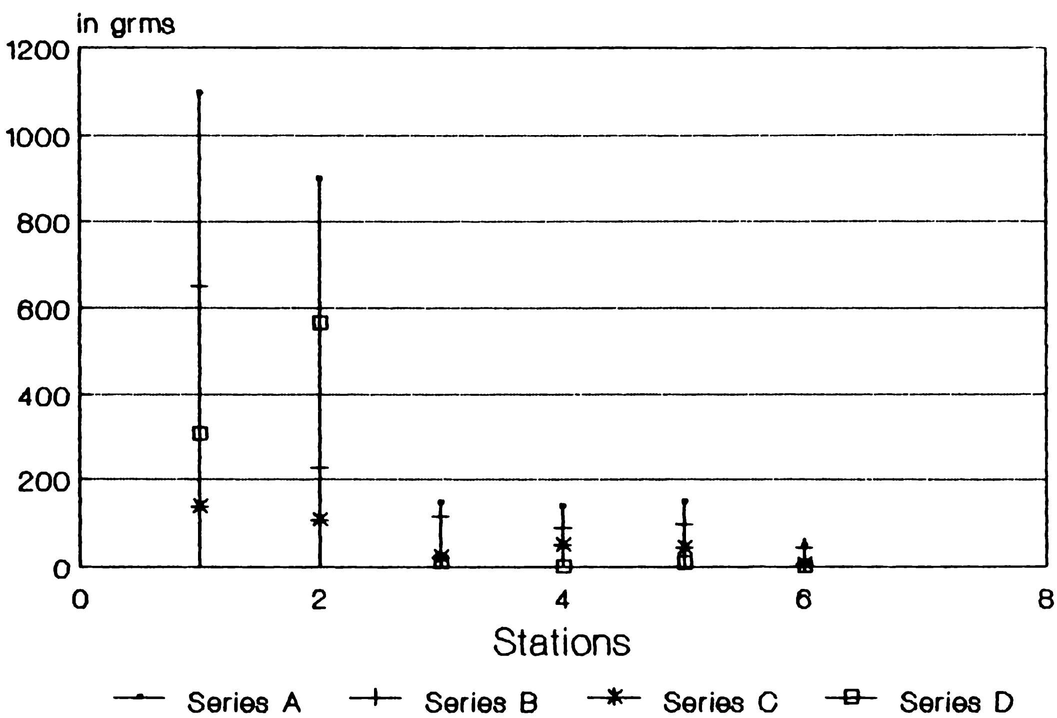
post-monsoon **a:total;b:fishes;c:prawns;d:crabs**

Fig.12 Hydrobiology of Vembanad Lake
Trend in fish catch



monsoon a:total;b:fishes;c:prawns;d:crabs

Fig. 13 Hydrobiology of Vembanad Lake
Trend of Fish catch (gms)



pre-monsoon

a:total;b:fishes:c:prawns ;d:crabs

Table 7. Fishery Resource of the Vembanad Lake

General trend in the total catch composition (n = 28)

Stations	1	%	2	%	3	%	4	%	5	%	6	%
Total catch (in gms)	2890		1799.85		1446.53		1151		436.6		229.6	
Fishes	2130.9	(74.0)	742.02	(41.20)	1314.70	(90.88)	447.80	(38.92)	247.7	(56.75)	197.0	(85.72)
Prawns	373.7	(12.64)	489.33	(27.22)	122.73	(8.50)	562.50	(48.87)	174.0	(39.87)	27.65	(12.20)
Crabs	386.16	(13.36)	568.50	(31.58)	9.0	(0.62)	140.8	(12.61)	14.8	(3.38)	4.80	(2.08)

Table 8. Fishery resource of the Vembanad Lake - Seasonal variation

Pre-monsoon						
Stations	1	2	3	4	5	6
Total (in gms)	1095	900.43	145.7	137.3	147.1	47.5
Fishes	650.2	227	115.10	89.1	96.9	42.63
Prawns	137.1	107.43	21.6	48.2	41.9	4.93
Crabs	307.7	566.0	9.0	0	8.3	-
Monsoon						
Total	552.66	295.72	299.2	166.9	88.10	183.20
Fishes	474.10	142.72	215.3	30.5	57.10	131.90
Prawns	16.40	153.00	83.8	120.7	30.90	21.60
Crabs	62.16	-	-	15.8	-	-
Post-monsoon						
Total	1243.1	603.7	1001.63	471.8	196.4	28.5
Fishes	1006.6	372.3	984.3	328.2	88.7	22.50
Prawns	220.2	228.9	17.33	393.0	101.2	1.12
Crabs	16.3	2.5	-	-	6.5	4.8

4.2.3 **Seasonal abundance**

In quantitative terms, it is apparent that the post-monsoon season is the most productive period in this ecosystem (Fig.13). Although the general trend is the same, crabs appear to be abundant only during the pre-monsoon period and mostly present in the northern zone. Compared to their abundance in the other two zones, prawns appear to be available in the central portion of the Lake, especially during the monsoon period. The abundance observed in the resource availability during post-monsoon period can be linked to the ecological changes occurring in the environment. It is a fact that large quantities of fresh water rich in nutrients and organic matter is discharged into the lake proper by the rivers. These nutrients in turn causes increased production at the various trophic levels which utlimately reflects in the overall abundance of the living resource. A generalised scheme of energy transfer in the Lake is given in the discussion.

The fish sample obtained from the experimental trawling mainly consisted of about fifteen varieties of fin fishes (Anchovies, Ambasis sp; Batrachus sp., Cat fishes, Carangids, Clupeids, Cynoglossus sp., Epinephelus sp., Geres sp., Gobiids, Leognathus sp., Sciaenids, Platycephalus Triacanthus and Trypochan sp.), four species of prawns (Penaeus indicus, Metapenaeus dobsoni, M. monoceros and M. affinis) two species of Caridians, (Macrobrachium rosenbergii and M. idella) and two species of Crabs (Scylla serrata and Neptunus pelagicus).

However, Jhingran (1982) reported that the composition of fish and prawn catches from these waters are as follows. Prawns (M. dobsoni, M. monoceros, M. affinis, Penaeus indicus and Macrobrachium rosenbergii); 60-70%; Mullets (M. cephalus, M. macrolepis, M. cunnesius, M. parsia, M. seheli) 11%;

pearl spots (Etroplus suratensis and E. maculatus) 10%; Cat fishes 9% and others 1%. Post larvae of different species of prawns exhibits considerable fluctuations in abundance. Those of M. dobsoni, M. monoceros, P. indicus are present almost throughout the year, the largest numbers were found during March-June and October-December. The prawn fishery is mainly contributed by the juveniles of M. dobsoni (30-95 mm), P. indicus (45-140 mm) and M. monoceros (35-120 mm). The fishery is abundant throughout the year though the catches are heavier during the monsoon and post-monsoon period.

To gather information on the relative importance of the various hydrographic parameters on the fish catch, a multiple regression of fish catch on the relevant parameters was worked out. The overall relationship was found significant as shown by a Significant Regression (Table 9) though the R-Square value was not very high (0.2381).

Table 9. ANOVA of the multiple regression

Source	DF	SS	MS	F
Regression	4	2422011.5000	605502.8750	3.671*
Residual	47	7751584.0000	164927.3125	
Total	51	10173595.0000		

The variables significantly contributing to higher catch were oxygen and water temperature in that order as shown by the significant regression coefficients corresponding to these variables (Table 10).

Table 10. Regression coefficients for the set

b(i)	SE(b)	b/Sb 7
100.313	41.809	2.40*
1.055	6.208	1
412.491	121.684	3.39*
-56.272	76.914	1

Temperature and salinity are highly correlated. Significant correlations are also observed between temperature and oxygen, salinity and oxygen and fish catch (Table 11).

Table 11. Correlation matrix for the set

Section 1

Row		Tem. 1	Salinity 2	Oxygen 3	Phosphate 4	Nitrite 5
T	1	1.0000	0.5416	- 0.3263	0.2528	0.2187
Sal.	2	0.5416	1.0000	- 0.3287	0.1071	0.0681
O_2	3	-0.3263	-0.3287	1.0000	0.0788	0.3309
P	4	0.2528	0.1071	0.0788	1.0000	0.0391
N	5	0.2187	0.0681	0.3309	0.0391	1.0000

Probably, the importance of salinity was not reflected in the correlation coefficient, owing to the differing salinity range preferences of the individual fish species constituting the total catch.

Rank correlation coefficients between fish catch and the hydrographical parameters, viz: temperature, salinity and dissolved oxygen were worked out, separately for each station. As the sampling was started in the early morning beginning with station-I, there was an increasing trend in the temperature regime from Station I to Station VI.

Temperature variation at Station I to VI

Station No.	Maximum Temperature (°C)
I	31.5
II	32.2
III	32.25
IV	33.0
V	33.5
VI	33.0

The rank correlation coefficients also confirmed the importance of temperature on fish catch (Table 12).

Table 12. Rank correlation between fish catch and hydrographic parameters - Cochin-Alleppey sector of Vembanad Lake

Stations	Characters		
	Fish-Temp.	Fish-Salinity	Fish-D.oxygen
I	0.521	0.229	0.260
II	0.0031	0.1937	- 0.021
III	0.516	0.456	0.3216
IV	- 0.006	0.257	0.0035
V	0.405	0.285	0.171
VI	0.313	0.0007	- 0.334

The seasonal differences in the hydrographical parameters were studied by employing Analysis of Variance technique. Seasonal differences in the total fish catch was not found to be significant though there was highly significant seasonal variations in temperature and salinity- and significant variation in oxygen content. Average temperature was found to be high in season 1 (pre-monsoon) (30.1°C) and this significantly differed from the average temperature noted in seasons 2 and 3 (monsoon and post-monsoon seasons), (28.3 and 28.4°C respectively) as judged from the critical difference (C.D = 0.74). Average salinity in the three seasons 24.1‰, 2.0‰ , 10.9‰ differed among themselves as can be seen from a C.D. of 3.5. Seasonal variation in oxygen (3.6, 3.9, 4.1 ml/L) was found to be significant only in Station I (C.D. 0.24). More or less similar trends were seen in stations II to VI except that the seasonal difference in the average oxygen content was not significant in these stations.

HYDROBIOLOGY AND POLLUTION OF THE LOWER PERIYAR AND COCHIN BACKWATERS

5. HYDROBIOLOGY AND POLLUTION OF THE LOWER PERIYAR AND COCHIN BACKWATERS

Of the fourty four rivers in Kerala, Periyar is the largest and the second longest river, after Bharathapuzha. The river is having a length of 244 km and finally joins the Arabian Sea mainly through the Cochin bar mouth. More than five million people take a share of this water everyday and the river sustains several thousands of biota. The State derives manifold benefits from Periyar which includes power generation, irrigation, drinking water supply, agricultural developments, industrial activity, tourism, inland navigation and fishing. However, it is reported recently that the river has lost its sanctity and utility due to various reasons such as environmental degradation, pollution mainly due to discharge of effluents from industries and civic bodies, non-availability of water, scourging of the sides of the river, removal of sand, salinity incursion etc. It is recognised that the quality of water in the river has progressively deteriorated and dangerously polluted at least in certain hot spots.

Although some reports are available on fish mortality, salinity incursion, heavy metal levels etc; from different parts of the environment, this is the first report comprising data on hydrography, primary secondary and tertiary levels of production based on a well designed collection and analysis programme. However, since a number of variables are involved in controlling the overall production, the variations can be caused by different parameters individually and also by the synergistic effect of a number of parameters acting together. Since it may not be possible to analyse all the parameters and study their individual role and effects, an attempt is made here to give an overall picture of the hydrobiology of this unique estuarine area.

5.1.1 Hydrobiological characteristics

The data presented here were collected from six stations which extends to a distance of about 12 km from the Cochin bar mouth. The stations are numbered 1 to 6 from Cochin estuary upstream in the ascending order (Fig. 1C). The first two stations are located in the estuarine region, stations 3 and 4 in the brackish water zone and stations 5 and 6 in the fresh water zone. Incidentally, stns: 4 and 5 are located in the impact zone of pollution from the industrial complex. The apparent variations in certain parameters such as the progressive increase in temperature as well as gradual decrease in salinity from stations 1 to 6 can be considered due to the effect of time and distance involved in the collection of samples and not entirely due to ecological factors. Hence, individual values in each station does not indicate a local effect except in the case of pH and nutrients. Annual average values, both station-wise and month-wise are given in Figs. (14 & 20).

Temperature

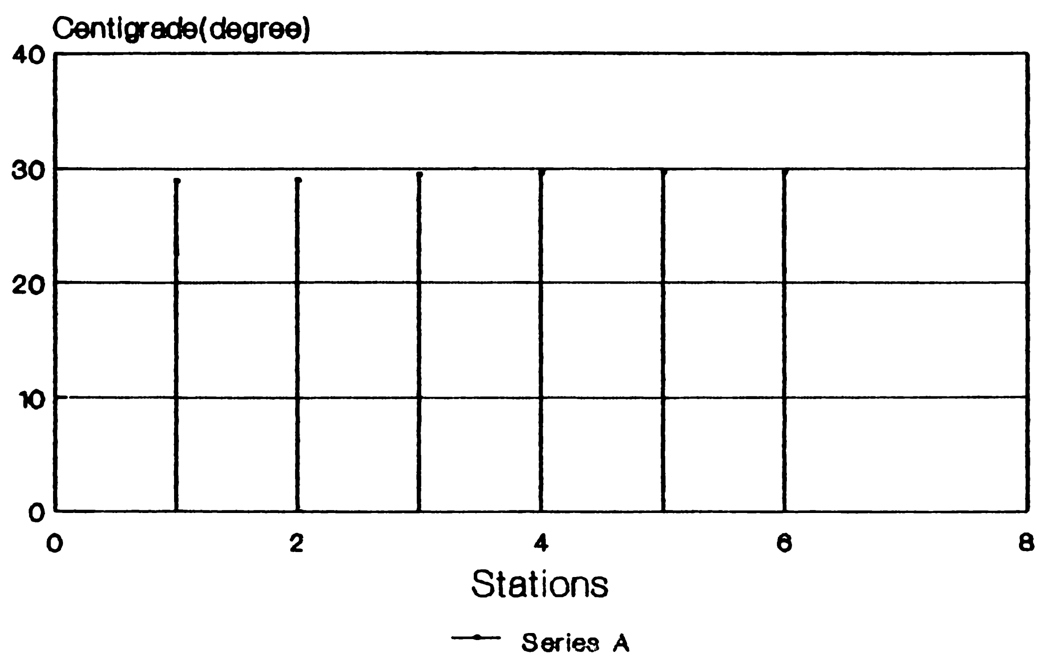
The highest range in surface temperature was observed during March and April, showing an average temperature of 32.41°C, while the lowest range was recorded in August (24.15°C). However, considering the general trend, temperature shows a bimodal fluctuation indicating higher values during pre-monsoon and post-monsoon seasons (Fig.14).

Salinity

As one of the most important parameter in an estuarine system, salinity has wide variations. When considered over the period of time, the salinity

Fig. 14

Annual Mean Values Stationwise
Hydrography and Fishery



A: Temperature:.

levels show a bimodal fluctuation as in the case of temperature. But when considered the range in distance, salinity indicates estuarine, brackish water and fresh water regimes which to a great extent influences the productivity also (Fig. 15).

Dissolved oxygen

The general trend in the distribution of dissolved oxygen did not show much variations over space as well as time. However, the range often showed much lower compared to saturation levels at stations 4 and 5 which are located in the impact zone. The lowest value of oxygen recorded was 1.47 ml/L at the bottom at Stn. 5 in June. This trend was not visible at other stations and hence it is apparent that the effect of pollution due to industrial effluents eventually causes a high oxygen demand in the ecosystem (Fig. 16).

Hydrogen ion concentration (pH)

The hydrogen ion concentration did not reveal any wide fluctuation except in certain stations (Stn. 4 and 5) which are located in the impact zone of pollution due to industrial discharge and also known for fish kills due to acidity resulting from pollution. The station-wise annual mean value also indicates the lowest pH of 5.80 recorded at Stn. 4 (Fig. 17).

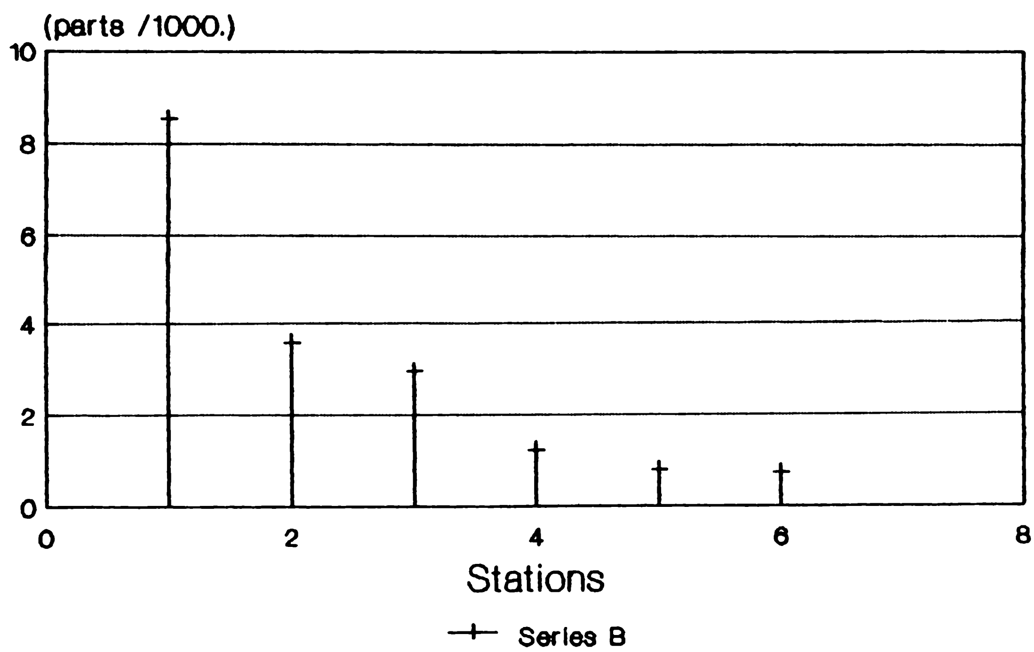
Inorganic phosphate

Usually in any estuarine ecosystem, the main sources of nutrients are the river water besides regeneration from the sediment and biological activity. However, in this ecosystem, other than the above sources, the discharge of effluents fom a fertilizer factory also adds to the source. Hence during certain

Fig. 15

Annual Mean Values Stationwise

Hydrography and Fishery

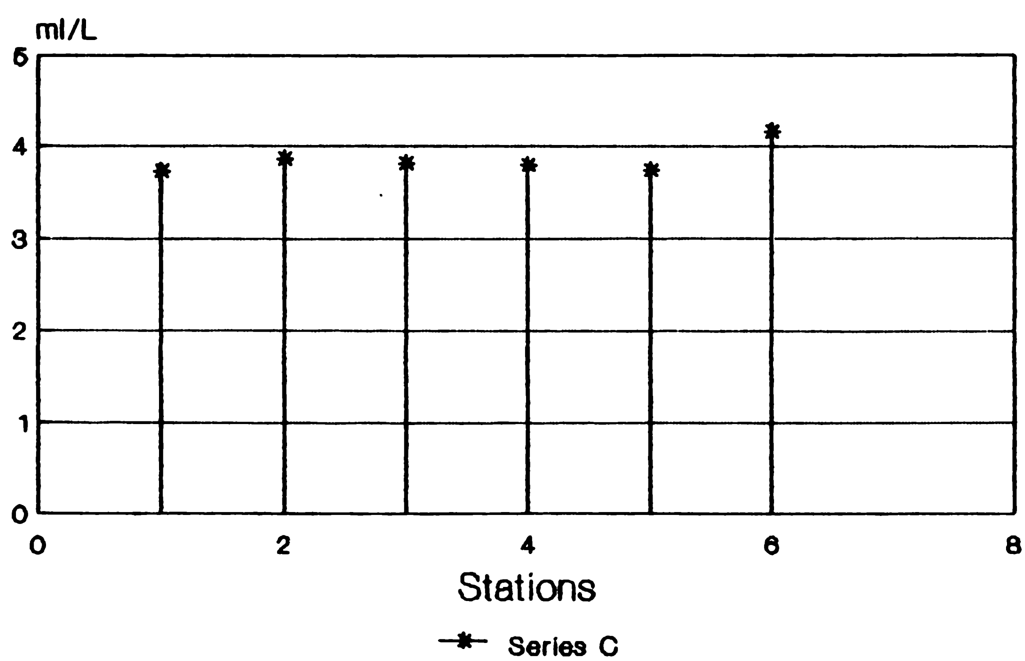


B:Salinity.

Fig. 16

Annual Mean Values Stationwise

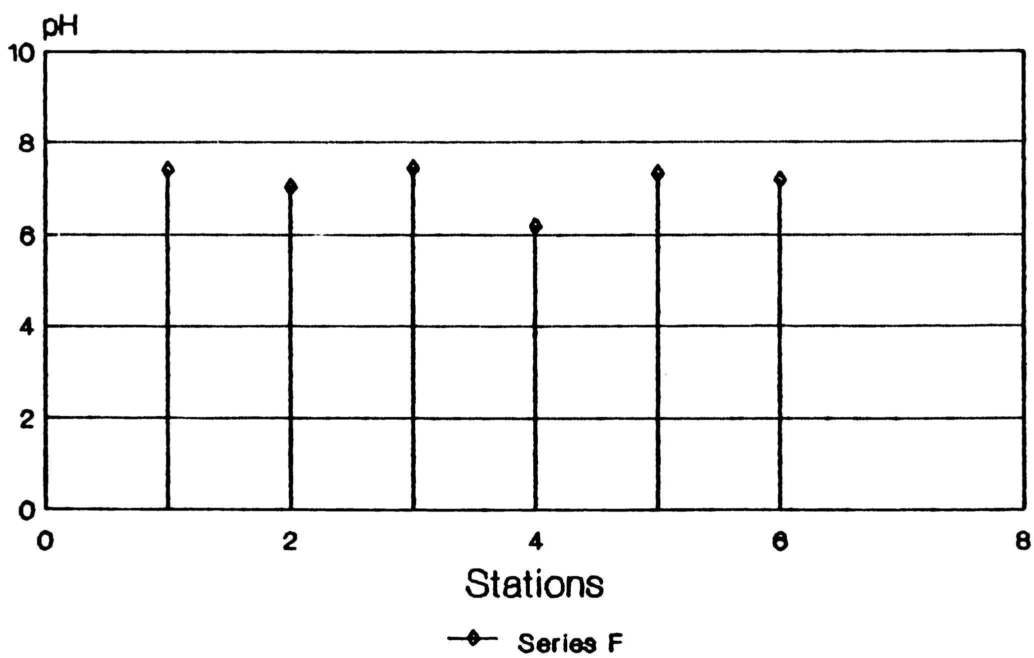
Hydrography and Fishery



C:Dissolved Oxygen

Fig. 17

Annual Mean Values Stationwise
Hydrography and Fishery



F:pH

period (especially in March) rather high values of inorganic phosphate has been recorded in stations situated in the vicinity of the fertilizer complex. Considering the overall distribution trend, comparatively higher values were recorded during summer season (Fig. 18).

Nitrite nitrogen

Nitrite nitrogen values were moderate or low during most of the months except in March, when higher values were recorded in all the stations excluding stn.6 which clearly indicates the source is from the industrial effluents. Compared to other stations, stations 2 and 3 showed higher levels apparently contributed by runoff from agricultural fields (Fig. 19).

5.1.2 Primary production

As mentioned earlier, the ecological zonation of an estuarine, brackish water and fresh water regime is apparent in the primary production rates observed in the study area, the stations located in the estuarine region always showing higher rates compared to the other two environments. However, during most of the months, the production rates were much lower in the stations located in the impact zone (Stns. 4 and 5) which clearly show the effect of pollution in the vicinity. The production rates at the control station (Stn.6) upstream were invariably high compared to the stations in the impact area. However, the picture of primary production on an annual basis indicates bimodal fluctuations with peaks during pre-monsoon and post-monsoon seasons (Figs. 21 & 22).

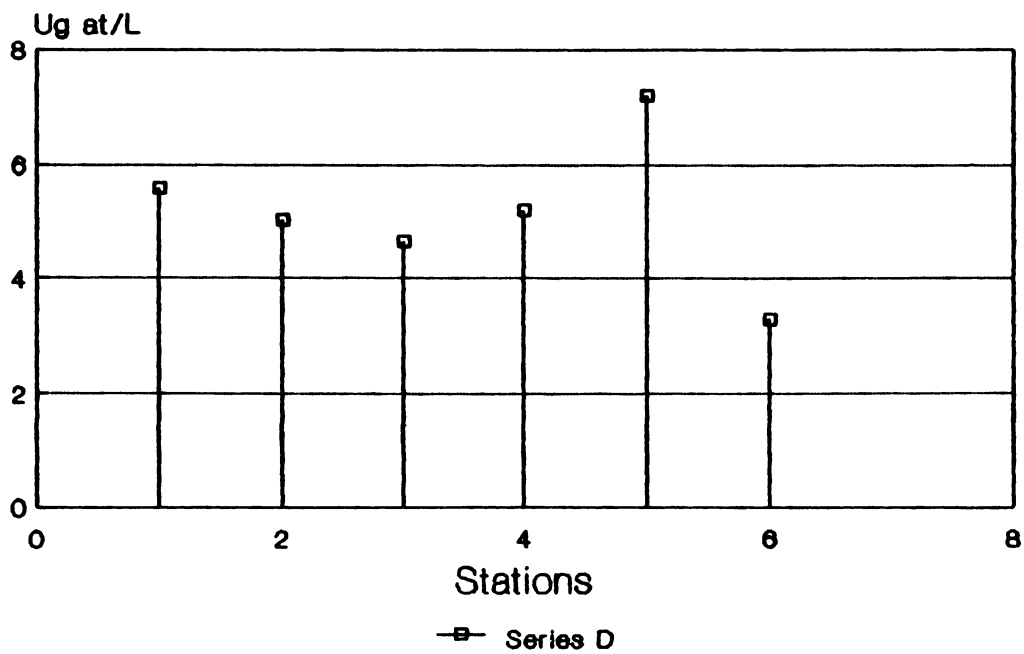
5.1.3 Zooplankton

The distribution and abundance of zooplankton also reveals the same trend as primary production rates but the effect of ecological zonation in

Fig.18

Annual Mean Values Stationwise

Hydrography and Fishery

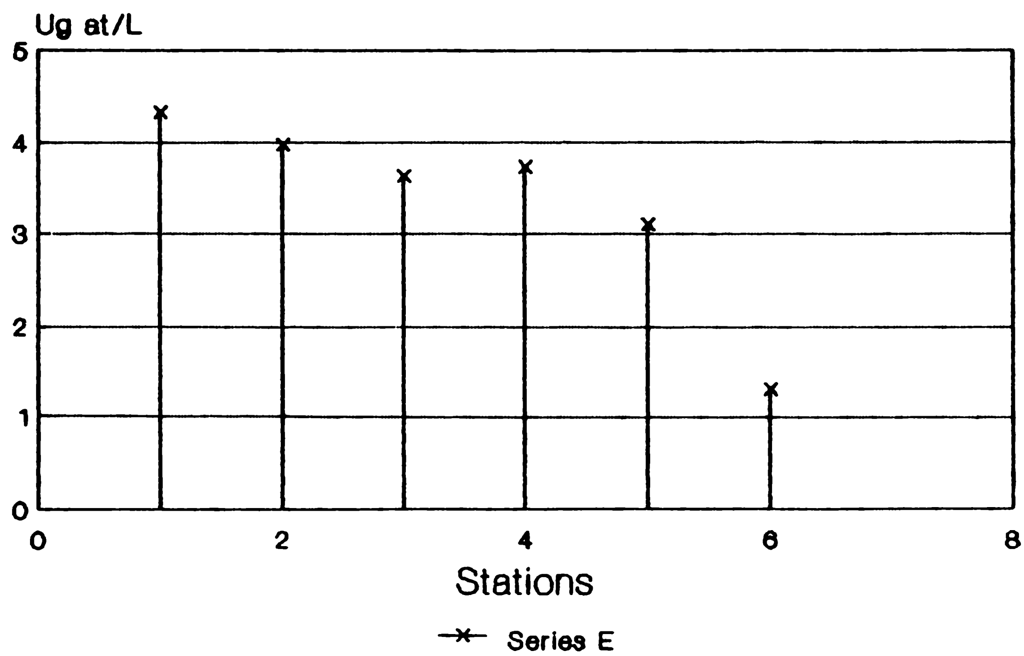


D:Phosphate

Fig.19

Annual Mean Values Stationwise

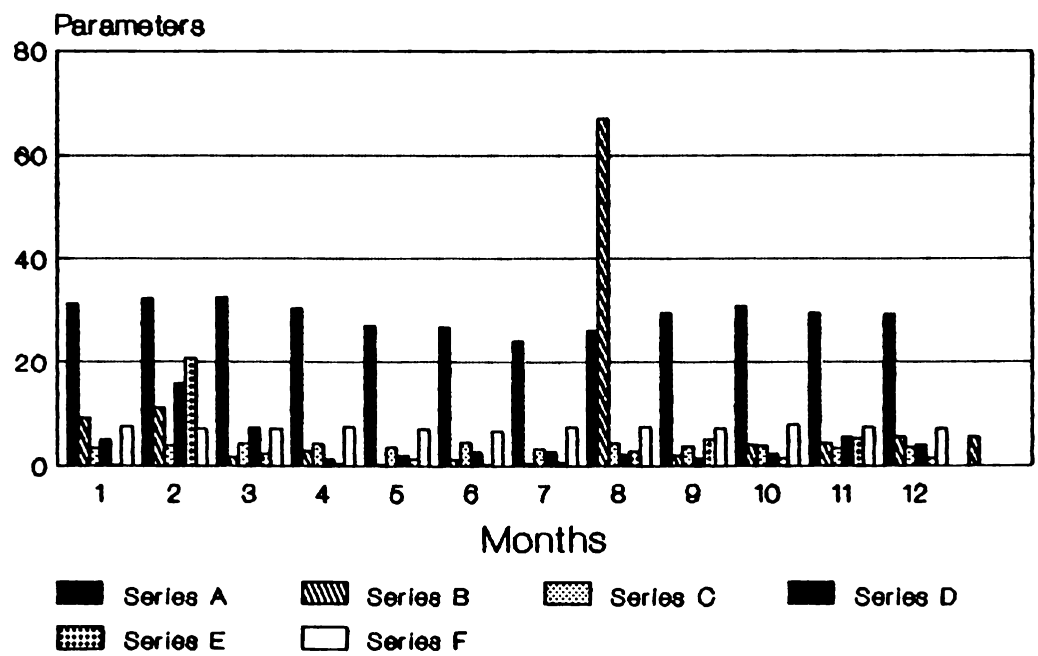
Hydrography and Fishery



E: Nitrite

Fig.20

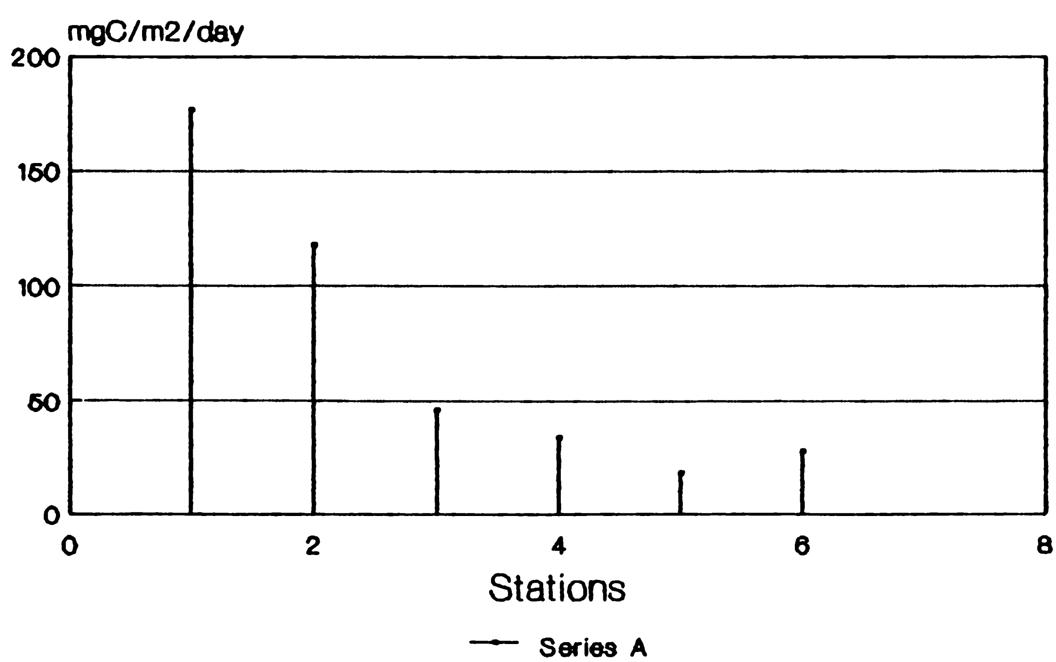
Monthly Average Values
Hydrography and Fishery



A:Temp. B:Sal C:Oxy D:Pho E:Nit F:pH

Fig. 21

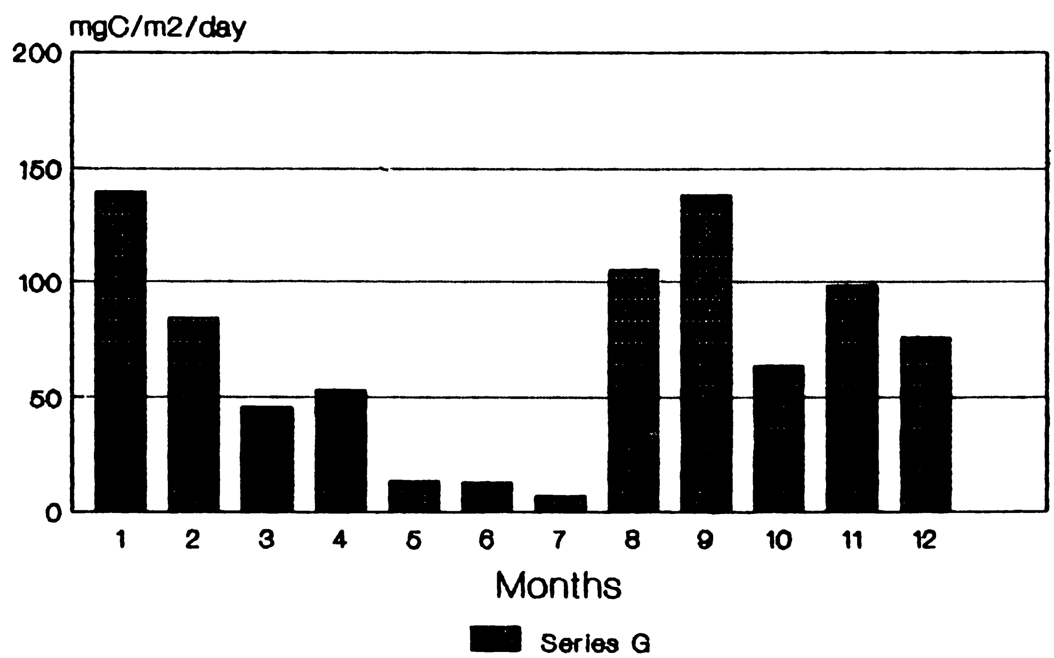
Primary production
Hydrography and Fishery



A:Primary production

Fig.22

Monthly Average Values
Hydrography and Fishery



G.Primery Production

the abundance of plankton is much more clear in this case. During monsoon season, there is practically no zooplankton production which can be due to large volume of fresh water discharge and consequent reduction of salinity in the entire area. As in the case of primary production, zooplankton biomass also shows a bimodal fluctuation with peaks during pre-monsoon and post-monsoon seasons (Figs. 23 & 24).

5.1.4 Fishery resource

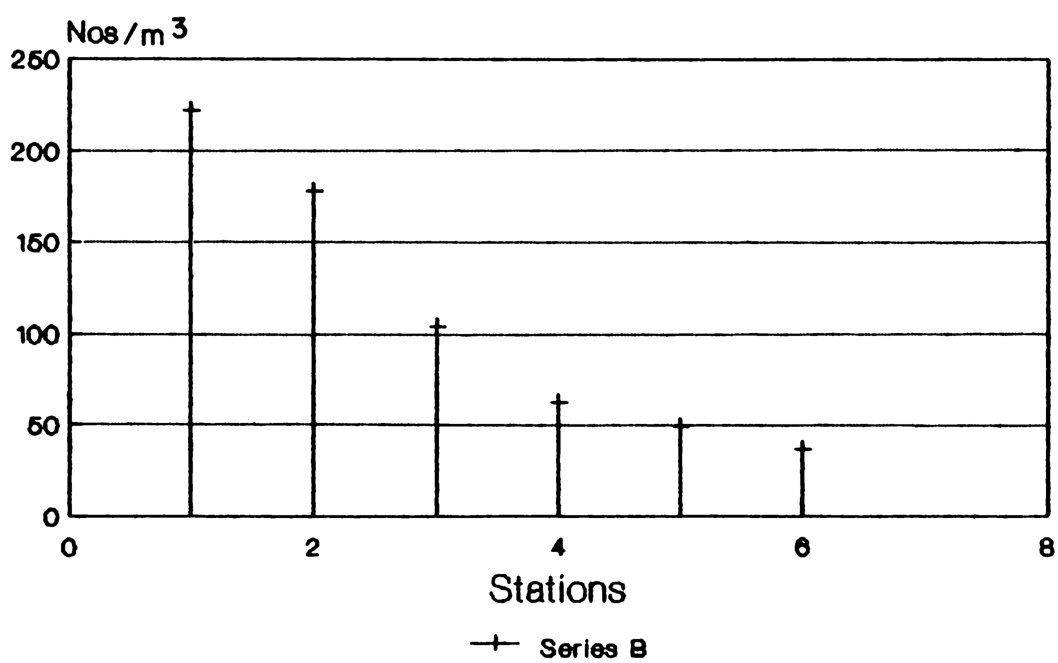
The fish samples were obtained by operating a small experimental trawl net for 30 minutes in each station. Hence the catch obtained may not reflect the true fish population in the study area. However, since the benthic and semi benthic fin and shell fishes form the bulk of the population, the data will reveal an overall picture of fish abundance in the study area. As it is seen from the data (Figs. 25 & 26) the fish catch shows that significant population is present only in stations situated in the estuarine area and virtually not many fishes were obtained from other stations. The fine clayey bottom available in Stns. 1 to 3 provides an ideal substratum to the benthic fishes, prawns and crabs. The detailed analysis of the fish catch data show that prawns constitute the major component in Stn.1, but in Stns. 2 and 3 almost 50% of the resource is represented by fin fishes. Some significant quantity of crab population of Scylla serrata was noticed in Stn.2 in certain periods. The pre-monsoon months of February, March and April is the peak season for prawns in the area.

Month-wise and station-wise variations in the hydrographical parameters, primary production, zooplankton and fish catch were investigated by Analysis

Fig.23

Zooplankton

Hydrography and Fishery

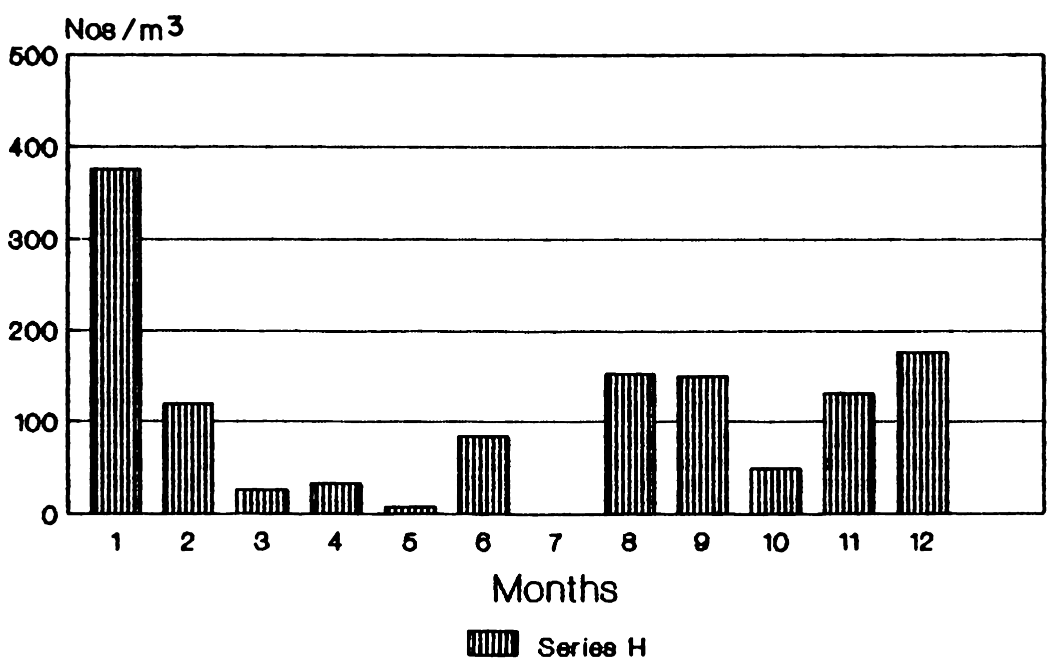


B:Zooplankton

Fig. 24

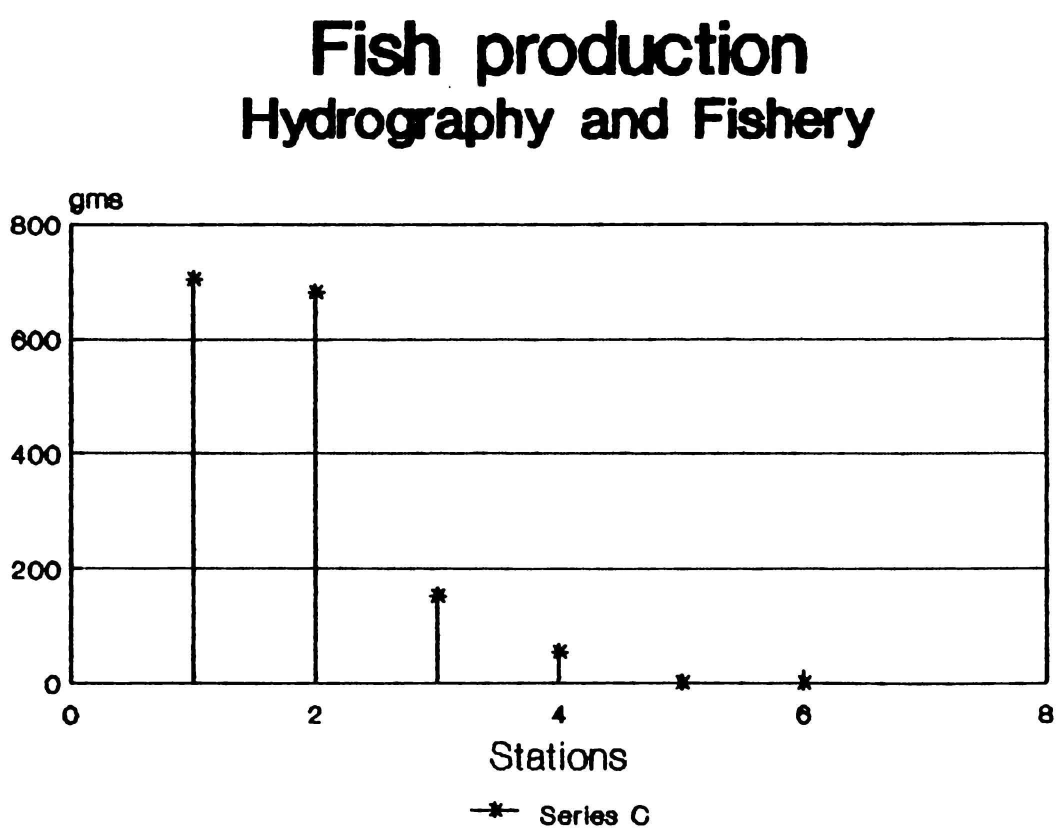
Monthly Average Values

Hydrography and Fishery



H:Zooplankton

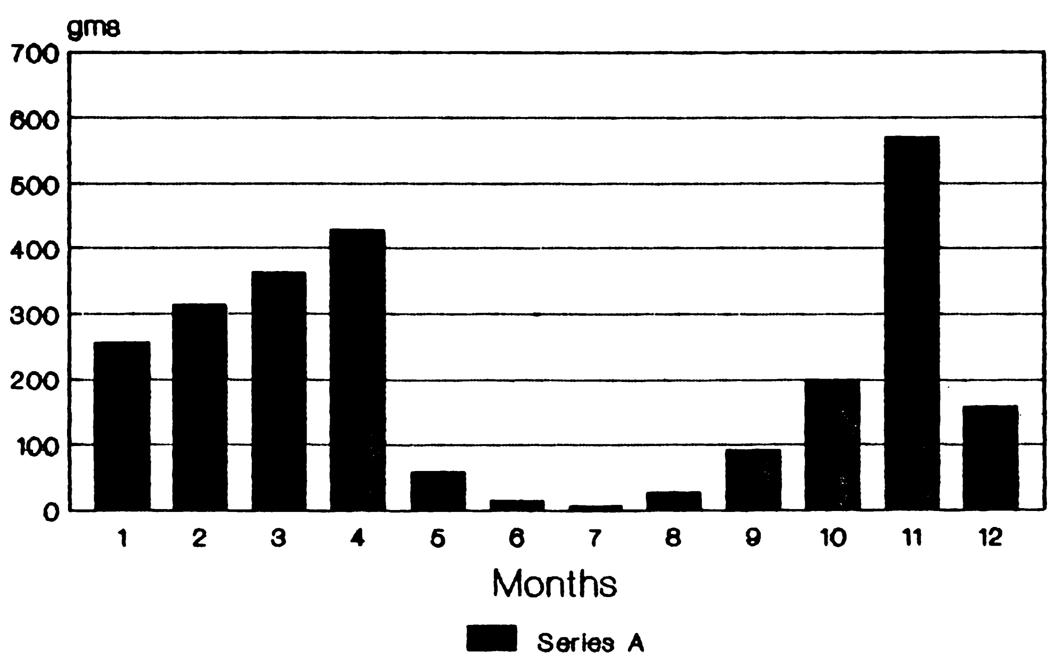
Fig. 25



C:Fish catch

Fig.26

Monthly Average Values
Hydrography and Fishery



Fish catch

of Variance (ANOVA). Results of ANOVA F-test are presented in Table 13. Month-wise variation in primary production and zooplankton were found to be highly significant, but not the monthly variation in fish catch. Temperature, salinity, oxygen, phosphate and pH measurements showed highly significant monthly variations both for the surface as well as for the bottom. However, monthly variations in Nitrite levels were significant only for the surface values.

Variations among stations were highly significant for primary production, zooplankton and fish catch data. Among the hydrographic parameters station-wise differences were highly significant for temperature and salinity levels, both at the surface as well as at the bottom. Differences in the bottom pH measurements were found to be just significant. Dissolved oxygen, phosphate and nitrite were not found to vary among stations either for the surface or for the bottom.

Table 13. Result of Anova F-Test

Parameters	F-value for differences between months (d.f = 11.55)	F-value for difference between stations (d.f = 5.55)
1. Surface temperature	91.55**	3.7**
2. Bottom temperature	66.6**	3.5**
3. Surface salinity	7.3**	10.3**
4. Bottom salinity	4.8**	6.8**
5. Surface dissolved oxygen	2.7**	0.84 (N.S)
6. Bottom dissolved oxygen	3.9**	2.2 (N.S)
7. Surface phosphate	13.4**	1.2 (N.S)
8. Bottom phosphate	5.9**	0.4 (N.S)
9. Surface Nitrite	26.4**	1.2 (N.S)
10. Bottom Nitrite	1.3 (N.S)	1.1 (N.S)
11. Surface pH	128.3**	0.7 (N.S)
12. Bottom pH	296.1**	2.9*
13. Primary production	2.5**	10.5**
14. Zooplankton	3.3**	3.5**
15. Fish Catch	1.9 (N.S)	8.4**

N.S - Not Significant

* - Significant at 5% level

** - Significant at 1% level

5.2 Case studies in fish mortality

In recent years, there has been a number of reports about fish mortalities due to water pollution in the Cochin estuarine system and adjacent waters, which included the Periyar River near the industrial area at Eloor and also the Chitrapuzha near Ambalamedu, another industrial suburb of Cochin, the effects often extending to the estuarine areas.

Water pollution to a limited extent was noticed in this region since the inception of the industrial complex about a decade ago. But recently, due to the addition of a number of factories and also due to the increased production in the existing factories, there is every indication that the quantum of pollutants has gone up substantially. The water becomes highly acidic in the impact area and fish kills are reported to be a regular phenomena. However, in another adjacent hotspot Chitrapuzha at Ambalamugal, the pollutant was ammonia.

Fish mortalities were recorded from these waters since 1973. On 8.1.1973, an instance of large scale fish mortality was noticed near the impact area at Eloor. The details of the data are given in Table 1. Dead fish were seen floating in large numbers and some were seen on the bottom with inflated belly. On the shore, dead fishes could be seen strewn all over the banks. The fishes represented almost all groups including crustaceans, pelagic as well as demersal forms indicating the effect of pollutant in the entire water column. The pH of the water at the spot showed as 4.8 which clearly indicated the water was highly acidic and might have caused instant death to the fauna. Water samples revealed that no planktonic organisms were present. Due to the complexity of the pollutants, the exact identity of the acid could not be detected.

Another instance of large fish kill was reported on 10.5.1973 in the Chitrapuzha near Ambalamugal. Enquiries showed that the large Fertilizer Complex there started production in the last week of April. In the first week of May, fish kills were seen in the river nearby. There was strong smell of ammonia in the air. Details of data collected are given in Table 14.

In the same area, a major fish kill occurred in June 1980. The main impact zone was Chitrapuzha River and the Champakkara canal which connects with Cochin backwater at Thevara (Fig. 3). The mortality was observed on 5.6.1980 in a stretch of about 10 km comprising estuarine and fresh water regions. The analysis of water samples collected from six stations (including one unpolluted station upstream) showed very high levels of ammonia (Table 15). In some areas, fishes could be seen struggling in the water obviously showing symptoms of suffocation. From the fish samples obtained from the affected area, 24 species belonging to 18 families were identified. These included pelagic, mid-water and benthic forms indicating the effect of the pollutant in the entire water column. The fishes also included fairly large sized forms like Wallago attu (upto 58 cm), Sciaenids (upto 50 cm) and comparatively sturdy species like Arius gella. Majority of the fishes were euryhaline forms having a wide distribution in the estuarine and contigous waters. A list of fishes collected are given in Table 17.

Water samples collected from various points in the impact area contained high concentrations of ammonia ranging from 27 mg/L to 119 mg/L while samples collected from an unpolluted station upstream recorded a value of only 5 mg/L. During normal conditions the concentration of ammonia in these waters is reported to be 0.02-0.61 mg/L. The ammonia persisted in the water in substantial quantities in the continuing floods for more than two months (Data collected on 23.7.1980 is given in Table 16) and fishes reappeared in the affected zone only after about three months. Hence, the overall effect on the ecosystem has been much more than what appeared during the time of mortality. Subsequently, there were few more instances of fish kills reported from both the locations, but were of lesser magnitude.

Apart from the effect of pollution, of late there have been other ecological changes caused by human interference which is reported to be causing environmental problems in the area. During the summer season, due to reduction of fresh water discharge in the Periyar river as the result of construction of dams upstream and diversion of water through canals, salinity incursion is a regular phenomena. The fresh water intake for most of the major industrial establishments were affected due to this. To prevent the flow of saline water towards upstream, a temporary sand bund used to be constructed in the vicinity of the factories during summer season every year. This bund has prevented the flow of water and in the area below and above the bund, water gets stagnated resulting in some water quality problems, especially acidity in the immediate vicinity of the bund towards the estuary causing fish mortalities also. Details of the data are given in Table 18. Low pH (4.2 and 3.2) and rather high salinity at the station nearest to the bund (6.09‰ at the surface and 15‰ at the bottom) as compared to that in Stn.6 situated upstream where the conditions are normal.

Table 14. Hydrographic features in the vicinity of fish mortality

Location : Cochin - Eloor. Date : 8.1.1973

Station	Temp. °C	Salinity ‰	D. oxygen ml/L	pH
1	S 30	0.42	3.20	7.05
	B 29	0.25	4.01	7.30
2	S 30.5	0.25	3.70	4.8
	B 29.5	0.68	4.70	6.9
3	S 30.5	0.76	4.05	7.20
	B 29.5	0.51	3.20	7.10

Table 15. Fish mortality in the Chitrapuzha

Location : Cochin - Ambalamugal region. Date : 10.5.1973

Stn.	T°C	O_2 ml/L	NO_2 µg at/L	Po4-P µg at/L	pH	NH_3 mg/L
1	33	0.86	0.90	1.20	8.85	333
2	33	0.00	0.07	3.4	8.8	330
20 days after the mortality (31.5.1973)						
1	31.5	1.28	0.66	1.56	6.3	0.61
2	32.0	0.76	0.04	1.80	7.8	0.02

Table 16. Environmental features and pollutant concentration at the site of fish mortality

Location : Cochin - Ambalamugal

Stn.	Water Temp. °C	pH	Salinity ‰	D. oxygen ml/L	Ammonia mg NH_3/L
5.6.1980					
1	30.0	7.9	0.4	3.9	5.1
2	30.0	8.2	0.8	6.3	118.6
3	29.0	7.9	1.0	4.3	26.6
4	29.5	7.2	2.6	3.9	39.9
5	29.9	7.5	2.1	4.1	39.9
6	30.0	7.8	5.1	6.1	39.9
23.7.1980					
1	28.5	8.6	0.0	3.3	0.2
2	28.5	8.8	0.0	4.8	38.6
3	28.5	8.6	0.0	3.8	20.8
4	29.5	7.2	0.0	4.1	3.0
5	29.0	7.0	1.8	3.9	3.0
6	29.5	7.0	4.0	5.1	8.9

Table 17. List of species of fishes and crustaceans collected from the zone of fish mortality

Sl. No.	Name	Nos. collected
Family:	Cichlidae	
1.	Etroplus suratensis (Bloch)	43
2.	Etroplus maculatus (Bloch)	9
Family:	Sciaenidae	
3.	Sciaena glacus Day	8
Family:	Platycephalidae	
4.	Platycephalus insidiator (Forskal)	9
Family:	Gerreidae	
5.	Geres filamentosus Cuv.	3
Family:	Siluridae	
6.	Wallago attu (Schneider)	3
Family:	Mastacembelidae	
7.	Mastacembalus armatus (Lacepede)	1
Family:	Clariidae	
8.	Clarius batrachus (Linnaeus)	14
Family:	Soleidae	
9.	Synaptura commersoni (Lacepede)	10
Family:	Anguillidae	
10.	Anguilla bengalensis (Gray and Hardwicke)	3
Family:	Serranidae	
11.	Epinephelus malabaricus (Schneider)	2

Table 17. (Contd...)

Sl. No.	Name	Nos. collected
Family:	Mugilidae	
12.	Mugil cunnesius Val.	1
Family:	Lutjanidae	
13.	Lutianus argantimaculatus (Forskal)	3
Family:	Apagonidae	
14.	Apogon sp.	2
Family:	Engraulidae	
15.	Anchoviella indicus (Van Hasselt)	1
Family:	Leognathidae	
16.	Leiognathus equata (Forskal)	3
Family:	Gobiidae	
17.	Glossogobius giurus (Hamilton)	1
Family:-	Taenioididae	
18.	Trypauchan vagina (Block and Schneider)	1
Family:	Ariidae	
19.	Arius gella	7
20.	Arius sp	7
Others		
21.	Barbus amphibius	22
22.	Ambasis urotaemia Bleeker	1
23.	Macrones sp.	
Crabs		
24.	Scylla serrata (Forskal)	2

Table 18. Details of hydrographic data collected from Cochin-Eloor area during summer season - indicating the effect of a temporary bund (April - 1982).

Stns.@		1	2	3	4	5	6
Depth (m)		3.75	6	3	2	3	2
Temp°C	S	30.90	31.60	31	33.20	33.30	33.40
	B	31.00	31.90	32.30	33.00	33.10	-
pH	S	7.90	6.80	6.30	4.2	3.20	7.8
	B	7.70	6.90	6.90	6.4	6.20	
Sal ‰	S	26.03	19.48	10.16	11.54	6.09	0.55
	B	26.22	20.96	17.63	15.51	15.00	-

@ Stations are marked 1-6 from the mouth of the estuary towards upstream and the last station above the bund.

5.3 Metal levels in bivalves from Cochin estuary

Several toxic pollutants, probably unknown to the biota before, have been introduced in large quantities into the estuarine and coastal environment. Trace metals, particularly cadmium, lead and mercury have received much attention from researchers because of their high toxic, transport, bioaccumulation and bioconcentration potentials. The capacity of some animals and plants to accumulate potentially toxic trace metals in their tissues far in excess of ambient level is well known and has become the focus of increasing number of studies from several parts of the Indian coastal waters.

To use bivalves for metal level monitoring is now widely accepted because of their ability to bio-accumulate the metals and also because of their sedentary habitat. From Cochin estuarine system, Sankaranarayanan et. al., (1978) have reported the concentration of some heavy metals in the oyster Crasostrea madrasensis. Lakshmanan and Nambisan (1983) reported seasonal variations in trace metal contents in bivalve molluscs V. cyprinoides, Meretrix sp. and P. viridis from Cochin. Nair and Nair (1986) described the seasonality of trace metals in C. madrasensis in the Cochin backwater. Rajendran and Kurian (1986) also reported C. madrasensis as indicator of metal pollution in Cochin backwaters. However, studies on the present lines are very few from this region and hence of much relevance here.

The bivalve mollusc Sunetta scripta which is available during most of the months in the Cochin bar mouth and fished in considerable quantity due to its economic importance was sampled and analysed for four metals, viz: Copper, Zinc, Cadmium and Lead for a period of one year. Details of the data are given in Table (19) (a). Other than the annual variations in the levels of the metals, the rate of accumulation in size groups were also estimated. Since bivalves have the ability to depurate the metals from their body tissue, the effect of depuration in clean sea water was also evaluated.

The general trend of metal load in the bivalve showed a definite peak in the pre-monsoon season and another peak during the post-monsoon period, but of lesser magnitude. Most of the metals showed low levels during monsoon season except cadmium. Metal levels noted were much less than the levels recommended for seafood export.

Another interesting observation was that the smaller sized animals showed higher levels of copper in the tissue compared to larger specimens. But other metals were always present in higher levels in the bigger animals. Details of the data are presented in Table (19) (b). Such characteristic phenomena regarding copper accumulation has been reported recently. (C.M. Katticaran, 1989). Depuration experiments showed considerable effect on the excretion of metals by the animal. While significant effect was noticed in the case of lead, the effect was only marginal in the case of copper and zinc compared to Cadmium and lead (Table 19) (c). However, since cadmium and lead are known to be more toxic to other organisms, it is advisable to depurate the clams before used for consumption.

In another study, species of V. cyprinoides was collected from three different locations in the Cochin estuary, the stations representing polluted (1) less polluted (2) and pollution free (3) area for a period of three months (Fig. 3). The data revealed a definite indication of location specific variation of metal levels in the clam analysed (Table 20). Seven metals were analysed. The levels of Fe, Mn, Zn, Cu, Cd and Pb were more at Stn.1 than at the other two stations. Compared to the positions of stations 2 and 3, station 1 is situated nearer to the major industrial area. This observation, although for a short duration, indicates the potential pollution hazard which calls for a continuous monitoring programme using suitable bivalves as sentinel organism for the Cochin backwaters.

Table 19. (a) Metal levels in bivalve Sunetta scripta - seasonal variations

Metals : (µg/g wet weight)

Period	Cu	Zn	Cd	Pb
1.1.89	5.15	19.86	0.18	0.11
10.2.89	4.4	34.39	0.81	0.65
15.3.89	4.4	31.65	0.84	0.42
9.5.89	5.43	36.50	0.70	0.33
4.7.89	6.10	29.85	0.99	0.50
5.8.89	4.0	28.74	0.59	0.26
22.9.89	4.22	26.13	0.10	0.44
7.10.89	6.14	30.07	0.31	0.33
27.11.89	2.21	33.48	0.21	0.61
17.1.90	6.11	32.40	0.36	0.44

Table 19 (b) Metal levels in Sunetta scripta - relation with size variations

Metals : (μg/g wet weight)

Period	Size	Cu	Zn	Cd	Pb
10.2.89	B.S.	3.73	46.71	1.35	0.75
	S.S.	5.07	22.07	0.27	0.56
15.3.89	B.S.	3.89	43.24	1.50	0.75
	S.S.	4.99	20.07	0.18	0.10
9.5.89	B.S.	4.13	51.83	1.14	0.41
	S.S.	6.74	21.18	0.27	0.26
4.7.89	B.S.	5.41	37.25	1.70	0.31
	S.S.	6.80	22.45	0.28	0.70
5.8.89	B.S.	3.72	34.92	0.96	0.28
	S.S.	4.28	21.57	0.22	0.25

B.S. : Big Size : 32-43 mm

S.S. : Small Size : 18-31 mm

Table 19 (c) Metal levels in Sunetta scripta - effect of depuration

Metals : (µg/g wet weight)

Period		Cu	Zn	Cd	Pb
22.9.89	'0'	4.22	26.13	0.10	0.44
	'24'	3.61	24.44	0.09	0.26
7.10.89	'0'	6.14	30.07	0.31	0.33
	'24'	6.99	32.92	0.67	0.16
27.11.89	'0'	2.21	33.48	0.21	0.61
	'24'	1.96	31.14	0.23	0.58
17.1.90	'0'	6.11	32.40	0.36	0.44
	'24'	6.02	33.16	0.37	0.30
29.5.90	'0'	8.31	28.48	0.62	0.39
	'24'	8.88	30.98	0.71	0.47

'0' : Fresh sample

'24' : Depurated in sea water for 24 hrs.

Table 20. V. cyprinoides var. cochinensis

Metal contents: µg/g dry weight (soft parts)

Stn.	Period	Size	Cu	Co	Cd	Fe	Pb	Ni	Zn
I	October '85	25-23	31.0	ND	3.5	1357.0	7.5	4.0	463.0
		29-26	28.5	ND	4.0	1150.0	7.0	1.0	452.5
	November'85	26-24	14.5	1.5	8.0	1121.5	5.5	3.0	428.5
		34-30	17.5	0.5	9.0	1260.0	5.5	4.5	488
	December'85	28-25	14.0	ND	9.5	1292.5	4.0	3.0	163.5
		38-33	15.0	ND	9.0	1136	4.0	2.5	153.5
II	October'85	25-24	17.0	1.5	2.0	1351.0	4.5	5.5	234.5
		28-26	16.5	1.5	2.0	1633.5	5.5	7.0	348
	November'85	25-23	17.0	ND	2.0	863.5	5.5	2.5	107
		31-29	17.0	ND	2.0	775	5.5	1.0	179
	December'85	23-21	18.0	1.0	2.5	1558	5.5	4.5	94.5
		29-27	18.0	0.5	3.0	1885	6.5	5.5	104.5
III	October'85	25-18	14.5	0.5	0.5	1191.0	1.5	1.5	124.5
		32-26	23	1.0	3.5	1318.5	2.5	1.0	141
	November'85	26-24	18.0	0.5	1.5	1695.5	3.5	2.5	179.0
		37-34	15.5	ND	2.0	863.5	6.5	1.0	174.5
	December'85	26-22	13	0.5	1.5	1437.5	5.5	2.5	66.5
		32-30	12	ND	1.5	2455.5	4.5	6.5	72.5

Mercury levels in the estuarine waters of Cochin

The toxic properties of mercury and its transformation in the environment by biological and chemical means are well established. The level of mercury in sea water is about 0.2 ppb. In the coastal areas subjected to mercury containing waste disposal mercury levels may exceed 3 ppb. According to an estimate 180 tonnes of mercury are introduced into the Indian environment every year of which 166 tonnes come from 38 caustic soda plants, including 23 units of mercury cell electrolysers of sea water. (Choudhuri, 1980). Mercury levels in the Indian marine environment has been estimated by several workers and found to be within the safe limits except for certain identified 'hot spots'. However, high levels of mercury are reported from Muvattupuzha river, joining Cochin backwaters, Thane creek near Bombay and Binge Bay of Karwar.

In the present study, data on total mercury levels in water were collected from two stations in the estuarine area of Cochin for a period of 18 months during 1987-88.

During August and September very high levels of mercury were observed at both the stations. At the bar mouth highest concentration of mercury was recorded during August'88 (66 ppb). This may be due to the monsoon rains washing off the sediment bound mercury of the estuarine region, and bringing it up into the water column.

The seasonal variation of the mercury levels indicated a peak period during October-November. Details of the monthly variation of mercury levels for 18 months are given in Table 21. It has been reported that a major portion is suspended and particulate heavy metals get precipitated before the bar mouth region and smaller portion of it would flow out into the sea. The average mercury levels for the two stations show fluctuations only to a smaller extent (0.8 ppb and 0.95 ppb respectively).

The tolerance limit for industrial effluents discharged into the coastal waters recommended by ISI is 0.01 mg/l (ISI:2490). However, the tolerance limit for water quality after receiving discharge is 0.0003 mg/l (ISI:2490) and the minimum risk concentration reported for mercury is 0.1 ppb (Bernard, 1981). Available data on mercury levels from the Indian coastal and estuarine waters are given in Table 22 for comparison.

Table 21. Total mercury levels in the estuarine water of Cochin (pp^b Hg)

Months	Stations	
	1	2
April 1987	1.00	0.70
May	0.70	1.10
June	0.70	0.70
July	0.70	0.80
August	0.45	0.65
September	0.65	1.50
October	0.95	0.50
November	0.90	1.60
December	0.90	1.00
January 1988	1.30	0.90
February	0.40	0.50
March	0.50	0.45
April	0.55	0.40
May	0.56	0.60
June	1.00	1.30
July	1.40	1.55
August	17.00	66.00
September	1.00	1.70

Table 22. Comparative account of mercury levels in the Indian coastal and estuarine waters (Hg/µg/L)

	Area	Level of mercury	Source
1.	Indian coastal waters	0.20	Sanzgiri _et. al._, 1988
2.	Arabian Sea	0.078	Qasim _et. al._, 1988
		0.013-0.018	Singbal _et. al._, 1978
		0.09	Sanzgiri _et. al._, 1979
3.	Bay of Bengal	0.045	Qasim _et. al._, 1988
4.	Binge Bay, Karwar	0.146-26.68	Kureishy _et. al._, 1986
		0.91-2.62	Krishnakumar and Pillai, 1990.
5.	Thane Creek, Bombay	0.247	Zingde and Desai, 1981
6.	Cochin backwaters (Moov. River)	1.2-50.0	Balchand and Nambisan, 1986
7.	Cochin inshore waters	1.02	Alavandi _et. al._, 1988.

HUMAN INTERFERENCE AND ECOLOGICAL IMBALANCE IN THE VEMBANAD LAKE

6. . HUMAN INTERFERENCE AND ECOLOGICAL IMBALANCE IN THE VEMBANAD LAKE

The Vembanad Lake and the connected backwater systems exert considerable influence on the socio-economics of the surrounding areas as the living resources available in the lake plays an important role for the people living on its banks. The annual average landings from this lake is reported to be about 5825 tonnes, of which 30% are prawns. Other than this, the lake also supports a major clam fishery amounting to about 2 lakh tonnes consisting of 25,000 tonnes of live clams and the rest contributed by semi-fossilised shell deposits.

The most important variable which controls the distribution, survival and growth of plants and animals in this ecosystem is salinity. The wide spectrum of divergence in salinity from almost fresh water to sea water enables the sustenance of a large variety of aquatic life both plant and animal, in the water. An ecological balance has been evolved over the period of its evolution by the biota surviving in this dynamic ecosystem.

6.1 Effect of Thanneermukkom Salt Water barrage

One of the major hazards to the cultivation of paddy in the agricultural fields lying adjacent to the Vembanad Lake is the incursion of saline water through tidal flow, especially during the summer period. To prevent salt water incursion and to promote a double crop of paddy in about 50,000 ha of low lying fields in the area, it was decided to construct a 1463 metre long barrage rising 92 cm above the level of high tide at Thanneermukkom in the Vembanad Lake at an estimated cost of Rs.485 lakhs. It has been assessed that a total quantity of 11000 million cubic metres of water is drained into the Arabian Sea annually by the rivers through the barrage.

Designed as a bridge cum regulator with facilities for allowing navigation, the work of the barrage was started in 1958. When it became temporarily functional in March 1975 with an earthern bund in the middle portion, it became the second biggest salt water barrage in the country, next to Farakka Barrage in the Ganga river. The barrage started regular functioning from the summer of 1976 and since then the regulators remain closed from January to May every year. This has resulted in some ecological changes in the lake in general, and in the area south of the barrage in particular. During the summer period when the barrage is kept closed, there is virtually no flow of water beyond the barrage towards the southern side. Due to this situation, in the southern zone an almost fresh water condition prevails throughout the year while there is varying grades of salinity in the northern region. This phenominal change in the hydrodynamics of the ecosystem has triggered off related ecological changes in the impact zone which in turn has affected the distribution as well as survival and abundance of the living resources.

Observations and Discussion

Salinity, Plankton and Fishery

It is apparent that in an estuarine ecosystem, salinity is one of the most significant factors controlling the survival, abundance and distribution of the organisms. Earlier observations reveal that during the pre-operation period of the barrange (before 1975) even at the southern most region of the lake, salinity was fairly high (range: 0.19 in July to 21.7% in November). During summmer season homogeneous groups of plankton populations which require higher salinity were occurring in this part of the lake. However, after the commissioning of the barrage, the southern half of the lake is almost fresh water even in summer. Salinity data collected during 1974-75 and during 1980 from four stations (two stations each in the southern and northern half) show significant change in salinity. For a salinity value of 24.13‰ and 24.38‰ (pre-bund period) at the two stations south of the barrage during 1974-75, the corresponding value of salinity for 1980 (post-bund period) for the same period was only 1.35‰ and 0.7‰ respectively. Details of seasonal variations in salinity during pre and post-operational periods of the salt water barrage are given in Table 23.

Apart from this, it is reported that large scale discharge of fresh water into the Moovattupuzha river (from a hydroelectric project upstream) which joins the Vembanad Lake near Vaikom is also contributing to the reduction in salinity in the northern half of the lake. About 800 cusecs of fresh water is discharged additionally into the river everyday (Nair and Pillai, 1982). Balchand and Nambisan (1986) state that 'the increased discharge of tail race waters from the hydroelectric project nearby provided dilution resulting nearly in fresh water conditions'. This regular discharge of fresh water has resulted in change in the estuarine habitat in the impact areas.

Studies conducted in the early seventies (Pillai, et. al., 1972) from the entire lake system showed that the zooplankton biomass exhibited two peaks, one in March-April and the other during October-January. Earlier studies by George (1958), Nair and Tranter (1971) and Haridas et. al., (1973) have

Table 23. Seasonal variation in salinity(‰)

A comparison between Pre (1974) and Post (1980) operational period of the salt water barrage

	I			II			III			IV		
	1974	1980	% reduction	1974	1980	% reduction	1974	1980	% reduction	1974	1980	% reduction
March	26.48	15.26	42.37	25.35	7.67	69.74	24.13	1.74	92.78	24.38	1.63	93.31
April	28.18	9.69	65.61	25.11	11.12	55.71	25.24	3.07	87.83	25.35	1.42	94.39
May	0.96	0.09	90.62	2.24	0.09	95.98	2.08	0.05	97.59	2.50	0.05	98.00
June	1.76	0	100	2.24	0	100	1.68	0	100	1.76	0	100
July	1.27	0	100	1.19	0	100	0.34	0	100	0.51	0	100
August	0.34	0	100	0.25	0	100	0.25	0	100	0.25	0	100
September	0.68	0.59	13.23	0.51	0	100	0.42	0	100	0.10	0	100
October	0.60	0	100	0.22	0	100	0.15	0	100	0.16	0	100
November	6.0	0	100	0.48	0	100	1.20	0	100	1.25	0	100
December	9.24	3.05	66.99	5.68	0.90	84.15	3.40	0.37	89.11	1.00	0	100

Source: The changing Ecology of Vembanad Lake
Nair, P.V.R. and V.K. Pillai, 1990.

also indicated the same sequence of zooplankton distribution in the entire backwater. But subsequent to the commissioning of the barrage the pattern has changed as seen from Table 24.

The effect of changes in the salinity is evident from the data on the distribution and abundance of zooplankton in the lake. The data obtained during 1971 shows that the zooplankton distribution is uniformly found in the lake except for the general reduction noticed during the peak monsoon period. However, during the post-operational period (1980) while considerable reduction is noticed in the overall abundance of zooplankton, there is substantial reduction in the southern side of the barrage.

It is also observed that the functioning of the barrage has adversely affected the distribution and abundance of the fishery resource in general and the prawn fisheries in particular. Though data collected on a systematic basis is not available for a direct comparison, information available indicates that there is some effect on the prawn fishery in the affected zone.

On the southern side of the barrage during monsoon season and afterwards the prawn Metapenaeus dobsoni is available in good numbers. The availability of this prawn in the southern zone during the period in which the barrage remain open reveal that in the absence of a barrier large scale migration of prawns takes place towards the southern half and subsequently and migrated population is trapped in the area when the barrage is closed. Table 25 indicates the availability of prawns in the southern zone during the pre and post-operational period of the barrage. However, Qasim and Madhupratap (1979) observed that the construction of the bund across the backwaters as a barrier to the

Table 24. Distribution of zooplankton (nos/m^3) in the Vembanad Lake - a comparison between pre and post-operation period of the salt water barrage

Period	Stns:	1	2	3	4
Jan. - Apr. 1971		9875	No data	8466	9499
May - Dec. 1971		1767	-do-	1104	244
Jan. - Apr. 1980		913	1616	477	52
May - Dec. 1980		55	199	43	97

The barrage remain closed during January - April and remain open during May - December since 1976.

Source: The changing Ecology of Vembanad Lake
Nair, P.V.R. and V.K. Pillai, 1990.

Table 25. Distribution of M. dobsoni in the Vembanad Lake during both the periods when the barrage is closed and open.

Period Stns.	I	II	III	IV
		Barrage closed		
February (1979)	250	786	20	1
March	28	64	1	1
April	12	93	1	-
		Barrage remain open		
May	-	3	-	4
June	-	21	-	2
July	128	246	22	32
August	140	60	2	10
September	5	33	3	2
October	60	112	5	1

Source: The changing Ecology of Vembanad Lake
Nair, P.V.R. and V.K. Pillai, 1990.

entry of saline water has prevented the entry of prawns and fishes with the result that there is practically no fishing left in the upper reaches of the backwaters. They also observed that prior to the construction of the bund, salt water used to enter the lake after the monsoon causing the decay of Salvinia weeds. Moreover, there used to be a regular flushing of the backwater due to tidal influence which has now ceased causing stagnation of the water. During the monsoonal outlet of fresh water, when the spillways remain open, enormous quantities of weeds are flushed into the water column thereby affecting the phytoplankton productivity.

Jhingran and Gupta (1989) in a reappraisal of the fisheries ecology of the Ganga river system stated that 'the fishery of anadromous hilsa, abundant till 1972 at all centres above the Farakka Barrage in lower Ganga has received a tremendous set back, the barrage posing an obstruction in the upward migration of fish'.

It is also reported that, large scale reclamation of the water areas in the Lake, pollution resulting from agricultural wastes such as fertilizers and pesticides and also extensive mining operations for lime shells contribute to the ecological changes to a great extent. Studies conducted by an expert committee constituted to evaluate the effects of dredging in the Lake (Kumaraswamy-personal communication) indicated that while the effect of silting noticed upto 0.5 km radius from the site of dredging, it took 40 hours for the silt to settle (0.155 g/L) and compared to the normal light penetration of 50-80 cm, the same was only 15-25 cm in the dredged area.

It is hypothesised that the changes in such an environment can affect the biota inhabiting an estuarine habitat like the Vembanad Lake in any one or more of the following ways, namely overall reduction of water area, change in the circulation pattern, lessening of average depth, interference of the exchange of water, changes in water chemistry due to the presence of toxic compounds and increased silt load. According to George (1968) the estuarine habitats in general are affected in two major ways, either by a net loss of the total area or by change in mean salt content and chemical composition of the ambient water.

6.2 Acidity, Pollution and Mortality

Extreme changes or variations in the environmental and climatic patterns in an area invariably cause certain undesirable and unforeseen events as well as ecological consequences. The severe drought conditions experienced in this part of the country during the summer of 1983 and subsequent environmental problems encountered in the area was such an unusual incident.

Large scale fish mortality was reported from the Vembanad Lake (especially in the area south of the barrage) during the last week of June 1983. The causes, effects and related environmental problems were investigated at 18 stations in the lake (Fig.1D). Water characteristics were monitored over the lake surface, adjacent canals and paddy fields to determine the causative factors and also to record the recovery in the situation during the course of time. It was found that in the middle region of the lake where the mortality occurred, lower salinities were recorded indicating a fresh water

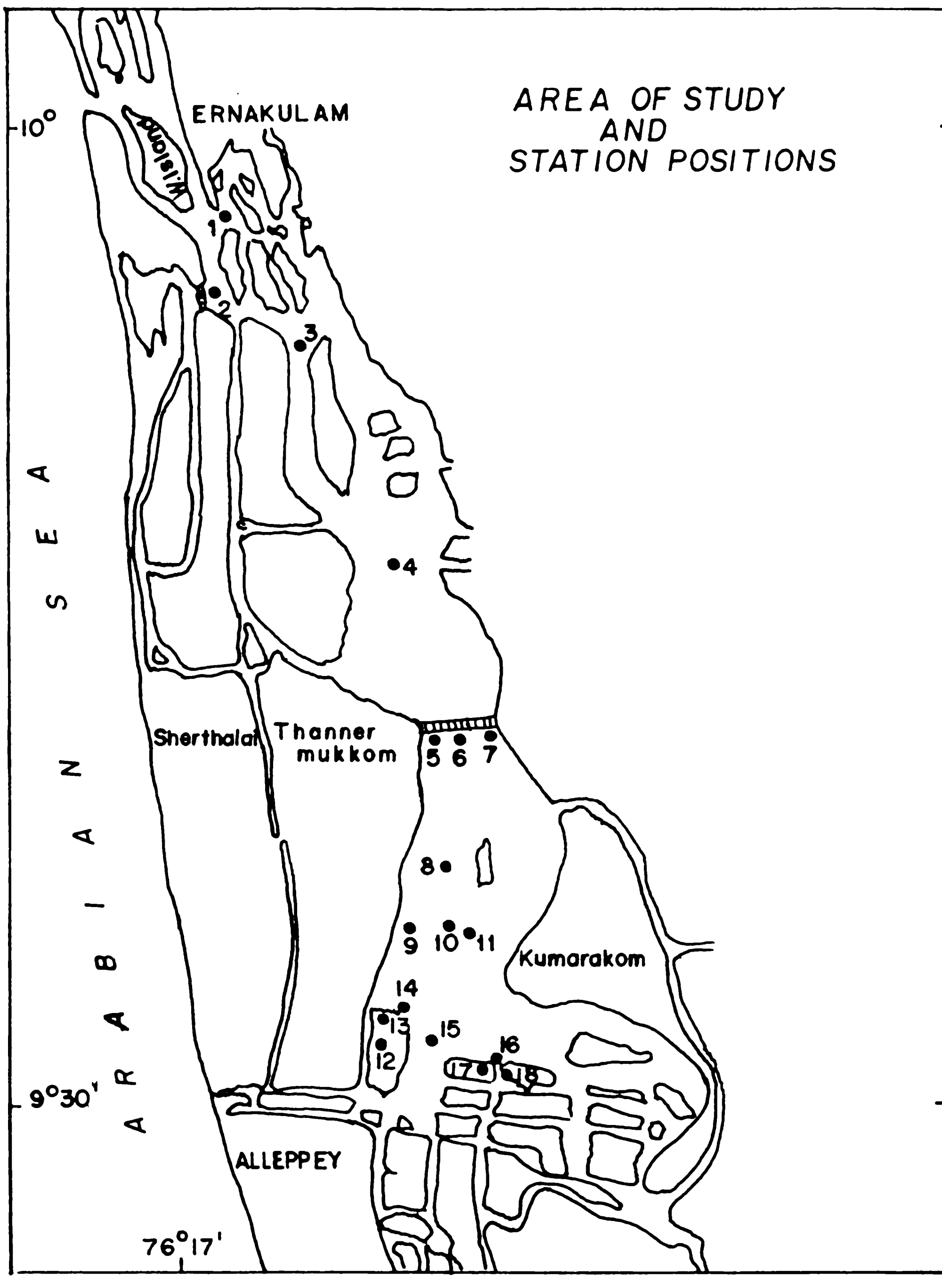


Fig. 1 D. Map showing station positions.

regime. The recorded dissolved oxygen values were within the normal range that could support aquatic life. Higher levels of ammonia were recorded in the area where extensive mortality had occurred. The source of this high ammonia could be the water pumped from the paddy fields where fertilizers had been used during the previous season. But these high levels of ammonia could not have caused mortality of fishes since at low pH the ionization of ammonia will be considerably reduced thereby reducing the lethal effect of ammonia. pH values recorded were in the range of 3 to 7 against the normal range of 7 to 8. On 28.6.83 at Thanneermukkom the pH recorded was 3.65 and 2 km towards the south pH was 4.85. It is significant to note that during the initial sampling time the pH of water showed less than 4 and of the water and from nearby paddy fields recorded a pH of 3.8. The first sampling was done on 28.6.83 and subsequently 6 more coverages were made (Table 26). The data obtained showed that the high mortality was caused by the leaching of acid waters from the paddy fields and adjacent canals.

The data showed that the effect of pH reduction seemingly influenced the ecosystem only upto the middle of the lake (from the south) and towards the northern part of the lake the effect appeared to get neutralised, probably due to the regular tidal action. However, even after a month or so from the period of initial impact, there was not much change in the situation in the affected area. Apparently the effect of acidity persisted in the water for quite some time. The common mineral acid in natural water is sulphuric acid which results from the oxidation of iron pyrite in the soil. As long as sediments containing pyrites are submerged and anaerobic, they remain reduced

Table 26. Variation in pH in space and time

Dates of collection	30.6.83 & 1.7.83		4.7.83		16.7.83		1.8.83		6.8.83	
Stations Location	S	B	S	B	S	B	S	B	S	B
1. Thevara	7.59	-	-	-	5.88	-	6.95	-	6.55	-
2. Aroor	4.80	6.44	-	-	5.18	5.70	5.55	-	6.22	-
3. Arookutty	6.22	6.44	-	-	5.88	6.10	6.55	6.40	5.88	6.07
4. Manalpuram Thanneermukkam bund	3.68	4.09	-	-	4.21	4.35	-	-	5.60	5.40
5. Western end	3.84	3.85	4.34	-	4.35	-	5.78	-	5.48	-
6. Middle	3.81	3.92	-	-	5.55	-	5.55	-	4.68	-
7. Eastern	3.99	4.06	4.03	-	4.25	-	5.77	-	4.30	-
8. Kaypuram Muhamma	4.00	4.30	-	-	5.30	5.41	6.00	6.15	5.48	5.50
9. Near shore 1	3.97	4.38	3.88	-	4.08	3.94	5.69	5.46	5.23	-
10. Near shore 2	-	-	-	-	3.85	3.83	5.92	5.50	-	-
11. Middle Punnamada	3.97	4.11	-	-	3.85	4.00	5.78	5.65	-	-
12. Cultivated fields	-	-	3.90	-	4.78	-	5.50	-	4.90	-
13. Canal connecting fields	3.90	-	3.80	-	3.70	-	5.40	-	4.80	-
14. Backwaters 1	4.00	-	3.90	-	4.30	-	5.40	-	5.33	-
15. Backwaters 2 East of Punnamada	4.00	4.20	-	-	-	-	-	-	5.47	5.45
16. Backwaters	3.18	-	-	-	-	-	-	-	4.24	3.93
17. Cultivated fields	3.80	-	-	-	-	-	-	-	3.90	-
18. Fallow fields	-	-	4.41	-	-	-	-	-	4.83	-

S = Surface; B = Bottom

Source: Marine Fisheries Information Service, Vol.52, 1984 and change little. However, if they are drained and exposed to the air, oxidation results and sulphuric acid is formed. The reason for the persisting low pH could have been that the river water input into the lake after several spells of monsoon showers has not been sufficient to flush the acid produced at the water soil interface continuing for several weeks, as the monsoon that season had been weak and halting in the initial period.

Except for the immediate mortality to fishes (including rays, Etroplus and Mugil), Crustaceans (crab-Scylla serrata, Macrobrachium sp.) and clams (Villorita sp.) the subsequent incidence of mortality was limited to the young ones of cat fishes. However, destruction to the clam beds was massive. Even after a month from the first reports there was not many live clam specimens available in the southern half of the lake beyond Thanneermukkom. Subsequent monitoring of the water acidity showed that the effect was slowly getting reduced, but as the process was very slow, it took several months for the ecosystem to be back to normal.

It is felt that, since the barrage remained closed during the summer months, very little water exchange had occurred in the affected zone where acid sulfate soil was predominant. However, if the barrage remained opened the impact could have been much less because of more flushing due to the tidal movement of the water.

DISCUSSION

7. DISCUSSION

Ecological changes in an ecosystem such as Vembanad Lake can be due to natural calamities or by human interference. Among the former may be mentioned changes brought about due to climatological events like floods and drought conditions. The changes due to interference of man are: (1) changes in total area of habitat resulting from large scale reclamation for agricultural purposes, (2) protective works such as salt water barrage, tide control structures (3) pollution due to domestic, industrial and agricultural wastes, (4) development of mineral resources by dredging. These changes in the environment affect the estuarine resources in any one or more of the following ways, namely, general reduction in acreage of habitat, change in circulation and thus affecting the distribution of salinity, temperature, loss of tidal exchange benefits, restricted influx of salt water, change in water chemistry due to presence of toxic compounds, increased silt load. In short, the estuarine habitats are affected in two major ways, either by a net loss of total area available or by change in mean salt content and chemical composition. There is an apprehension that the cumulative effect of these changes over the years in this dynamic estuarine system would be considerable and may eventually lead to the loss of valuable living resources.

The energy inputs of the Vembanad Lake and adjacent backwaters comprise not only the primary and secondary productions but the huge quantities of inorganic and organic matter that are carried into the estuary every year. With an annual average rate of gross production ranging from 150-650 gC/m^2 in different regions and a total annual production of 100,000 tonnes of carbon, the lake and the connected backwaters can be considered as highly productive area, almost comparable to the inshore area of the west coast of India, where there is constant replenishment of nutrients. This is for a column of water where the euphotic zone varies from 1.5 m during monsoon to 4 m during pre-monsoon unlike the inshore waters where the euphotic zone ranges from 15-69 m.

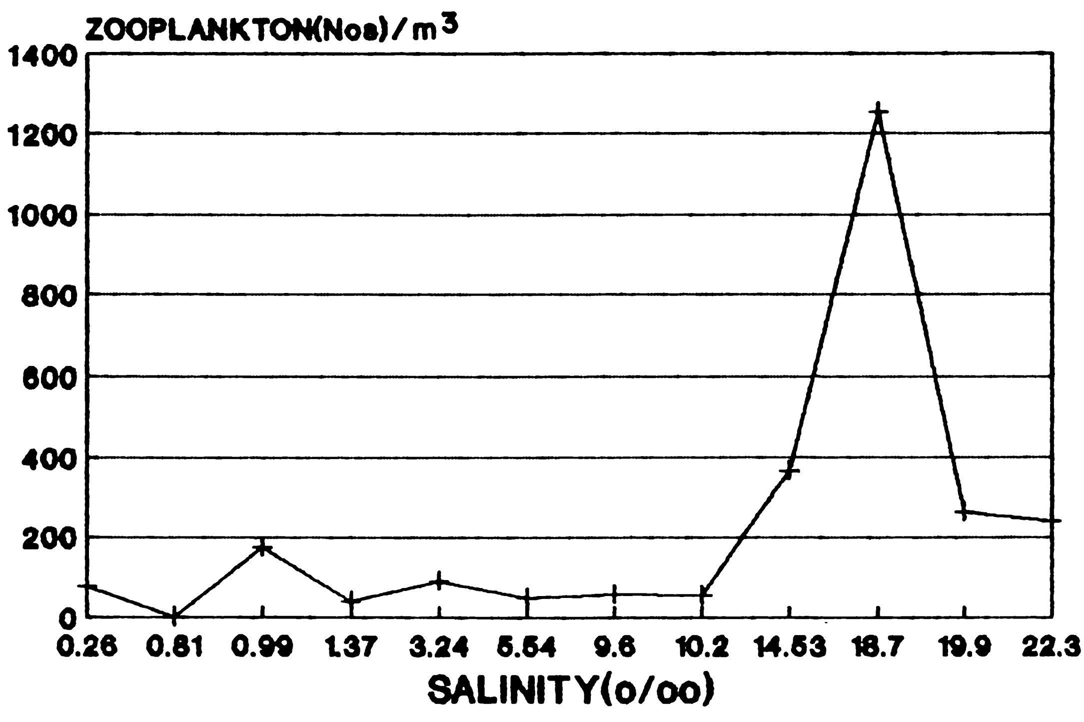
The production of organic matter forms only a small fraction of the detritus sedimentation (0.9 to 1.0%, Qasim and Sankaranarayanan, 1972). Computing from the average values for each month a total of 4 million tonnes of detritus is available in the food chain apart from the phyto and zooplankton production. Though the caloric values are not high as zooplankton the same authors found that the juvenile specimens of the shrimp, Metapenaeus dobsoni kept without food for 2-3 days readily consumed the dried pellets made of detritus.

The source for such a high rate of productivity are due to the cycle of events taking place in the estuary which is fairly regular. The monsoon season (May to September) is associated with sudden changes in the estuary. With the heavy rains the estuary becomes a focal point of fresh water discharge with high nutrient and organic detritus. During this period extremely significant changes occur in the environmental features of the estuary. The southern most region becomes almost a fresh water environment. The fresh water influx far surpasses the usual tidal influence. Therefore the surface salinity remains low whereas the sea water remains as a distinct bottom layer. This bottom water of the estuary is considered as the same as the upwelled water of the Arabian Sea with its typical characteristics (Ramamritham and Jayaraman, 1963 and Qasim and Sankaranarayanan, 1969).

During this period there is high rate of primary production in the inshore environment due to the presence of rich nutrients. In the estuary it is not the case as there is considerable resistance to the mixing of the bottom waters with those of the surface almost till the end of October. Effective utilization of the nutrients does not take place till that time. This accounts for the low rate of primary production in the estuary during the monsoon. The nutrient distribution is thus dependent on the marine influx and fresh water discharge.

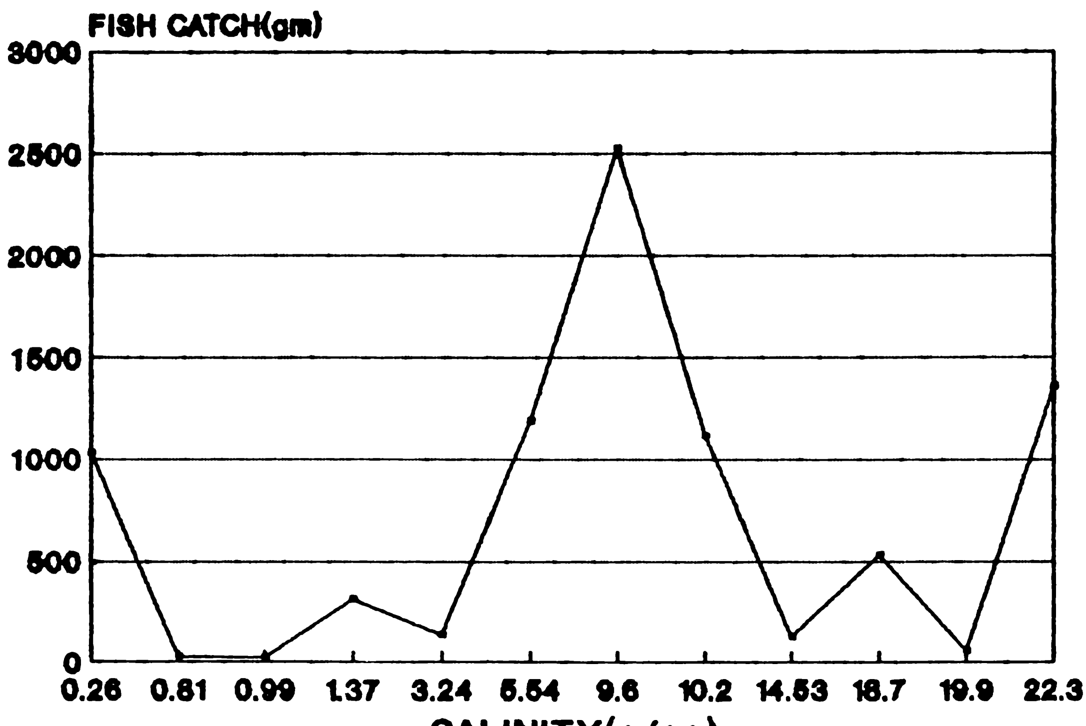
Salinity is one of the prime factors that, perhaps influences most in the species composition, diversity of the species of phyto and zooplankton as well as fish catch, as evidenced by Figs. 27-30. This relationship may only be incidental and could be governed by other factors such as the constant influx of nutrient rich water and a richer benthic fauna. However, salinity as it is has no direct influence on primary production. The variations in productivity are very much influenced by the relative mix of fresh water, estuarine and marine forms of phytoplankton which dominate at different zones. Qasim et. al., (1969) observed assimilation ratios (phytosynthesis to chlorophyl a) varying from 0.6 to 15. They observed seasonal fluctuations which very often fell in accordance with a rise or fall in the primary production rates. These authors also observed that there was no correspondence between nutrient supply and production rates. This is natural as the physiological adaptation of the different populations vary with the changing regimes of salinity. Joseph and Pillai (1975) observed that the fresh water species that appear in large number during monsoon disappear in summer. They make their appearance in varying

Fig.27 RELATION BETWEEN SALINITY AND ZOOPLANKTON



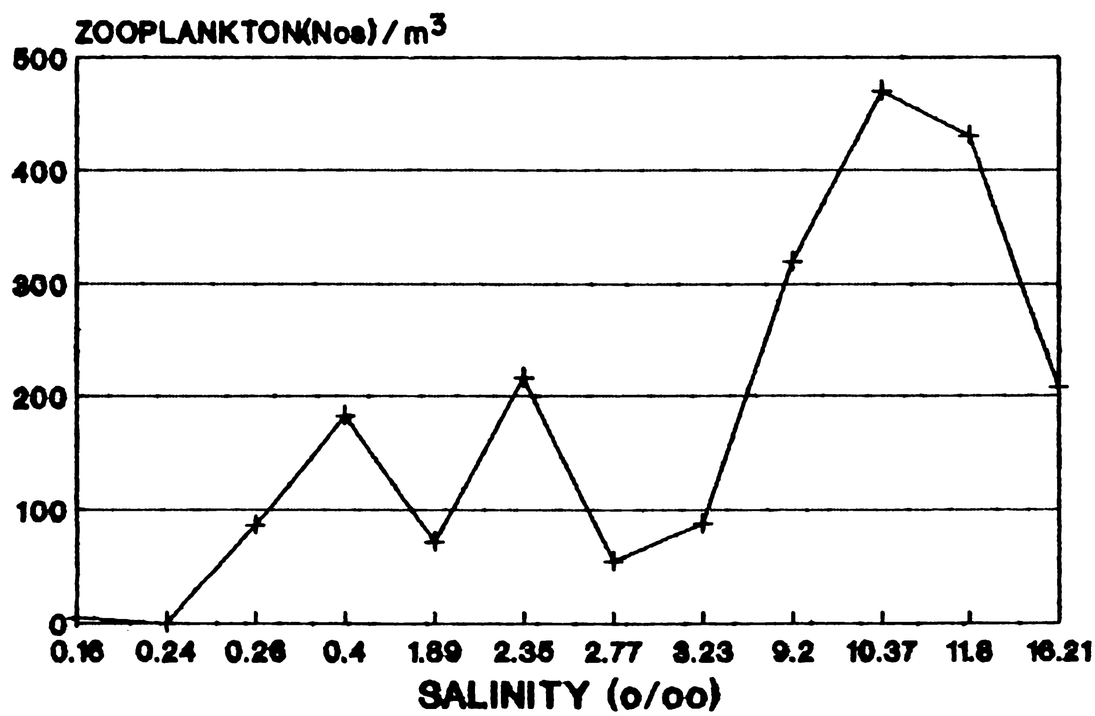
STATION I C-E SECTOR

Fig.28 RELATION BETWEEN SALINITY AND FISH CATCH



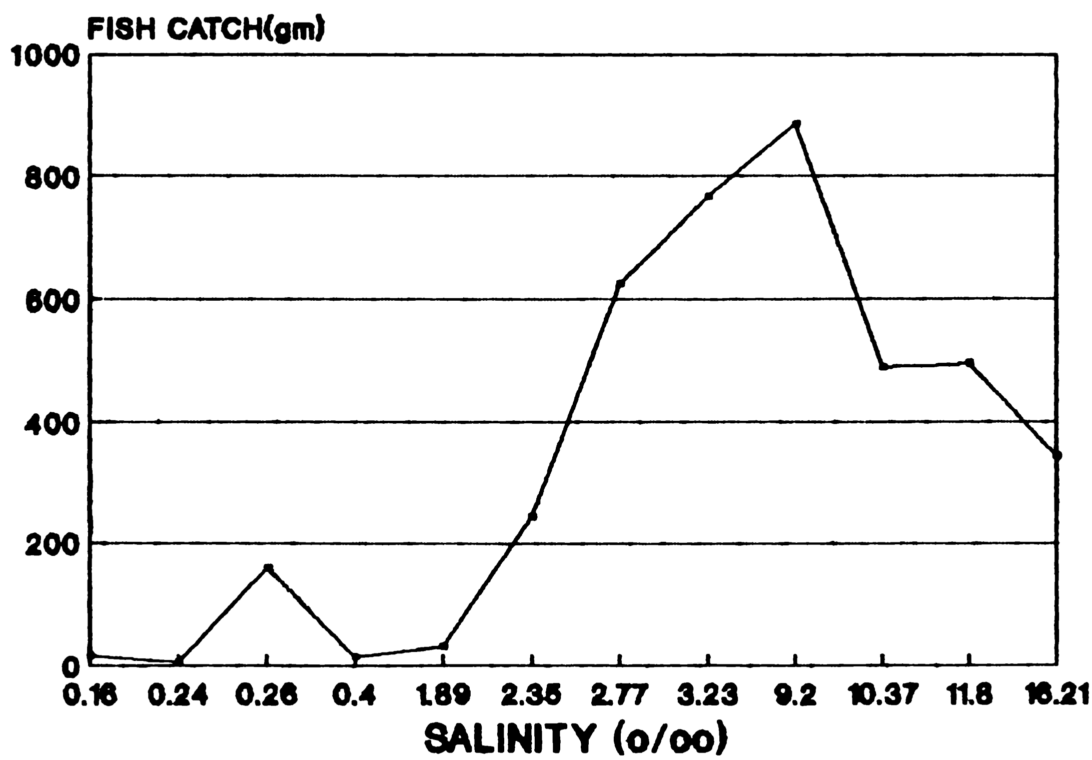
STATION I C-E SECTOR

Fig.29 RELATION BETWEEN SALINITY AND ZOOPLANKTON



STATION II C-E SECTOR

Fig.30 RELATION BETWEEN SALINITY AND FISH CATCH



STATION II C-E SECTOR

numbers at different stations. It has also been observed that many organisms bloom successively at exceptionally low salinity in the backwater indicating water of low salinity support a greater abundance of phytoplankton. This adaptation for phytoplankton for maximum photosynthesis in response to low salinity is considered as an adaptation to make use of the large quantities of nutrients (Qasim et. al., 1972). Hence it can be concluded that though salinity does not have a significant bearing on the rates of primary production in the lake, the constituent flora responsible for the production differ forming different ecological zones.

Nair et. al., (1972) studied the role of nutrients in the productivity of the lake. They reported that highest concentration of phosphate is in the southern region during the monsoon or the post-monsoon. In the lower reaches of the estuary the phosphate values are low. Besides the land drainage, the interchange of phosphorus between the sediments and overlying water plays a major role in the recycling of nutrients.

Studies conducted by several workers on the nutrient levels of Cochin backwaters since the sixties reveal interesting variations over the period of time. Gopalan (1986) quoting previous studies by Sankaranarayanan and Qasim (1969), Sreedharan and Salih (1974), Sankaranarayanan et. al., (1986) stated that the growing concentration of nitrate nitrogen in Cochin backwater can be seen from the recorded minimum value of 0.3 µg at/l in 1965-66; 1.5 µg at/l in 1973-74 and 4.0 µg at/l in 1978-79. In this connection it is significant to state that in Cochin backwater for the period 1988-89 the candidate observed rather high levels of ammonia in the estuarine reegion with significant increase during pre-monsoon period. The levels ranged from 46.81 μg at/l NH_3-N in March to 83.22 μg at/l in June; the maximum value recorded was 104.78 μg at/l in April, 1988. The source of such high levels of ammonia is from the discharge of effluents of the fertilizer complex at the nearby industrial area and to large quantities of treated and untreated sewage reaching the estuarine area.

Gilbert and Pillai (1986) made a comparative study of the chemical composition of soil samples collected from fifty two stations in the Vembanad Lake and adjacent prawn culture fields. They studied soil pH, exchangeable cations, viz: sodium, potassium, and calcium, and also total phosphorus along with grain size distribution of sediments. Among the cations, sodium was the highest in concentration in the soil followed by calcium and potassium. The distribution of these cations did not show any specific pattern of variation. However, the heavy rains during the monsoon period had a sequential effect on the concentration of the cations registering considerably lower values during that period. All cations showed appreciable amount of leaching during the monsoon period, with calcium displaying the maximum variation. The concentration of the cations showed inverse relationship with the dominance of sand fraction which indicated that higher concentrations were associated with lower fraction of sand in the soil. The cations also showed direct relationship with silt fraction of the sediment while **clay did not show any relation.** Total phosphorus also showed direct relationship with silt and clay fraction of the soil. It also showed a definite pattern of spatial distribution, the northern and north central regions of the Cochin backwaters recording higher concentration of phosphorus while the southern areas showed relatively lower values.

In general, it was observed that in the Cochin area the soil predominantly composed of the finer fragments of silt and clay were nutrient rich and ranks high in fertility. In soils with higher proportion of sand, these nutrients were found to leach out particularly during the heavy rains and correspondingly reducing the soil fertility which in turn can adversely affect the productivity of the area.

Further sedimentological studies in the Vembanad Lake were by Murthy and Veerayya (1972, 1973 and 1981), Veerayya and Murthy (1974) and Mallick and Suchindan (1985). Veerayya has reported four major sediment units; sands, silty sands, clayey silts and silty clays in the lake. The organic matter contents of these sediments were found to range from 0.10% to 6%. The studies conducted by them further revealed that the presence of finer sediments in the southern half of the lake has been attributed to the shallowness of the area, the presence of a number of big and small rivers that supply the finer material to the lake during the monsoon months and bring in fresh water conditions for the major part of the year. The sediments in the estuarine region are due to the deposition of suspended load by flocculation during the post and pre-monsoon months and the supply of fine material from the sea through tidal currents during these months.

The distribution of trace elements in the Vembanad lake has been studied by Murthy and Veerayya (1981). They have recorded that Fe, Mn, Ni, Cu and Co bear significant relationship with organic matter of the sediments. The river sands were found to contain very low concentrations of all elements and in the lake sediments, the elemental concentrations increased with decrease in grain size. The synergestic or antagonistic role of trace metals and their interaction with nutrient elements in algal production is a complex problem involving metal speciation. The status of nutrient metals of the Lake is thus congenial for supporting a high turnover rate.

The observations of many authors indicate that the zooplankton production is not commensurate with the energy inputs through primary production and detritus settlement. The pioneering attempt on a quantitative study is by George (1958). In recent years a few authors studied the amplitude of seasonal and spatial changes on zooplankton (Nair and Tranter, 1972; Menon et. al., 1972 and Haridas et. al., 1972). Detailed investigations on the variations in the relative proportion of specific groups such as copepods, chaetognaths, hydromedusae, siphonophores, decapod larvae and cladocerans have been studied by various authors such as Wellershas (1972), Pillai (1972); Pillai et. al., (1973); Nair (1972); Rao et. al., (1975) and Madhupratap (1980). A composite picture of zooplankton of Cochin estuary was brought out by Silas and Pillai (1977) and Pillai (1975) and some of the salient features have been discussed earlier in the thesis.

It has been estimated that the consumption by zooplankton covers only about 25% of the net production leaving a large quantity of surplus food in the estuary (Qasim, 1970). Madhupratap et. al., (1977) have estimated the ratio of secondary production to production at the lower reaches is high with a transfer quotient of 12.5%, but when extrapolated for the entire estuary it is a bare 2.7% although they have not given an explanation for the low transfer. The correct conversion factor depends upon the relative distribution of copepods and other forms in the zooplankton. Cushing (1971) observed that a transfer quotient of 6.5% is possible in nutrient rich waters of the sea where upwelling takes place. Considering the eutrophication in the estuary and the utilization of detritus in the food chain, a 15% food conversion efficiency is a possibility as Vijayakumaran (1991 M.S.) observed a conversion ratio of about 5-20% for crustaceans.

Dry weight of zooplankton (secondary production) as estimated by Madhupratap et. al., (1977) is a little over 11,000 tonnes per year. An energy flow diagram has been constructed with available information and based on the pathways of energy in the food web using the concept of alternate pathways of Qasim (1970) (Fig.31).

Apart from a lucrative fishery for table fishes the prawn fishery of the lake is mainly contributed by juveniles of M. dobsoni, P. indicus and M. monoceros. The fishery is abundant throughout the year, but the peak periods are during the monsoon and post-monsoon months. As per the recent estimate (Srivastava, 1983) there are 32 fishing villages situated on the shores of Vembanad Lake in which live about 9400 fishermen who depend on the resources of the lake for their livelihood. There are about 5200 boats which are engaged in fishing activity. The fishermen use a variety of nets such as stake nets (3654), chinese dip nets (990) and miscellaneous variety of gears totalling about 15,000. In the commercial catch, usually about a dozen varieties of fin fishes and prawns are commonly found. The most striking feature of this lake system is the extensive dip net and stake net fishing found all along the lake. These nets are usually operated for prawns and mullets, which constitute the most important commercial fisheries in the northern half of the backwaters.

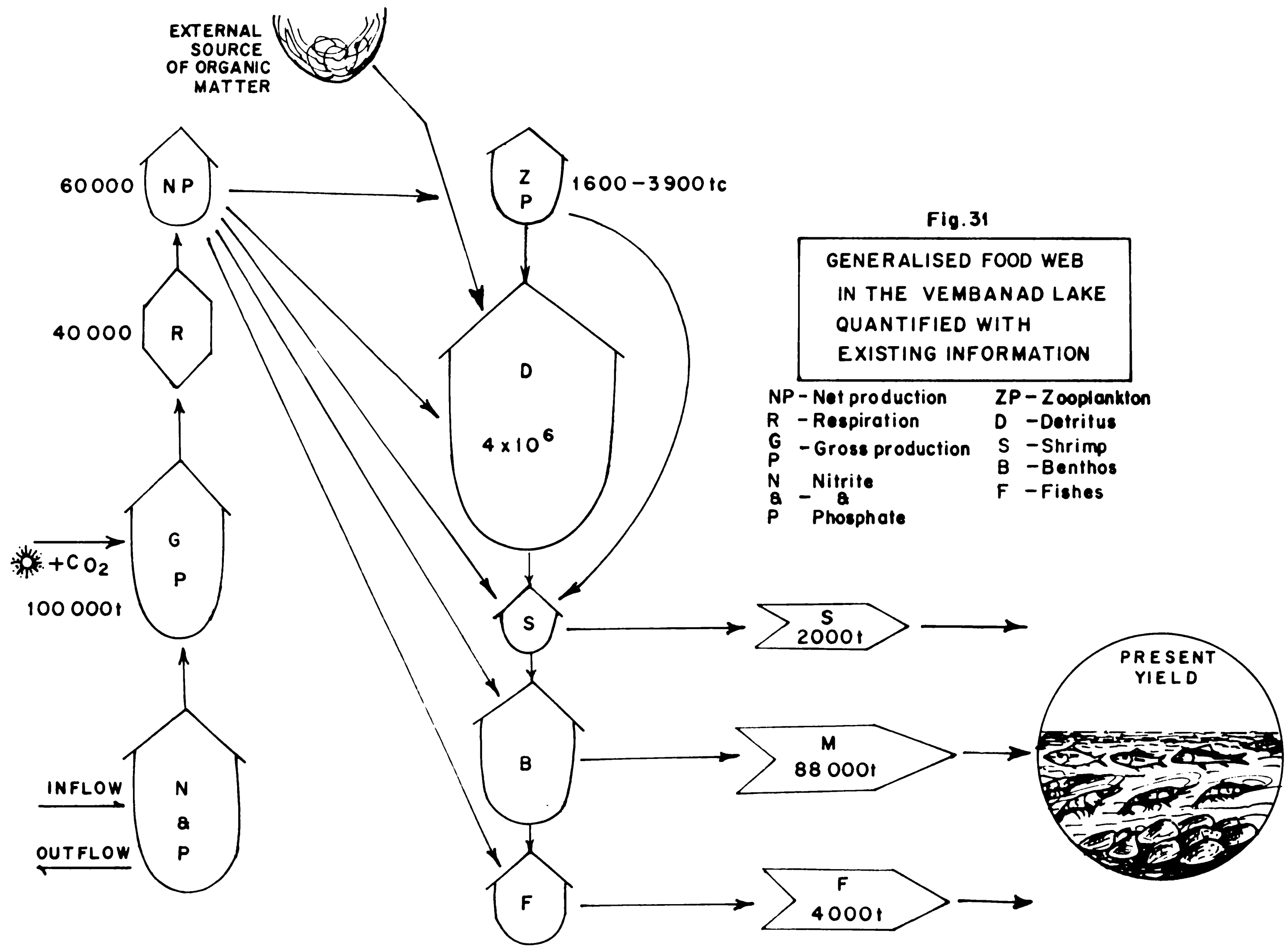


Fig.31

GENERALISED FOOD WEB IN THE VEMBANAD LAKE QUANTIFIED WITH EXISTING INFORMATION

NP - Net production
R - Respiration
GP - Gross production
N & P - Nitrite & Phosphate
ZP - Zooplankton
D - Detritus
S - Shrimp
B - Benthos
F - Fishes

Table 27. Area and production in lakes in Indian coastal region

Name	Area (ha)	Total production (tonnes)	Production/ha (kg)
Chilka	90,600	6513	71.89
Pulicat	46,100	1412	30.63
Vembanad	30,000	5825	199.17

Source: Inland Fish Marketing in India-VI, 1984.

Other than the fin fishes and prawns, there is a rich resource of clams represented by the species of Meretrix and Villorita exist in the lake. Apart from this there is a substantial fishery for dead clam shells which is available only in the southern half of the lake proper. In the northern part of the lake where salinity is comparatively high the genus Meretrix is abundant. In the southern parts, the species of Villorita which can tolerate fresh water are abundant. It is hypothesised that the clams which got an ideal habitat for growth were yearly subjected to the southwest and northeast monsoon rains. During monsoon, flood waters from the rivers carry large quantities of mud and silt into the lake which settle on the clam beds. It is presumed that larger clams which do not have much locomotive ability to escape were smothered by the silt were buried and perished. This process along with natural mortality of the population might have contributed over the centuries to the acretion of a wealth of lime shell deposits in the lake.

The present harvest of resources from the lake is of the order of 88,000 tonnes of molluscs (live clams), 1800 tonnes of prawns and 4000 tonnes of fin fishes for an area of 30,000 ha. Incidentally, a comparative statement about the production details reveals that among the three well known lakes in the Indian coastal areas, Vembanad lake has the highest production rate per ha (Table 27)(Sreevastava, 1984).

As it is the potential harvest could only be marginally higher for all the three resources. From indications on inputs of production and detritus the resources may be even double, considering the assimilation and conversion efficiencies among prawns and other omnivorous fishes found in the lake. But without venturing on such an unchartered and uncertain course, the prospects of utilizing perennial and seasonal culture fields for intensive culture operations shall be examined.

The results of investigations conducted by the candidate and some colleagues (Gopinathan et. al., 1980) on the environmental characteristics of seasonal and perennial prawn culture fields located adjacent to the lake indicates that there is a highly productive area north and south of Cochin bar mouth with production rates ranging from 2-3 $mgC/m^2/day$ probably due to the incursion of sea water and influx of the river water.

Regions which are moderately productive with 1-2 $gC/m^2/day$ which is in the northern half of the estuary and the waters comprising the Vembanad Lake proper. A low productive zone around Vaikom in the south probably due to the restricted entry of nutrients laden water where the average production is less than 1.0 $gC/m^2/day$. In such areas high rate of additional inputs of energy would be required for successful culture practice.

The amount of detritus, nutrient levels such as phosphate and organic carbon as well as magnitude of primary production could therefore be taken as the criteria for estimating the stocking potential and also to determine the other inputs required for taking an optimum sustainable yield.

The environmental changes taken place in the Vembanad Lake during last two decades are mainly caused by human interference and due to various types of pollution. There is a chronic pollution situation in the northern half of the lake around Cochin estuarine system mainly caused by industrial effluents and sewage. Due to the rapid industrialisation which took place during the last twenty years in this region, effluents from a variety of industries are polluting the waters at various levels, causing synergistic effects on the flora and fauna. The tidal flushing and the freshwater discharge appear to be considerably reducing the impact of pollution downstream. But instances of fish kills are often reported from the impact zones at Eloor and Ambalamugal from Periyar and Chitrapuzha respectively pointing to the need for a continuous monitoring programme on the water quality. On the southern half it is a cumulative as well as synergistic effect resulting from the human interference on the environment. Now it is an accepted fact that the functioning of the Thanneermukkom barrage has resulted in considerable ecological changes in the lake proper. The main impact is the drastic reduction in salinity which in turn has affected the distribution and abundance of the resources. At the same time, due to the closure of the barrage during the summer months, the water is virtually stagnant in the southern half of the lake. It is reported that the large quantity of pesticide residue originating from the rice cultivating fields ends up in the lake which often results in fish kills and other undesirable effects. However, more scientific information on this aspect is yet to appear. Apart from this, in the absence of periodic tidal flushing and water movement, the organic wastes reaching the canals and streams in the nearby areas also cause serious health hazards to human population. To a lesser extent, the practice of coconut husk getting in certain areas in the lake results in location specific pollution problems. The menace of Salvinia weed proliferation which was causing a serious threat in some parts of the lake especially during the post-monsoon period appears to be on the decline for the last few years.

In this connection the role of water quality studies in the Cochin estuarine systems and a need for the continuous monitoring have been emphasised by the candidate at a recent Water Quality Seminar held at Kochi in June, 1990 (M.S. V.K.P.) and the report is appended. The status of water pollution due to the dumping of 1.2 lakh kilolitres of effluents from the industrial belt at Eloor and Ambalamugal, toxic concentration of ammonia associated with high pH ranges resulting in fish kills, possible mercury pollution and other heavy metal pollution as well as the overall impact of Thanneermukkom bund on the ecology and pollution of the lake have to be considered in totality. The conclusions and recommendations on water quality have been embodied in the above referred report. The general conciousness in the environmental protection and constant monitoring by scientists of various institutions and campaigns like "Save Periyar" are hopeful signs in the preservation of this vital estuarine system.

SUMMARY

SUMMARY

The thesis embodies the results of investigations on the hydrobiological features of Vembanad Lake and adjacent waters carried out during the seventies and have been compared to those collected in the eighties in order to have an understanding of the changing ecology due to human interferences. The study also covers aspects of pollution from industrial effluents discharged from the surrounding industrial belt of Cochin with case studies on fish kills and related problems such as heavy metal uptake by the biota.

The area of study covers a distance of 90 km north-south in length and approximately has an area of 256 sq.km. consisting of the estuary and backwaters running parallel to the south-west coast of India.

A total of twenty two stations have been sampled covering the different zones of the lake system during different time frames in order to include all the cycle of events that follow the monsoon season, the proceeding and succeeding periods as well as the tidal incursions from the marine environment. Thus the sampling has been in such a manner as to get a comprehensive picture of the ecology of Vembanad Lake covering all the seasonal and cycle of events.

Details of the methodology adopted for various parameters have been presented along with standardisation and intercalibration results. Analyses of metals in biological samples have been included with details of methods used for achieving a high degree of precision and accuracy have been elaborated.

The changing hydrobiological features of the Vembanad Lake and adjacent waters have been presented with computer drawn diagrammes to illustrate

the seasonal and quantitative variations in parameters such as water temperature, salinity, pH, dissolved oxygen, phosphate, nitrite, phytoplankton productivity and secondary production.

Primary and secondary productions have been estimated for the entire lake system. There is considerable spatial variability consequent on the intensity of mixing of sea water and fresh water and also due to nutrients availability. Floral and faunistic compositions also are found to vary. Taking the mean values from many regions a total annual primary production of 100,000 tonnes of carbon has been estimated.

Zooplankton biomass has two peaks with the primary peak in March-April and the other during October-January with the middle zone of the lake having the maximum density. Correlation has been worked out for different parameters and rank correlation coefficients have been estimated for the various stations.

The zooplankton data for six months representing fifteen groups were used for analysis of variance which was applied to examine the difference in counts from place to place, from time to time and from group to group and also to see whether there were any significant interactions between two of the three factors: Space, time and groups.

Compared with monthly variations, spatial variation is low. The interaction between stations and months is significant. The interaction between months and group is found to be highly significant. The different groups, do not have any particular preference for any particular station.

The months, the groups and the interaction between these two account for a good amount of variation in numbers of zooplankton. The significance of correlation between salinity and zooplankton population in the present study suggests that the groups constituting zooplankton population and predominant in the estuary prefer high salinity. It is thus possible that a large part of variation of zooplankton abundance in space and time is brought about by the variation in salinity.

The rank correlation analysis showed high correlations of temperature, salinity, and zooplankton in almost all the stations.

Distribution of fish, prawn and molluscan resources has been indicated with the possible relation with salinity and temperature which are the limiting factors in the lake ecosystem. The fishery is abundant throughout the year. But the catches were much higher during post-monsoon season and post-monsoon appears to be the most productive period in the lake.

From indications on imputs of production and detritus, the sustainable resources may be even double that of the present yield, considering the assimilation and conversion efficiencies among prawns and other omnivorous fishes found in the lake.

The areas covering the lower Periyar River and part of the estuary have been studied in depth to evaluate the effect of industrial pollution on the hydrography and distribution of the biota. Six stations extending to 12 km from the bar mouth were covered for ecological studies.

Results of ANOVA-F tests have been presented for various parameters. Variations among stations were highly significant for primary production, zooplankton and fish catch data.

Monitored values of selected heavy metals (Cu, Zn, Cd and Pb) in bivalves Sunetta scripta and Villorita sp.) and levels of mercury in the estuarine water have been presented to indicate the current status of heavy metal pollution in the Cochin estuarine area. Metal levels in bivalve Sunetta scripta indicated a peak during pre-monsoon season. Certain phenomena such as higher level of accumulation by smaller sized animals, especially for copper were also apparent. The effect of depuration in clean water was also demonstrated by the animals. In the case of Villorita sp. a location specific increase in metals was observed (almost three fold increase) in animals collected from a polluted zone when compared to animals collected **from** less polluted area. The levels of mercury in water were rather high during monsoon season indicating the effect of fresh water discharge washing down the polluted areas into the estuary.

Impact of human interference such as Thanneermukkom salt water barrage has been dealt with in detail. The data collected during the pre-construction period of the bund have been compared with those of the post-operative period. There is substantial reduction of zooplankton abundance south of the barrage. The distribution and abundance of the fishery resource in general and prawn fishery in particular have been adversely affected apart from causing large scale pollution south of the barrage. Destruction of clam beds, due to soil acidity in contiguous fields following a hot spell of summer and subsequent rains is a distinct possibility south of the barrage.

A general discussion has been incorporated on inputs of energy in the lake system and possible pathways of the food web have been illustrated with a note on the present yield. The possibility of developing culture practices in different areas in relation to productivity has been discussed. The cultivable areas located adjacent to the lake have been classified as highly productive, moderately productive and low productive zones. A highly productive area north and south of Cochin bar mouth and near Azhicode bar mouth; a moderately productive region in between the highly productive areas and a low productive area consisting of the water bodies on the hinter land around Vaikom in the south could be identified based on the overall productivity. The magnitude of primary production, the amount of detritus, nutrient levels such as phosphate and organic carbon could be taken as the criteria for estimating stocking potential and also to determine other inputs required for obtaining an optimum sustainable yield.

The need for monitoring the estuarine system for water quality has been indicated in order to preserve the health of the environment and also for assessing the level of pollution.

Three reports have been appended on water quality, water wealth and fishery resource of Kerala.

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APPENDIX

WATER QUALITY STUDIES IN THE COCHIN ESTUARINE SYSTEM
NEED FOR CONTINUOUS MONITORING

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WATER QUALITY STATUS OF KERALA
27th JUNE, 1990, COCHIN.

AND
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WATER QUALITY STUDIES IN THE COCHIN ESTUARINE SYSTEM- NEED FOR A CONTINUOUS MONITORING

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Introduction

Cochin estuarine system with the adjacent backwaters is well known for its role as a nursery ground for commercially important prawns and fishes. But in some problem areas, the water quality deterioration caused by agro-industrial effluents has become a disconcerting fact. A number of reports are available on various aspects of pollution as well as fish kills caused by industrial pollutants. (Unnithan et. al., 1975; Silas and Pillai, 1976; Sreedharan and Sali, 1974; Nair et. al., 1983; Balchand and Nambisan, 1986; Alavandi et. al., and Kaladharan et. al., 1990).

An estimated 1.2 lakh kilolitres of effluents are dumped into the Periyar river by 11 leading industries in the Eloor industrial area alone. The above industries consume daily on an average about 1.8 lakh kilolitres of water from the Periyar. When the industrial area at Ambalamugal is also taken into account, the total quantity of effluents discharged is reported to be about 200 million litres per day. The waste water from the Cochin City and organic wastes reaching the estuarine areas form an additional load.

It appears that water pollution to a limited extent was noticed in the Eloor area even as early as the sixties. Subsequently the industrial expansion came into existence at Ambalamugal in the beginning of seventies. However, one of the earlier reported incident of fish mortality was that of Silas and Pillai (1976). They had reported two instances of fish kills (at Eloor and Ambalamugal areas respectively). The cause of fish kill at Eloor was acidity (pH: 4.8 at the surface and 6.9 at the bottom) in the vicinity of the fish kill near the industrial area at Eloor in the Periyar river. The normal pH in the nearby area was 7.1 to 7.2. Fifteen species of dead fishes and prawns were collected from the vicinity. The other instance reported from Chitrapuzha at Ambalamugal which was due to high levels of ammonia (330-333 mg/l) against the normal range of 0.02-0.61 mg/l. Ten varieties of dead fishes were collected from the vicinity.

A major instance of fish kill was reported from the Ambalamugal region of Chitrapuzha which extended to Cochin backwaters in the first week of June, 1980 (Nair et. al., 1981). Compared to the earlier reported occurrence, this instance was of unprecedented scale in its intensity as well as in the magnitude of destruction. Thousands of fishes, both pelagic and bottom living were found dead and floating for several kilometres of water area from Ambalamugal to Cochin estuary. All the organisations and scientists who worked on this instance unanimously concluded that the cause of the fish kill was due to high levels of ammonia (Nair et. al., reported upto 118 mg NH_3/l) present in the water.

There were also reports of deteriorating water quality due to organic pollution (Unnithan et. al., 1975) and about the nutrient enrichment (Sreedharan and Salih, 1974 and Sankaranarayanan et. al., 1983).

Some Recent Observations

The toxic properties of mercury, its transformation in the environment by biological and chemical means are well established. In the coastal areas subjected to mercury containing waste disposal, mercury levels can exceed 3 ppb (Higgins, 1975). Alavandi et. al., (1989) studied total mercury levels from Cochin estuarine system for 18 months. They reported on an average the concentration of mercury inside the estuary was 0.8 ppb and 0.95 ppb (average of eighteen months, except the value in August, 1988). However, rather high values of mercury (66 ppb) was recorded at the bar mouth during August, 1988. This may be attributed to the monsoon rains washing off the sediment-bond mercury of the estuarine Region and bringing it up into the water column. The tolerance limit for industrial effluents discharged into the coastal waters recommended by ISI is 0.01 mg/l (ISI:2490). However, the tolerance limit for water quality after receiving discharge is 0.0003 mg/l (ISI:2490) and the minimum risk concentration reported for mercury is 0.1 ppb (Bernard, 1981). Under these circumstances, to evaluate the effect of mercury in these waters even at low levels is highly essential and continued monitoring for mercury is required to assess the long range effect on the ecosystem. Incidentally, much higher levels of mercury were reported by Balchand and Nambisan (1986) from the Moovattupuzha river, a few kilometres upstream from the Cochin bar mouth. The reported range were 1.2-50 ug/l and they attributed the cause to discharge of industrial effluents containing mercury into the river from a paper-pulp industry. Comparative statement of mercury levels in the Indian coastal waters is given in Table 1.

Although in the Cochin estuary the observed values for the ambient water attains significance since it is apparent from studies that even at lower concentrations mercury and other metals can inhibit phytoplankton productivity. A recent study carried out in the inshore waters of Cochin (Kaladharan et. al., 1990) revealed that cadmium, nickel, lead, chromium and mercury even at low concentrations are found to inhibit primary productivity of in situ phytoplankton populations. Nickel is found to be the least toxic and mercury is the most toxic metal at either end of the scale inhibiting primary production. It was also observed that synergistic effect of inhibitions is more acute when the metals are present in combination than each metal individually. Details are given in Table 2. Other than metals, nutrients in the estuarine waters also showed interesting variations over the last several years. Gopalan (1986) quoting previous studies by Sankaranarayan and Qasim (1969), Sreedharan and Salih (1974), Sankaranarayanan et. al., (1986) stated that the growing concentration of nitrate nitrogen in Cochin backwater can be seen from the recorded minimum value of 0.31 µg at/l in 1965-66; 1.5 µg at/l in 1973-74 and 4.0 µg at/l in 1978-79. The present author (unpublished data) observed for the period (1988-89) rather high concentrations of ammonia in the estuarine region of Cochin with significant increase during pre-monsoon period (range: 46.81 µg at/l (March) - '83.22 µg at/l NH_3 (June). The maximum value recorded was 104.78 µg at/l in April 1988. The source of the ammonia can be either due to the discharge of industrial affluents from the fertilizer complex at Eloor and Ambalamugal and also due to organic waste reaching the estuarine area.

Conclusions and recommendations

Although the information available is not indicative of a serious condition of water pollution, it does suggest a deteriorating condition of the water quality and it will be interesting to evaluate the changes occuring over a period of time and to study the effect of water quality deterioration on the fauna and flora of this ecosystem. Central Marine Fisheries Research Institute has an on going project on marine pollution with the main objectives to (1) monitor metal levels in the estuarine and inshore waters and (2) to evaluate lethal and sublethal effects of selected pollutants on important living resources.

In this context, it is felt that, it is essential to ascertain whether standard methods are being followed and also to check the precision and accuracy of estimations made and reported by various institutions. As far as pollution problems are concerned, in order to enfore any legal procedure on industries polluting the rivers and backwaters it is necessary that the methods adopted in the estimation of vital parameters are accurate. Necessary standardisation of methods employed is a must. Besides various agencies concerned should participate in intercalibration programmes for enabling comparability of the data collected and reported.

As part of the work to evaluate the precision and accuracy of the estimations, scientists of CMFRI have carried out percentage recovery estimations, in addition to participation in intercalibration exercises with NIO regarding metal analysis in biological samples.

In the light of recent interest shown by the Government, Scientific Institutions, industries and the public in the water quality deterioration of this area, which resulted in the campaign of 'Save Periyar', it will be worthwhile to make the following suggestions:

1. Institutions may be identified based on their experience and expertise to carry out monitoring programmes as well as laboratory studies to evaluate the water pollution and its effects.

2. Information/data collected by various organisations by research projects founded by Governmental agencies may be made available to laboratories engaged in pollution research.

3. Periodic workshops/intercalibration exercises may be organised to emphasis the need for precision and accuracy in the analytical techniques employed by different laboratories.

Table 1. Comparative account of mercury levels in the coastal waters of India (Hg: ug/l)

Area	Arabian Sea	Bay of Bengal	Indian Coastal waters	Binge Bay Karwar	Thane creek Bombay	M.O. River Cochin	Cochin estuary
Hg	0.078	0.045	0.20	17.83	0.247	1.2-50	1.1
Ref.	Qasim et. al., 1988	Qasim et. al., 1988	Sanzgiry et. al., 1988	Kureishy et. al., 1986	Zingde & Desai, 1981	Balachand Nambisan 1986	Alavandi et. al., 1988

Table 2. Combined effect of metals on primary productivity of *in situ* phytoplankton populations (Metals: Cd, Ni, Pb, Cr and Hg)

Metals	Primary Production mg Cm^3/hr	% over the control
All metals	0.10	100
Mixture without Hg	0.33	330
Mixture without Cr	0.26	260
Mixture without Pb	0.17	170
Mixture without Cd	0.16	160
Mixture without Ni	0.075	75

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IMPACT OF AGRICULTURE ON THE FISHERY RESOURCES OF KERALA

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IMPACT OF AGRICULTURE ON THE FISHERY RESOURCES OF KERALA

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Agriculture plays a dominant role in the economy of Kerala and the total area under cultivation is 29,23,804 ha of which 7,40,000 ha are rice lands and produce about 12,00,000 tonnes annually. In addition, the commercial crops like rubber, plantations and spices also contribute substantially to the total agricultural production. Other than the agricultural products, the state plays a vital role in the fisheries sector. The inland and estuarine water resources of the state mainly comprises of rivers, canals, tanks and ponds, reservoirs, brackish water lakes, backwaters and estuaries. The estimated extent of various types of inland water resource in the state are given in Table 1.

Table 1. Inland water resources of Kerala State

Type of water	Estimated area (ha)
Rivers	85,000
Tanks and ponds	3,300
Reservoirs	24,137
Brackish water lakes	97,100
Backwaters including mangrove swamps	2,02,300
Estuaries	40,300
Total	4,52,137

Source : Water resource of Kerala - problems of utilization and pollution; P.V.R. Nair & V.K. Pillai - paper presented at the Seminar on Development and Environment, Cochin, June 5, 1982.

It is estimated that 5,117 ha are being utilised for traditional fish culture practice, 243000 ha are potential areas for future developments. The inshore marine area within 0-18 m depth zone is estimated as 259000 ha which already sustains a good capture fishery and also suitable for open sea mariculture development. The current production from the marine sector is about 3.25 lakh tonnes and the contribution from inland fisheries is around 0.25 lakh tonnes. The marine products exported from Cochin and Calicut Ports earn about Rs.140 crores annually. The aquatic ecosystem consisting of the brackish and inshore areas play a significant role in sustaining the commercial fishery resources.

Of late, there have been reports of fish kills as well as significant reduction in the catch of some of the important fishery resource of the estuarine and fresh water areas and also the prawn fishery of the coastal waters. One of the reasons attributed to the same is degradation of water quality due to various pollutants including industrial and agricultural wastes, the latter playing an important/dominant role at least in some areas of the ecosystem like the Vembanad Lake. Human interference such as construction of barrages and land reclamation adds to the environmental degradation.

The influence of backwaters and estuarine on marine prawn resources

The role played by the extensive backwater ecological system, consisting of the various swamps, inland bays, lagoons, lakes, backwaters and estuaries along the entire coastline of the state from the point of view of prawn production is well known. Owing to the high productivity and extremely favourable physical and biological conditions for growth and propagation the animals associated with these brackish water environments are rich and varied. In addition to the permanent inhabitants of the area many fishes and invertebrates of marine origin including the commercial prawns temporarily utilize this biotic niche for completing their life-cycle. Thus the estuaries and backwaters play a dynamic role in influencing the overall prawn production.

From the biological point of view the interesting feature is that most of these prawns have a peculiar life history characterised by a period of more or less predictable length which is passed in an estuarine or brackish shallow water environment. In most of these important species the parent population breeds in the sea at various distances from the shore line, producing large numbers of microscopic eggs which are shed into the sea. These semi-buoyant eggs quickly hatch into small planktonic larvae known as nauplii. Metamorphosis takes place rapidly through protozoeal and mysis stages, all the while being transported towards the shore, especially towards mouths of rivers or openings, of shallow lakes and backwaters. Depending on the species the time taken between hatching in the offshore waters and entry of the small post-larvae into the brackish water varies, usually from 2 to 4 weeks. Once in the brackish waters they leave the planktonic existence and descend to the bottom, reaching different parts of the shallow waters. Over the subsequent 6 to 9 months they grow rapidly and reach certain sizes, varying with species. After these sizes are attained they return to the sea where the life cycle is completed. Considerable variations occur among the various species, both in the degree to which the brackish water environment is utilized by each species in the life history and in the distribution of parent and juvenile populations in the gradient zones of the brackish marine environments. The giant fresh water prawn Macrobrachium rosenbergii which is known for its periodic migration between fresh and brackish water areas for the feeding and breeding migrations also utilize this environment for their survival and growth.

Changes in the brackish water environment are brought about in two different ways, viz., by natural adversities as well as by activities of man. Among the former may be mentioned the changes brought about due to climatological events like floods. The changes due to interference of man are (1) changes in total area of brackish water habitat resulting from large scale reclamation for agricultural purposes, (2) protective works such as salt water barrages, tide control structures etc., (3) pollution of waters by domestic, industrial and agricultural wastes and also by large scale retting of coconut husks, and (4) development of mineral resources by dredging of fossil shell deposits. These changes in the environments affect the estuarine phase of the life of the commercial prawn in any one or more of the following ways, namely, general reduction in acreage of habitat, change in circulation and thus affecting distribution of salinity, temperature etc., lessening of average depth, impeded exchange of fresh and salt water, loss of tidal exchange benefits, restricted influx of salt water, change in water chemistry due to presence of toxic compounds, increased silt load etc. In general, the estuarine habitats are affected in two major ways, either by a net loss of total acreage available or by change in mean salt content and chemical composition. Scientists who studied the developments over a number of years often expressed the doubt that whether the estuary dependent prawns of commerce can adjust to the environmental changes and consequent modifications in the various factors and still maintain their stocks at the present level (George, 1968). In the absence of exact statistics of the catch from the estuarine regions as a whole, the available data for Calicut and Cochin area show a declining trend for the last few years.

Table 2. Estuarine prawn fishery at selected centres

	1979-80	1980-81	1981-82	1984-85
Calicut				
Estimated catch in tonnes	67.3	46.4	46.4	132.0
CPUE in Kg/net	(11.1)	(8.8)	(7.3)	(3.2)
Fishing gears - stake nets				
Important species: M. dobsoni, M. monoceros, P. indicus				
Cochin				
Estimated catch in tonnes	2068	1556.4	1786	1036
CPUE in kg/net	(2.10)	(1.9)	(2.39)	(1.4)
Fishing gear - stake net				
Important species: M. dobsoni, M. monoceros, P. indicus				

Source: Annual Reports of CMFRI

Although it can be argued that the overall reduction in the capture as well as traditional culture fisheries in the Vembanad Lake and adjacent backwater areas may be caused by the cumulative effect of several factors mentioned above, it has to be remembered that ecological changes originated from agricultural and related developments have played a predominant role in the subsequent ecological changes in the ecosystem. However, when the impact on the aquatic ecosystem caused by the agriculture development programmes are elucidated, the effects can be mainly linked to three areas:

viz., (1) human interference on the ecosystem, (2) toxic effects of pesticides on aquatic organisms, and (3) effects of fertilizers on aquatic ecosystem.

1. Human interference on the ecosystem

This is mainly caused by constraints on available space and related changes by both reclamation of available water areas and also by construction of salt water barrages and tide regulators. A typical example is the Vembanad Lake, known to be the biggest water surface available in the state. It is a known fact that considerable reclamation has been carried out in the past two or three decades for agricultural purposes. According to Gopalan et. al., (1985) in the beginning of this century Vembanad Lake, the major brackish water body on the west coast of India had an extent of nearly 36,500 ha, but by the middle of this century about 25% of the system had been reclaimed mainly for agricultural and harbour development programmes. Although, large scale reclamation has been restricted for sometime, still a lot of reclamation is going on by individuals in this region.

One of the major hazards to the cultivation of paddy in the Kuttanad fields lying adjacent to the Vembanad Lake is the incursion of saline water through tidal flow, especially during the summer period. To prevent the salt water incursion and to promote a double crop of paddy in about 50,000 ha of low lying fields in the area, it was proposed to construct a 1463 meter long barrage rising 92 cm above the level of high tide at Thanneermukkom in the Vembanad Lake at an estimated cost of Rs.485 lakhs. It has been assessed that a total quantity of 1100 million cubic meters of water is drained into the Arabian sea annually by the rivers through the barrage.

Designed as a bridge-cum regulator with facilities for allowing navigation, the work of the barrage was started in 1958. When it became temporarily functional in March 1975 with an earthern bund in the middle portion, it became the second biggest salt water barrage in the century. The barrage started regular functioning from the summer of 1976 and since then, the regulators remain closed from January to May every year. This was resulted in some ecological changes in the lake in general, and in the zone lying south of the barrage in particular. During the period from January to May when the barrage remains closed the free flow of water from Cochin backwaters to the interior of the lake is virtually prevented. While in the northern zone there is considerable reduction in salinity, in the southern zone an almost fresh water condition prevails throughout the year. Gopalan (1986) states that the construction of Thottapally spillway in 1965 and Thanneermukkom bund in 1974 has ecologically severed off about 6,900 ha of brackish water area lying south of Thanneermukkom and converted it into practically a fresh water zone. The reduction in depth and volume of the water area due to siltation caused by such changes also adds to the problem. Gopalan (1985) observed that in the course of fifty years the average depth of the brackish waters of central Kerala has been reduced from 6.7 metres to 4.4 metres.

It is an established fact that the recruitmment and distribution of penaeid prawns in the backwaters and estuaries are greatly influenced by the prevailing physico-chemical conditions of which salinity is the most deciding factor. The drastic change in the ecology of the lake as a result of the functioning of the barrage has severely restricted the incursion of penaeid prawns towards the upper reaches of the lake. During the summer months when the regulators are closed the penetration of prawns beyond the barrage is totally arrested and whatever migrated through the barrage during the monsoon period are virtually prevented from returning to the sea.

There is an apprehension that the cumulative effect of these changes over the years in this dynamic estuarine system would be considerable and may eventually lead to the loss of valuable living resources.

When the ecological changes and the consequent effects on the resources of an aquatic ecosystem is dealt with, it is rather difficult to pin point the exact role played by a single factor or input. It can be a synergistic effect of one or two factors or it can be a cumulative effect of several inputs acting simultaneously. Sometimes natural calamities can trigger off an ecological phenomena. Human activity can directly or indirectly add to the problem. A typical example of such a phenomena was reported from the Vembanad lake in 1983. Immediately after the first monsoon rains, in the third week of June large scale mortality of fishes and clams were reported from the Vembanad Lake. Scientists from CMFR Institute who investigated the phenomena traced the causative factor to the lowering of pH originated from soil acidity (Pillai et. al., 1983). They reported very low pH (4.0) at the southern end of the lake and a pH of 3.8 for the water pumped out of the paddy fields. Since the soil in the fields were acidic and due to an unusually severe summer conditions in 1983 the acid soils were exposed to the sun which aggravated the problem. They observed that this low pH originated mainly due to the leaching out of acid waters from the paddy fields and adjacent canals. Although the mortality to fishes were immediate and of a short-term nature, the destruction of clam beds were massive and it took several months for the ecosystem to the back to maintain the normal balance of equilibrium between the environment and the living organisms.

2. Toxic effects of pesticides on aquatic organisms

Pesticides are chemicals or mixture of chemicals used for killing, repelling, mitigating, phasing or even regulating with a view to minimise the damage by pests to the crops. In India we use about 400 g tech/ha on an average as compared to 10,790 gms in Japan, 1490 gms by USA, 1870 gms by Europe and 127 gms by Africa (Bhat, 1985). Table 3 gives an approximate idea on the demand pattern of pesticide use in the country.

Table 3. Demand pattern of DDT & BHC and other pesticides during VII Five Year Plan period (Tonnes)

	1984-85	1986-87	1989-90
DDT	17,750	18,750	19,750
BHC	42,500	44,750	47,000
Others	19,800	23,400	26,940
Total	80,050	86,900	93,690
DDT & BHC % of the total	75%	73%	71%

Source: DDT & BHC controversy - A scientific analysis. K.N. Mehrotra, INSA News, 76, June 1986.

When the impact of pesticides on the ecosystem is considered, the main aspects are their effect on non-target organisms, their ability to persist in the environment and also their tendency to bioaccumulate in various trophic levels. Most of the pesticides applied to the crop ultimately find their way into the soil. The important sources of pesticide residues in soil are application of pesticides as soil insecticides, spray run off/fall out, dust fall out and through crop and animal remains. An estimated 90% of the pesticide applied to crops foliage does not reach the target (Mehrotra, 1986). Nearly 50% of the applied insecticide finds its way to the soil either as spray drift or as run off that falls on to the ground. Soil is thus a reservoir from where pesticides might move into the aquatic system and get accumulated in plants and animals. The great sorptive capacity of estuarine sediments and their ability to act as a pollutant sink, thus providing a continuous source of pesticide residues is now well-known. Low water solubility and high lipophilic property of some of the pesticides, especially DDT & BHC makes them to concentrate in the organisms. Residues of both these insecticides and their metabolites have been reported in a large number of aquatic and terrestrial animals in various parts of the world.

As insecticides were developed for the specific purpose of killing arthropodes, it is not surprising that they effect estuarine forms such as zooplankton, shrimp and crabs. Penaeid shrimp are among the most sensitive crustaceans to organochlorine insecticides. Results of recent studies with insecticides and marine organisms demonstrate that concentrations which are not sufficient to control many species of pestiferous insects, including several species of salt marsh mosquitoes, nevertheless can inhibit the productivity of phytoplankton populations, kill or immobile crustaceans, fishes and molluscs, kill eggs and larve of bivalve molluscs, induce deleterious changes in tissue composition of molluscs and teleosts, disrupt the schooling and feeding behaviour of fishes, and interfare with ovary development in molluscs and teleosts.

It is reported that the total quantity of pesticides used annually in Kerala is about 1000 tonnes, of which about 250 tonnes are used in the rice fields of Kuttanad alone.

Table 4. Pesticide consumption in Kerala (Technical grade - in metric tonnes)

Period	Quantity
1980-81	1092
1981-82	925
1982-83	950
1983-84	1050
1984-85	1028
1985-86	984

Source: Directorate of agriculture, Govt. of Kerala

Although there have been many reports about fish kills due to pesticide pollution from the backwaters, scientific data on a quantitative basis is virtually lacking especially for the aquatic environment. Perhaps it may be due to the lack of availability of sophisticated instrument set up and necessary infrastructure for such type of investigations. One of the recent studies conducted by the scientists of CIFT, Cochin showed the following residual levels in some organisms collected from the coastal areas of Calicut (Radhakrishnan et. al., 1986).

Table 5. Levels of chlorinated pesticides (pg/g)

Pesticide	Water	Prawn	Catfish	Mussel
BHC	8.45	5548	2908	51031
Lindane	15.10	Trace	Trace	2372
Heptachlor	27.55	Trace	Trace	3025
Aldrin	191.00	Trace	5413	13266
Heptaepoxide	Nil	Trace	1849	3822
PP' DDE	46.25	Trace	3163	1177
OP' DDD	Nil	1615	Trace	5865
Dieldrin	44.70	1310	Trace	2353
OP' DDT	200.25	1018	Trace	9524
Endrin	171.95	Nil	3063	2053
PP' DDT	713.10	1918	6616	13542
Total	1418.35	11409	23012	108030

Radhakrishnan, A.G. et. al., 1986. On the use of mussels as a pollution indicator - paper presented at the National Seminar on mussel watch, 13-14 Feb. 1986, Cochin.

They reported a clear increase in total pesticide content, the order being mussel > catfish > prawn > water. They also observed that the chlorinated pesticide content has accumulated 8 times in prawn, 16 times in catfish and 75 times in mussel compared to the surrounding water. Incidentally, one of the reasons attributed to the virtual disappearance of the giant fresh water prawn Macrobrachium rosenbergii from the Vembanad Lake and adjacent areas is the toxic effect of pesticide residues in the water. However, no specific data is available. It is also possible that the life history of the fresh water prawn might have been adversely affected by the extensive reclamation of shallow regions of the lake.

It is gratifying to note that the growing concern about excessive use of pesticides and its consequent ecological damage is slowly bringing about changes in the use of such chemicals. Use of DDT for crop protection is virtually banned, and not much BHC is used in paddy fields. However, the large quantity of fungicides used in the plantations adds to the problem. The rate of input towards metal pollution form this source is yet to be studied. The current thinking appears to be for 'need based use' and the future programme is to look for an 'integrated pest management' which are healthy signs. However, monitoring programmes for pesticide residues in the aquatic environment including the fauna should be given priority from the point of view of ecological protection and resource management.

3. Effect of fertilizers on aquatic ecosystem

Fertilizer is the king pin for increasing productivity in Agriculture. The per unit area consumption in India is estimated to have gone upto 48.39 kg/ha. In Kerala, the total annual consumption of fertilizers amount to 141330 tonnes, a substantial portion of which is used in the rice fields and the recommended dosage ranges from 80-180 kg/ha of NPK. Table 6 gives the details of fertilizer application in the State from 1980-81 to 1985-86.

Table 6. Year-wise fertilizer consumption in terms of NPK (in MT) 1980-86

Year	N	P	K	Total
1980-81	41696	23403	32431	97530
1981-82	40612	23215	30934	94761
1982-83	45233	26555	38065	109853
1983-84	62480	31178	35819	129477
1984-85	57657	32642	37346	127645
1985-86	59263	34412	47655	141330

Source: Directorate of agriculture, Govt. of Kerala

It is believed that only about 50% of the applied fertilizer will be utilized by the crops and the rest is leached out or gets deposited in the soil. This unutilized fertilizers, especially nitrogen and phosphate contained in the fertilizers and remaining in the agricultural and paddy fields finally end up in the aquatic environment through rain and land seepage. Nutrient enrichment to a certain extent is beneficial and may show an increase in primary production, but when the rate is too high it may show damaging trends. The presence of high concentrations of phosphates and nitrates can sometimes directly help the growth of certain plankters (algal blooms) which can successfully compete with other groups. Algal blooms can cause many undesirable side effects like creating bad odour, interference with filter feeding animals, excessive demands on oxygen and even release of certain biotoxins.

It has been reported by several investigators (Sankaranarayan & Qasim, 1962; Nair et. al., 1975; Sankaranarayanan et. al., 1983) that when the estuarine system remain predominantly marine, the nutrient concentrations are low and homogeneous throughout the water column, while during the period of fresh water discharge high concentrations of nutrients occur. Nair et. al., (1975) reported that high concentrations of PO_4-P (upto 32 µg at PO_4 P/l) were observed in the southern region of Vembanad Lake either during the monsoon or during the post-monsoon period. Very high concentration of PO_4-P were observed only in the southern regions whereas in the lower reaches, PO_4-P values are low. They observed that the uneven distribution of phosphate has been attributed to external sources like land drainage and fresh water run off. Gopalan (1986) quoting previous studies by Sankaranarayanan and Qasim (1969), Sreedharan and Mohammed Salih (1974), and Sankaranarayanan et. al., (1986) states that the growing concentration of nitrate nitrogen in Cochin backwater can be seen from the recorded minimum value of 0.31 µg at/l in 1965-66, 1.5 µg at/l in 1973-74 and 4.0 µg at/l in 1978-79. He also observed that the value of phosphate phosphorus showed an increase from a minimum of 0.36 µg at/l in 1965-66 to 0.85 µg at/l in 1974. Nitrogen and phosphorus, though they are not directly harmful to any living organisms contributes to destructive changes in the ecological balance in the aquatic ecosystems. High BOD and eutrophication is a common phenomena in many of the polluted fresh water and estuarine areas. The menacing abundance of water weed Salvinia spp. (African payal) in the Kerala waters is another type of ecological imbalance in the aquatic ecosystem.

Conclusions

Although precise data are lacking on some of the parameters discussed, it is evident that the ecological balance of the aquatic ecosystem has been affected by the various interferences and their effects on the living resources are apparent. Of course, it can be argued that the situation is not alarming, but the need for a vigil and regular monitoring of the situation is now called for. Intensive research has to be carried out to collect data on the prevailing conditions in the ecosystem and also suitable monitoring programmes planned for major pollutants like the pesticide residues in the aquatic environment. The question arises as to what will happen if the estuary dependent prawns are deprived of the environment and also how far they can adjust to the new conditions prevailing in the environment. Considering the interests in the use of brackish waters for the development of aquaculture and the agricultural developments in future, it is proposed that a comparative long-term cost-benefit analysis be made to study the effect of large scale reclamation of land as well as construction of structures like salt water barrages as pointed out by George (1968). Let us plan for the development of both agriculture and aquaculture.

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INLAND WATER RESOURCES OF KERALA IN RELATION TO FISHERIES DEVELOPMENT

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Introduction

The inland water resources of Kerala are equally vast like the extensive coastline and productive inshore waters. With forty one west flowing and three east flowing rivers together with connected canals, lakes and backwaters, the water resources of this state provide great potential for multiple use (Fig.1). The total estimated area of these water resource is about 4,52,000 ha (Table 1). These extensive water resources support a lucrative capture fishery of fin fishes and shell fishes. The fishery resources, both marine as well as inland, play a vital role in the economy of the state. The current production from the marine sector is about 3.25 lakh tonnes and the contribution from inland fisheries is around 0.25 lakh tonnes.

Of late, there have been reports of fish kills in some areas and also about reduction in the catch of some of the important fishery resources of the estuarine and fresh water areas and also the prawn fishery of the coastal waters. The main reason attributed to this phenomena is degradation of water quality due to pollution from industrial and agricultural wastes. The main sources of these pollutants are agro-industrial effluents and human wastes released into the aquatic environment. In addition, environmental modifications resulting from human interference in these ecosystems such as the construction of dams, salt water barrages and large scale reclamation of water areas which reduce the available environment for development of the natural resources often adds to the problem of ecological imbalance resulting mainly in the loss of total available area or by change in the chemical composition of the ambient water.

The inland water resources

Other than the forty four rivers, there are a number of lakes and back-waters formed by the branches of the major river systems. They also play an important role in sustaining inland fishery development. There are about fifteen estuaries contributing to the fishery resources to varying degrees of production. As already mentioned, the important lakes of the states are Vembanad, Kayamkulam and Ashtamudi, of which the Vembanad lake is the largest, well known for its role as the nursery ground for the commercially important prawns of the inshore waters.

Important estuaries and lakes of Kerala

1. **Chandragiri**

The main estuarine region extends to about 5 km upstream along the river and includes a backwater extension upto Kasargod.

2. **Neeleshwar**

The Neeleshwar estuary is formed of the branches of Neeleshwar and Karingote which join at Kottapuram near Neeleshwar and they open to Arabian sea through a common barmouth at Thaikadappuram.

3. **Madakara**

The lower reaches of the rivers Mattul, Valapatnam and Irinam constitute this estuary. The Mattul estuary is relatively shallow. The Valapatnam estuary is deeper.

4. **Mahe**

This is a smaller estuary extending upto Koriyad village from the bar-mouth (salinity is invariably high).

5. **Kottakal**

This estuary has a northern extension upto Badagara and a southern extension to Iringal village.

6. **Korapuzha**

The Korapuzha estuary is formed of the main Korapuzha backwater to which joins the Elathur river. The estuary is relatively shallow.

7. **Beypore**

The lower reaches of the river Chaliyar is known as Beypore estuary.

8. **Purapuzha**

The Purapuzha estuary is formed by the Kadalundi river basin, which at Vellikunnu village forms Kadalundi estuary.

9. **Ponnani**

The confluence of the rivers Bharathapuzha and Tirupuzha forms the brackish water source of this area.

10. **Puthuponnani**

The Puthuponnani estuary covers the region extending from the Veeyam Dam to the bar mouth.

11. **Chetwai**

Lying between Puthuponnani and Azhikode estuaries, Chetwai is an important estuary of central Kerala with a complex system of inter-connected backwaters and canals.

12. **Cochin backwater (north)**

This backwater system occupies the area between Azhikode in the north and Cochin bar mouth in the south. The major rivers, namely Chalakudi and Periyar empty into this backwater.

13. **Cochin backwater (south)**

This backwater is located between Cochin bar mouth and Alleppey, the main component of this backwater is the Vembanad lake.

14. **Kayamkulam**

The Kayamkulam lake which extends from Haripad to Ayiram Thengu is deeper in the central region.

15. **Ashtamudi lake**

The Ashtamudi lake is formed of the lower reaches of the river Kallada and it joins the sea at Neendakara.

Vembanad Lake

The Vembanad Lake is the largest brackish water lake system of south west coast of India, situated between latitudes 9°28' and 10°10'N and longitudes

76°13' and 76°31'E. It has a length of about 90 km and extends from Alleppey in the south to Azhikode in the north. The total area is about 256 sq.km. The depth at the Cochin navigation channel varies from 8-12 m and the depth of other parts of the lake is 1-5 m. The width of the lake varies from a few 100 m to about 8 km. The main source of fresh water for the lake are two large rivers. Periyar in the north and Pamba in the south. Four other rivers viz: Achancoil, Manimala, Meenachil and Moovatupuzha also empty into the lake. During the south west monsoon the lake receives an average rainfall of 3300 mm and is virtually converted into a fresh water basin.

A 1447 m long bund was constructed across the lake at Thanneermukkom in 1975 for preventing the penetration of salt water into the upper Kuttanad areas so as to enhance paddy cultivation. The water flow through the bund is regulated by spill ways and the bund is kept open during June to December and will be closed during the rest of the periods.

Fishery resources

As in the case of other maritime States of the country, the inland waters of Kerala also supports a variety of fresh water and brackish water fish species, with some obvious distributional variations in abundance and species composition. From the information available for the last several years (Table 2) it is evident that the prawns dominate the total catch.

The brackish water and estuarine fisheries of Kerala

Although there is a limited fishery from the riverine waters, the bulk of the inland fishery is from the brackish water and estuarine areas (Table 2).

As already indicated, the tributaries of the rivers and their lower reaches within the tidal influx, the brackish water lakes, backwaters and the adjacent low lying fields, the mangrove swamps and marshes constitute the estuarine and brackish water resources of the State. The total extent of this water resource is estimated at about 0.3 million ha.

Consequent on the varied ecological endowments and prevalence of tidal currents, river and land drainage, this ecosystem forms an ideal habitat for several organisms. It also serves as nursery grounds for several marine and fresh water organisms including the commercially important fishes, crustaceans and molluscs. Over 90 species of fishes, 40 species of prawns and shrimps, 43 species of crabs occur in these waters. However, the biographic distribution varies depending on the species, their ecological adaptations and environmental conditions.

Rough estimates show that the fish landings from the Kerala backwaters amount to 14,000-17,000 tonnes per year. In addition about 88,000 tonnes of live clams and 1-7 lakh tonnes of dead mollusc shells are collected annually. The composition of fish and prawn catches from the backwaters of Kerala is as follows: Prawn (*Metapenaeus dobsoni*, *M. monoceros*, *M. affinis*, *Penaeus indicus*, *Macrobrachium rosenbergii*) 60-70%; Mullets (*Mugil cephalus*, *M. macrolepsis*, *M. cunnesius*, *M. parsia*, *M. seheli*) 11%, pearl spots (*Etroplus suratensis*, *E. maculatus*) 10%, cat fishes, 9% and others 1% (Jhingran, 1982).

Post-larvae of different species of prawns exhibits considerable fluctuations in abundance. Those of *Metapenaeus dobsoni*, *M. monoceros* and *P. indicus* are present almost throughout the year, the largest numbers were found during March to June and October-December. The prawn fishery of Cochin backwaters is mainly contributed by the juveniles of Metapenaeus dobsoni (30-95 mm), Penaeus indicus (45-140 mm) and M. monoceros (35-120 mm). The fishery is abundant throughout the year though the catches are heavier during the monsoon and post-monsoon months than in the pre-monsoon period.

Samuel (1969) reported fish landings from the Vembanad lake during 1965-66 to be 1,252 tonnes of which about 518 tonnes were captured by 'chinese dipnets' about 695 tonnes by stake nets and 39 tonnes by boat seines. A preliminary survey of the lake conducted by Shetty (1963) in March 1959 indicated that the major commercially important forms are: prawns, M. dobsoni, M. monoceros and P. indicus, and fishes, Mugil cephalus, M. cunnesius, M. parsia, M. macrolepis and M. waigiensis in the upper half of the backwaters and Lates calcarifer, Chanos chanos and Etroplus suratensis in the lower half. In addition to these, the sciaenids (Sciaena coiter) the perch (Lutianus argentimaculates) and the cat fishes (Tachysurus spp.) are found in good numbers all along the backwaters. Among those of lesser commercial importance may be mentioned Caranx sansum, Tylosurus strongylurus, Hemiramphus cantori, Etroplus maculatus and Scatophagus argus in the lower stretches and Thrissocles spp., Anchoviella spp. and Elythronema tetradactylum in the upper stretches. Shetty reported 120 varieties of fishes including crustaceans and crabs. However, in a recent study, Kurup (1982) reported 150 species of fishes belonging to 100 genera and 56 families from the Vembanad Lake.

The lime shell fisheries

The lime-shells and the living clams occur in very large quantities in the different backwaters and estuaries of the state. Extensive beds of sub-soil deposits or white shells are found in the Kodungallore, Vembanad and Ashtamudi Lakes and in the estuaries of the Kadalundi and Korapuzha rivers. The Vembanad being the largest lake is the major source of lime shell to the state (Rasalam and Sebastian, 1976).

The clams that contribute to the fishery area: Villorita cyprinoides (Gray); V. cyprinoides var. cochinensis (Hanley); V. cyprinoides var delicatula (Preston); V. cornucopia Prashad; Meretrix meretrix (Linnaeus) and M. casta var ovum (Hanley). Villorita contribute to more than 90 percent of the clams from this lake.

Rasalam and Sebastian (1976) reported that in 1965 about 20,542 tonnes of live lime-shells were fished from the Vembanad Lake. For the period 1965-68 maximum shell fish catch was recorded in 1968, when about 26,858 tonnes were fished. Similarly the semifossilised lime shell catch in 1968 was 1,01,312 tonnes.

Environmental degradation of inland water resources

The pollution caused by the discharge of partially treated or untreated wastes from the factories, sewage and chemicals from agricultural operations (both fertilizers and pesticides) finding their way into the water bodies are the main factors contributing to the water pollution problems of Kerala. It has been estimated that more than 5 lakh m^3 of industrial effluents are being discharged into the rivers of this State everyday. Fairly wide areas of our rivers have lost their ability to keep the natural ecological equilibrium and restore their own pure quality. One of the major river system of north Kerala which is known for its polluted waters and consequent problems is the Chaliyar river. As per an accepted figure, the total intake of water per day by the factory here was between 34,000 to 45,000 m^3 per day. The total effluent volume was about 54.7 million litres per day (Nair and Pillai, 1982). The average annual flow of water in the river based on ten years discharge data is calculated to be 149 m^3/sec and average minimum flow is 393 m^3/sec. Hence during the summer months the flow is not sufficient to render the stream harmless for aquatic life. Hence there was acute pollution in the immediate vicinity especially in summer months and the recovery takes place only at about 16 km downstream. This effect of pollution in these waters has almost devastated the fin fish and shell fish resources which was the main source of livelihood for quite a large number of rural folks occupying the banks of the river. Since the plant has been shut down for quite some time now, the problems does not exist now, however, it is likely that with the proposed reopening of the plant it is possible that the same story will repeat in future also.

In recent years there have been a number of reports about fish kills due to water pollution in the backwaters around Cochin, which included the Periyar river near the industrial area at Eloor and also the Chitrapuzha near Ambalamedu, another industrial suburb of Cochin. The quantity of effluents discharged into the rivers from this area together is estimated to be around 200 million litres per day (Nair, 1982). The water pollution problems in the

Eloor-Alwaye belt is known for the past several years. Several instances of fish kills have been reported from this area (Silas and Pillai, 1972). In recent years, during summer, a temporary bund is constructed in the Periyar River to prevent salt water entry in the upstream, which has caused stagnation of polluted water aggravating the pollution problem and often causing fish kills in these waters.

A major instance of fish kill was reported in the Chitrapuzha which extended to Cochin backwaters in the first week of June, 1980. Compared to the earlier reported occurrence this instance was of an unprecedented scale in its intensity as well as in the magnitude of destruction and the causative factor was reported to be high levels of ammonia (upto 118 mg NH_3/l) reaching the river system (Nair et. al., 1981).

The water pollution at Punalur in the Kallada river originating from paper industry is also reported for the past several years, although the magnitude of the same is rather less compared to other polluted areas.

In harbour areas like Cochin and Neendakara where chronic oil pollution problems occur regularly, the same way affect the recruitment and survival of young fishes and shrimp larvae to the estuary.

When the impact of pesticides on the ecosystem is considered, the main aspects of the problem are their effects on non-target organisms, their ability to persist in the environment and also their tendency to bioaccumulate in various trophic levels. As insecticides were developed for the specific purpose of killing arthropods, it is not surprising that they affect estuarine forms such as zooplankton, shrimp and crabs. It is reported that the total quantity of pesticides used annually in Kerala State is about 1000 tonnes, of which about 250 tonnes are used in the paddy fields of Kuttanad region situated adjacent to the Vembanad lake. Although there have been many reports about fish kills due to pesticide pollution from the backwaters, quantitative data are virtually lacking, especially for the aquatic environment. Incidentally, one of the reasons attributed to the virtual disappearance of the giant fresh water prawn Macrobrachium rosenbergii from the Vembanad lake is the toxic effect of pesticide residue in the water and sediment. Although specific data are not available, the possibility of pesticide pollution cannot be ruled out. Monitoring programmes for pesticide residues in this aquatic environment including the fauna should be given priority from the point of view of ecological protection and resource management.

Another serious problem affecting the ecology of lakes and rivers are the man made constructions such as barrages and bunds. A typical example is the Thanneermukkom salt water barrage constructed across the Vembanad Lake. To prevent the salt water incursion and to promote a double crop of paddy in about 50,000 ha of low-lying fields in the area, it was decided to construct a 1463 meter long barrage at Thanneermukkom at an estimated cost of Rs.485 lakhs. Designed as a bridge cum regulator with facilities for allowing navigation, the work of the barrage was started in 1958. When it became temporarily functional in March 1975, it became the second biggest salt water barrage in the country. The barrage started regular functioning from the summer of 1976 and since then, the regulators remain closed from

January to May every year. This has resulted in some ecological changes in the lake in general, and in the zone lying south of the barrage in particular. During the period from January to May when the barrage remains closed the free flow of water from Cochin backwaters to the interior of the lake is virtually prevented.

It is an established fact that the recruitment and distribution of penaeid prawns in the backwaters and estuaries are greatly influenced by the prevailing physico-chemical conditions of which salinity is the most deciding factor. The drastic change in the ecology of the lake as a result of the functioning of the barrage has severely restricted the incursion of penaeid prawns towards the upper reaches of the lake. During the summer months when the regulators are closed the penetration of prawns beyond the barrage is totally arrested and whatever migrated through the barrage during the monsoon period are virtually prevented from returning to the sea. There are reports that since the barrage remain closed during summer season, due to stagnation of water on the southern sector, pollution from pesticides and organic wastes has reached dangerous proportions. However, scientific data on the residual concentrations of pesticides are lacking.

There are also several seasonal bunds constructed annually in the rivers near Cochin and Calicut to prevent saline water entering the water intake to the factories during the peak summer season. This results in stagnation of water upstream which subsequently aggravates the problem of pollution.

When the ecological changes and the consequent effects on the resources of an aquatic ecosystem is dealt with, it is rather difficult to pin point the exact role played by a single factor or input. It can be a synergestic effect of several inputs acting simultaneously. Sometimes natural calamities can trigger off such ecological phenomena. A typical example of such a phenomenon was reported from the Vembanad lake in 1983. Immediately after the first monsoon rains, in the third week of June large scale mortality of fishes and clams were reported from Vembanad lake. Scientists from CMFRI who investigated the phenomenon traced the cause of the incident to the low pH originated from soil acidity (Pillai et al., 1983).

Hence it becomes evident that ecological changes in the brackish water environment are brought about in two different ways, by natural adversities as well as by activities of man. Among the former may be mentioned the changes brought about due to climatological events like floods. The changes due to interference of man are (1) change in total area of brackish water habitat resulting from large scale reclamation for agricultural purposes, (2) protective works such as salt water barrages, tide control structures etc., (3) pollution of waters by domestic, industrial and agricultural wastes and also by large scale retting of coconut husks and (4) development of mineral resources by dredging of fossil shell deposits. These changes in the environment affect the estuarine phase of the life cycle of the prawns in any one or more of the following ways, namely, general reduction in acreage of habitat, change in circulation and thus affecting the distribution of salinity, temperature etc. lessening of average depth, impeded exchange of fresh and salt water, change in water chemistry due to presence of toxic compounds, increased silt load etc. In general, the estuarine habitats are affected in two major ways, either by a net loss of total acreage or by change in mean salt content and chemical composition (George, 1968).

Fisheries Development in future

A number of schemes have been in vogue in the State during the past few years sponsored by various agencies, mainly the State Fisheries for the development of the inland fisheries sector. However, some impact is evident mainly on the brackish water sector because of the demand and commercial value of highly priced shrimps in the export market. In the riverine sector there is still much scope to increase production by giving proper training and conducting extension programmes. The other important aspect is to reduce industrial pollution to the fresh water systems by strict enforcement of environmental protection laws.

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Table 1. Inland water resources of Kerala

Type of water	Estimated area (ha)
Rivers	85,000
Tanks and ponds	3,300
Reservoirs	24,137
Brackish water lakes	97,100
Backwater including mangrove swamps	2,02,300
Estuaries	40,300
Total	4,52,137

Source: Water resources of Kerala - problems of utilization and pollution; P.V.R. Nair and V.K. Pillai, Proc. Seminar on Development and Environment, Cochin, June 5, 1982.

Table 2. Species-wise composition of inland fish landings in Kerala (1975-76 to 1979-80)

Quantity (in Tonnes)

Sl. No.	Name of fish	1975-76	1976-77	1977-78	1978-79	1979-80
		Quantity	Quantity	Quantity	Quantity	Quantity
1	2	3	4	5	6	7
1.	Prawns	4032	4929	5106	5204	4652
2.	Etroplus	3031	2880	2402	2638	2847
3.	Murrels	2859	2755	2810	2752	2883
4.	Mullets	1979	2068	2020	2043	2196
5.	Cat fish	2165	2257	2320	2385	2638
6.	Barbus	252	134	281	243	256
7.	Tilapia	2691	3429	3590	3720	4018
8.	Labio	235	194	15	45	12
9.	Mrigala	187	69	17	22	10
10.	Carpio	109	49	13	58	24
11.	Catla	142	93	31	46	9
12.	Rohita	91	-	-	-	-
13.	Gourami	71	27	221	257	8
14.	Chanos	59	22	100	139	162
15.	Cirrhina	61	-	-	-	-
16.	Scianidae	1554	2000	1435	1272	1367
17.	Crabs	541	358	351	313	362
18.	Mirror carps	40	-	-	-	-
19.	Macrones	125	-	-	-	-
20.	Eels	-	15	10	35	46
21.	Miscellaneous	2984	2689	3407	3340	3590
	Total	23208	23968	24129	24512	25080

Source: Kerala Fisheries, Facts and Figures, 1980. Government of Kerala, 1983.