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Critical Habitat Information System for Cochin Backwaters - Kerala

Integrated Coastal and Marine Area Management
Project Directorate
Department of Ocean Development
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1. Introduction

The coastline of India extending to over 7,500 km comprises various biotopes such as estuaries, lagoons, backwaters, mangroves, salt marshes, coral reefs and creeks. Estuaries act as a transition zone between the two aquatic ecosystems namely freshwater and marine. These are highly productive ecosystems and provide substantial support to the inhabitants of many coastal communities through their role in sea food production and nurturing of many valuable marine organisms. These areas are also rich in biodiversity and act as breeding and nursery grounds for fin/shellfishes.

Recognising the importance of marine and estuarine ecosystems and their resources, an Integrated Coastal and Marine Area Management (ICMAM) programme was initiated in 1998 by establishing a Project Directorate at Chennai as a technical unit of Department of Ocean Development. The concept of ICMAM is being promoted extensively to ensure the sustainable development of the coastal areas, rational utilisation of marine and estuarine resources and proper management of the coastal environment to prevent its degradation from developmental, commercial or other activities. The overall goal of ICMAM is to improve the quality of life of human community, which depends on coastal resources, while maintaining the biological diversity and productivity of coastal marine ecosystems.

In this context, with the support of the World Bank, the ICMAM Project Directorate, selected 11 critical habitats from east and west coasts of India to study and develop GIS based information for effective management of these habitats. Cochin Backwaters (Kerala State) is one among the 11 critical habitats identified for such a study, on the basis of its biodiversity value. The major objective of this study is to create information on the resources of this region using Geographical Information System (GIS) incorporating its components of remote sensing and an external database. This would help the decision makers in effectively monitoring and managing the biological wealth of this area.

2. Cochin Backwaters – General Description

The Cochin Backwaters is a part of long chain of lakes and canals extending between 9° 40' 12" and 10° 10' 46" N and 76° 09' 52" and 76° 23' 57" E with its northern boundary at Azheekodu and southern boundary at Thannirmukham bund (Fig:1). The total area of the Backwater is about 157 sq.km (from SOI toposheet, 1981) with depth ranging from 2 m to 8 m. Two rivers, Periyar and Muvattupuzha discharge into these backwaters.

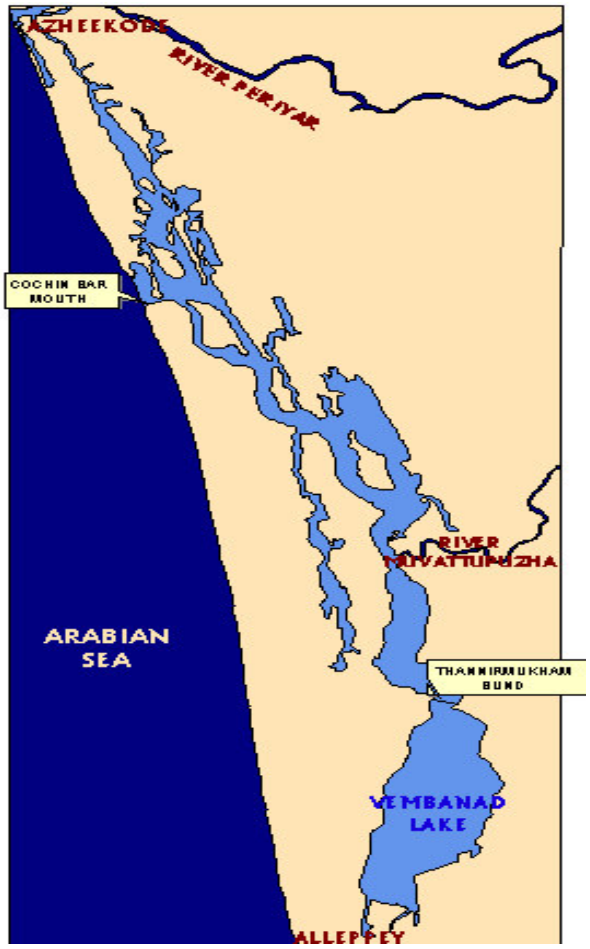

Fig. 1 - Map showing Cochin Backwaters and its environs

The Thannirmukham bund regulates flow from four rivers viz., Meenachil, Manimala, Achankovil and Pamba. The backwaters stretch for the most part, parallel to the coastline and are separated from the sea on the west by low belts of sand. These backwaters are connected with the Arabian sea at the Cochin harbour by a barmouth of 450 m width and average depth 8-10 m. Adjoining the backwaters at the Thannirmukham bund is the Vembanad lake, which is the second largest lake in Kerala. The Vembanad lake lies between 90° 29' 44" and 90° 40' 12" N and 76° 22' 03" and 76° 23' 56" E covers an area of 84 sq. km (as per SOI toposheet, 1981).

The backwaters receive run off during the south-west monsoon and also to some extent during the north-east monsoon season. The discharge of freshwater from the rivers, particularly, during the southwest monsoon period reduces the salinity of backwater system considerably even in areas around barmouth where salt water ingress occurs below 5 m depth only. As per the Environmental (Protection) Act, 1985 (29 of 1986), the Cochin Backwaters have been classified under the "Ecologically Sensitive Zone".

3. Cochin Islands

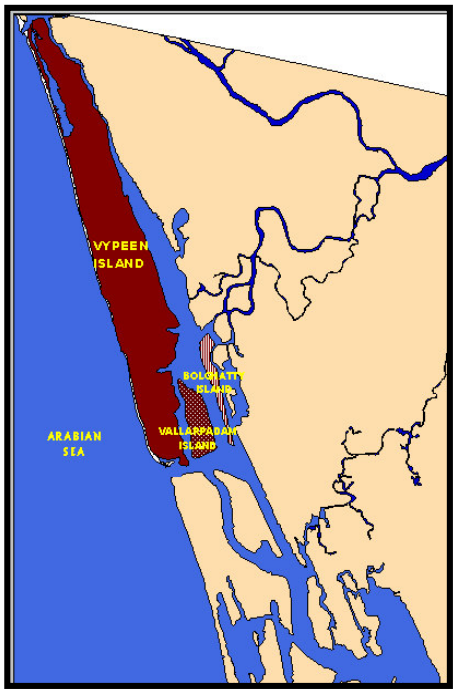

Fig. 2 - Map showing Cochin islands

There are three islands off Cochin viz., Vypeen, Vallarpadam and Bolghatty (Fig.2) apart from many smaller islands scattered along the coast.

The total area of three islands is 56.95 sq. km (SOI toposheet, 1981) with a population of 1,88,520 (1991 census). The population density of these islands is 2158/sq.km. The main occupation of the islanders is fishing and agriculture.

Vypeen island (Fig.3) is the biggest island and is bound by the Arabian Sea on the Western side and the Cochin Backwaters on the eastern side. The total area of the island is about 51.49 sq. km. The inter-island accessibility is mainly through water ways. However, bus services are available within the island.

Fig. 3 - Vypeen island in Cochin Backwaters

The Bolghatty island (Fig.4) is a long narrow palm fringed island and is easily accessible from the mainland by boats. The Bolghatty palace is situated in the island amidst 15 acres of lush green lawns built by the Dutch. The total area of the island is 2.61 sq. km.

Fig. 4 - Bolghatty island in Cochin Backwaters

Vallarpadam (Fig.5) lies between Vypeen and Bolghatty islands and covers an area of about 2.8 sq. km.

Fig. 5. - Vallarpadam island in Cochin Backwaters

4. Ecological Importance

- The salinity gradient in the Cochin Backwaters supports diverse species of flora and fauna, according to their tolerance for saline environment.
- This tropical estuary, with high productivity acts as a nursery ground for many species of marine and estuarine finfishes, molluscs and crustaceans.
- The low lying swamps and tidal creeks dominated by sparse patches of mangroves provide shelter to juveniles of many important species.
- The areas of the backwaters with fine sediments and rich organic matter supports abundant and diverse benthic fauna.
- The changes in the hydrology of backwaters controlled by the seas play an important role in regulating the migrant fauna of the estuary.

5. Development of the Resources Information System

The Resources Information System of Cochin Backwaters developed by ICMAM Project Directorate, integrates the existing diverse coastal and environmental data collected by various organisations on biodiversity.

The information system incorporates the following:

- Thematic maps of the Cochin Backwaters namely Geomorphology, Landuse, etc.
- Compilation of work done on the biological resources of this area.
- Present status of distribution of phytoplankton, zooplankton and benthos.
- Mapping of distribution of mangrove vegetation.
- Threats and their impacts on the Cochin Backwaters
- Management solution

Remote Sensing and Relational Database Management System (RDBMS) along with field survey were used in developing the Resources Information System for Cochin Backwaters. Field and satellite data were selected as primary sources of information and GIS and RDBMS were used as tools to analyze and develop the complete information system. Data were collected on distribution of phytoplankton, zooplankton, benthos and mangroves. The collection methodology varied with respect to parameters studied.

5.1 Components of the information System

5.1.1 Remote Sensing

The present observation was made using IRS IC LISS III 28.1.1998 data (Fig. 6). The Survey of India toposheet was used to rectify the digital data. Base map was digitised using toposheets and onscreen digitisation of the same was also done in order to get an idea about the present location of the coastline of Cochin. Thematic maps on land use, Geomorphology and Shoreline were derived from IRS 1C LISS III, January 1998 data.

Digital image processing was carried out using ERDAS – IMAGINE 8.4. The spatial information system was developed using ARC/INFO 8.0.2 and ARCVIEW 3.2. Tables were created and stored in ORACLE 8.0 database with DEVELOPER 2000 as the front-end. Scripts were written using AVENUE programming language. Finally, Resource Information System for Cochin Backwaters was presented in ARCVIEW as it is a powerful and easy-to-use tool that has the capabilities to visualize, explore, query and analyze the data spatially.

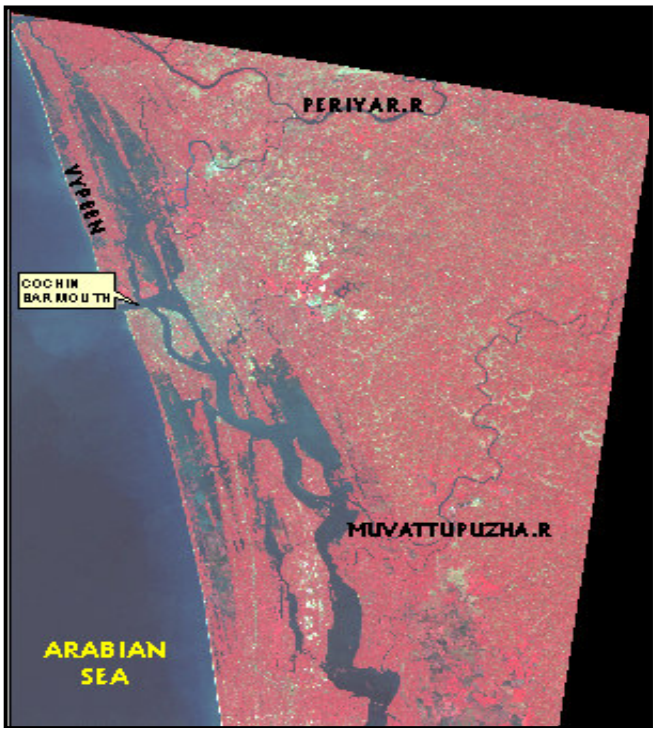

Fig. 6 - Satellite Imagery of Cochin Backwaters

5.1.2 Relational Data Base Management System (RDBMS)

RDBMS is an acronym for "Relational Data Base Management System" which is essentially a set of data storage in the form of tables and a set of programmes to access it.

5.1.3 Collection of Field Data

Data on physico-chemical parameters, phytoplankton, zooplankton and benthos were collected by the School of Marine Sciences, Cochin University of Science and Technology, Kochi, during July 1998, December 1998 and May 1999. Data were collected in seven stations (Fig. 7) along both estuarine and neritic zones.

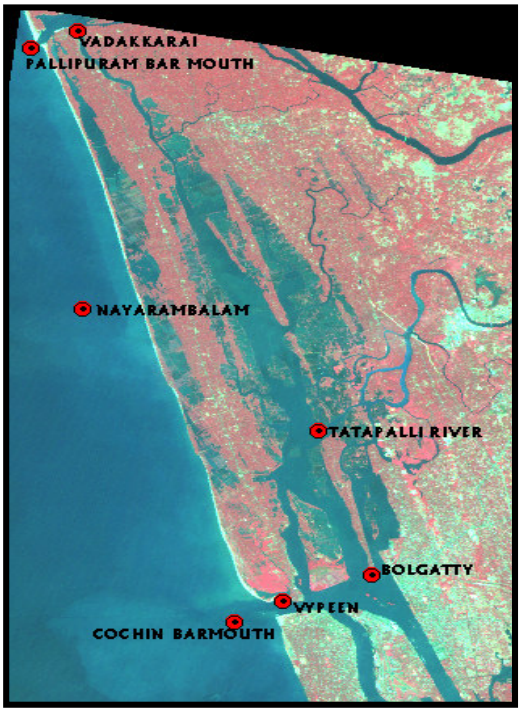

Fig. 7 - Sampling locations

Data on all these attributes collected from the various sources were stored as separate tables in the oracle database and linked using common identities. Tables were created to hold information on physico-chemical details, culturable and non-culturable bacteria, flora and fauna and socio-economics.

5.1.4 Geographical Information System

Geographical Information System (GIS) is a system for capturing, storing, checking, manipulating, analyzing and displaying data, which are spatially referred to the earth. GIS is used for a wide range of applications pertaining to coastal areas. Satellite data were selected as the primary source of information and RDBMS was developed using field data collected by a team of scientists from Integrated Coastal and Marine Area Management Project Directorate, Chennai, during November 2000. Remote Sensing, GIS and field data were used to analyze and develop the complete information system.

6. Geomorphology

The State of Kerala is the South Indian precambrian terrain, preserving units of Archaen continental crust such as granulite, granite, gneisses and green stones. The state is a strip of land with a coastline of 560 km long and width varying from 11 to 124 km. About 16 to 54% of land terrain along the Kerala coast is in the range of 10 to 300 m above the mean sea level. These are termed coastal plains, lagoons and lowlands depending upon the extent of elevation.

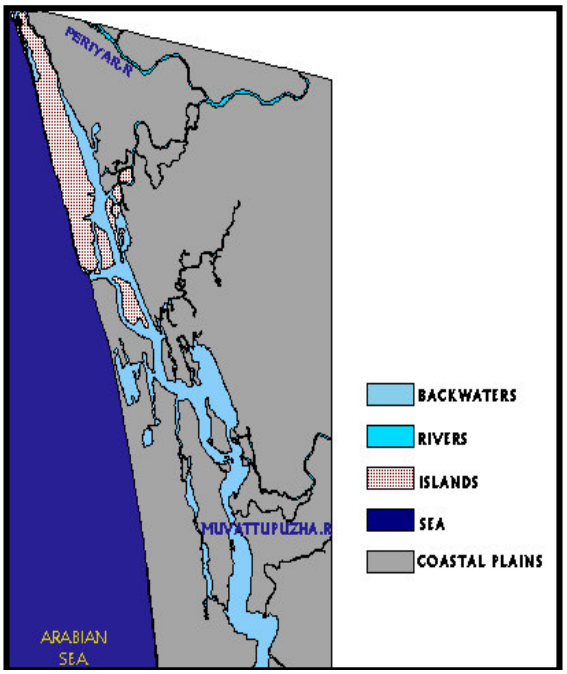

Fig. 8 - Geomorphology of Cochin Backwaters

The Cochin Backwaters is a coastal plain and topographically a low-lying area (Fig.8). It is characterised by its long axes running parallel to the coast (coastal plain formation of quarternary period) and is separated from the sea by barrier spits interrupted by tidal passes. It has a free permanent connection (Cochin gut-tidal inlet) with the sea.

It has three dredged channels namely the approach channel oriented along east-west direction of around 10 km length and 500 m width and the two inner channels located on either side of the Willington Island, i.e., Ernakulam channel of around 5 km length with a width of 250-500 m and Mattancherry channel of 3 km length with a width of around 170 - 250 m.

7. Land use/ Land cover

The area around Cochin Backwaters comprises a variety of landuse/landcover classes such as Agriculture, Aquaculture, plantations, wasteland, human settlement, etc. Agriculture is one of the major occupations in the region (Fig.9). Coconut plantation is the dominant vegetation, while paddy, red gram, groundnut; maize, millets,

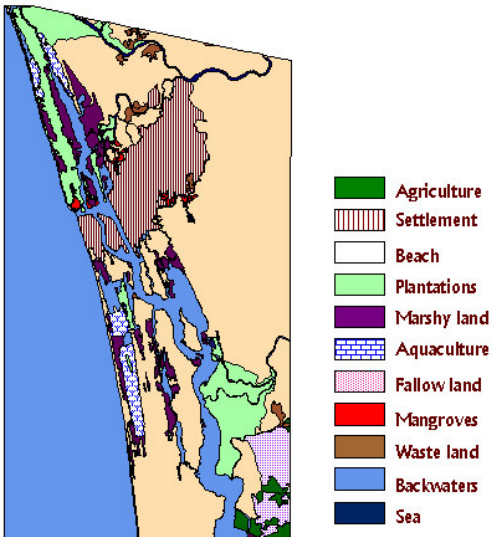

Fig. 8 – Geomorphology of Cochin Backwaters

tapioca, cereals, banana and papaya are grown successfully as intercrops. The major landuse categories as classified using IRS IC satellite imagery are tabulated below (Table-1).

Table 1 - Major Landuse/ Landcover around Cochin Backwaters

S.No	Landuse / Landcover	Area (sq. km)
1.	Backwater	132
2.	Built-Up area	133
3.	Beach	4.5
4.	Aquaculture	31
5.	Fallow Land	47
6.	Mangroves	7
7.	Settlement & Vegetation Mixed	854
8.	Agriculture (Paddy field)	4.5
9.	Agriculture (Plantation)	132
10.	Waste land	12
11.	Wetland	65

Cochin Backwater systems support intense shrimp farming activities. The traditional system of shrimp farming is carried out on paddy fields adjacent to the Vembanad lake (Pokkali fields). Cochin Backwaters has been experiencing high level of anthropogenic pressure during the last five decades. The area of backwaters in 1912 was 315 sq. km (Gopalan et al., 1983), which has shrunk to 157 sq. km by 1989 (SOI Toposheet).

As per the satellite data of 1998 the area has further reduced to 132 sq. km. vast areas have been reclaimed for harbour and urban development. The reclamation of Cochin Backwaters over the decades for various purposes (Menon et al., 2000) is given in Table 2.

Table 2 - Reclamation of the Cochin Backwaters over the decades

Period	Area reclaimed (ha)	Purpose
1834-1903	2227	Agriculture
1912-1931	5253	Agriculture
1920-1936	364	Willington Island
1941-1950	1325	Agriculture
Till 1970	5100	Paddy-cum-shrimp culture
1970-1984	800	Paddy-cum-shrimp culture
1975	6900	Bunding at Thannirmukham
1978	11	Fishing harbour
1981-1985	142	Vallarpadam-Ramanthuruthu, Candle Island
1981-1985	142	Southern extension to Willington Island
1981-1985	24	Urban development
1981-1985	12	Cochin Shipyard and tanker berth

(Source: Menon et al., 2000)

The results from the present study showing reduction in the backwaters, Vembanad lake and increase in island areas are shown in Table-3. It is evident from the table that there is a reduction in backwater areas while there is substantial increase in the island areas over a period of two decades. The difference in the total area calculated indicates that backwater area has been converted in to other land use categories.

Table 3 - Area of the Backwaters and Islands off Cochin as per SOI toposheet and IRS I C data

Sl. No.	Category	Area calculated (in sq. km)	
		Toposheet (SOI, 1981)	***Satellite data (IRS I C, LISS III) 28.1.1998***
1.	Backwaters	157.00	132.00
2.	Vypeen island	51.49	56.02
3.	Vallarpadam	2.85	4.23
4.	Bolghatty	2.61	2.34
	TOTAL	213.95	194.59

8. Physical Parameters

a. Temperature

The average atmospheric temperature ranged from 23.8°C to 34.52°C with minimum and maximum values in January and May, respectively (Table-4). The average relative humidity values varied from 77.09% in January to 93.66% in September.

b. Rainfall

The climate is typical of tropical areas. The average monthly rainfall (south- west monsoon) during 1998 ranged from 5 mm in March to 649 mm in September (Table-4) and the rainfall from the north-east monsoon was negligible.

c. Tides

Cochin estuary has a perennial connection with the Arabian Sea near the main entrance of Cochin harbour. This region is subjected to semi-diurnal tidal influence with a variation of about 1 m.

d. Currents

The maximum speed of the flood current varies from 1 to 1.5 knots, while the ebb current always has a greater intensity and during the monsoon months it varies from 2.5 to 3.5 knots (Gopinathan and Qasim, 1971).

Table 4 - Monthly variation of temperature, rainfall and humidity during 1998

Month	Temperature °C		Rainfall (mm)	Relative Humidity %
	Minimum	Maximum		
January	23.8	33.5	0	77
February	24.9	33.3	8	77
March	25.8	33.3	5	77
April	26.8	34.3	52	75
May	26.8	33.5	104	79
June	24.7	29.9	489	93
July	24.2	29.9	379	91
August	24.7	30.0	122	93
September	24.2	29.4	649	93
October	24.2	29.5	483	90
November	24.1	30.3	95	87
December	24.1	30.8	42	87

9. Hydrological Parameters

Marine water quality monitoring is required to predict changes in the quality of a particular marine environment, so that curative or preventive measures can be taken to restore and maintain the ecological balance in the habitats. Physico-chemical conditions of this estuary are controlled by freshwater drainage and precipitation during monsoon and seawater intrusion during high tide. Hydrological parameters were studied during 1998-99 July-August (Monsoon); November-December (Winter) and April-May (Pre-Monsoon) in different locations of the backwater as well as nearshore environment of Cochin.

a. Surface Water Temperature

The surface water temperature varied from 23.3° C to 31° C. While the lowest temperature was recorded in July-August, the highest temperature during April-May.

b. Salinity

The salinity in Cochin Backwaters varied between three distinct periods in a year (i) a period of low salinity (June-September), (ii) a period of gradual rise in salinity (October-January) and (iii) a period of high salinity (February to May). The salinity values recorded in the three seasons are given in Table-5.

Table 5 - Salinity values of Cochin Backwater & nearshore area (ppt)

Station	Pre-monsoon		Monsoon		Post-Monsoon	
	Surface	Bottom	Surface	Bottom	Surface	Bottom
A. Backwater Zone						
Vadakkarai	23	30	2.22	3.09	25.93	36.49
Tatapalli river	10	11	0.04	0.50	2.08	4.14
Bolghatti	4	6	3.52	4.99	18.27	18.87
Vypeen (mouth)	21	31	2.16	17.98	25.64	33.29
B.Neritic Zone						
Cochin Barmouth	26	31	13.52	18.30	20.61	35.01
Nayarambalam	33	35	15.58	18.01	31.8	32.9
Pallipuram (Barmouth Azheekodu)	30	34	12.51	18.1	30.6	32.6

The low values were observed in Backwater region and high values in neritic zone (near barmouth). During south-west monsoon, the entire Backwaters became a freshwater zone barring the barmouth. The strong river current together with the tides caused a mixing of water from the surface to bottom. In neritic zone (near barmouth) there was stratification in the surface layer with a low salinity and bottom layer with a high salinity, showing an increase in salinity with depth. From November to January, partially mixed conditions prevailed, whereas, in June it was moderately stratified to partially mixed. During the post and pre-monsoon period, the freshwater inflow decreased leading to an increase in the surface salinity.

c. pH

During the study period pH varied from 6.7 to 8.3 during monsoon, 6.5 -8.6 during post-monsoon and 6.7 – 8.1 during pre-monsoon. Higher pH values were observed in the neritic zone, while lower values were encountered in stations located near the freshwater zones.

d. Dissolved Oxygen (DO)

DO in the surface waters varied from 3.9 to 5.27 mg/l in pre-monsoon, 3.59 to 5.39 mg/l during monsoon, and 3.44 to 5.59 mg/l during post-monsoon. Seasonal and station-wise, DO values are given in Table-6.

Table 6 – Dissolved Oxygen in Cochin Backwaters and its near shore waters (mg/l)

Station	Pre-monsoon	Monsoon	Post-monsoon
	Surface	Surface	Surface
A. Backwater zone			
Vadakkarai	4.71	3.59	5.59
Tatapalli river	5.27	5.39	5.16
Bolghatti	4.6	4.37	4.95
Vypeen (mouth)	4.88	4.11	4.73
B. Neritic zone			
Cochin Barmouth	3.90	5.39	3.44
Nayarambalam	4.6	4.62	5.16
Pallipuram (Barmouth Azheekodu)	4.42	4.62	4.73

The low values recorded could mainly be due to retting of coconut husk in nearshore as well as Backwater areas.

e. Suspended Sediment Concentration (mg/l)

Suspended sediment concentration in the Cochin Backwater varied considerably with tides and seasons. The tides are of a mixed type, predominantly semidiurnal (Qasim and Gopinathan, 1969). The suspended sediment concentration values are given in Table-7.

Table 7 - Suspended Sediment Concentration in Cochin Backwaters and its near shore waters (mg/l)

Station	Pre-monsoon		Monsoon		Post-monsoon	
	Surface	Bottom	Surface	Bottom	Surface	Bottom
A. Backwater Zone						
Vadakkarai	14.38	31.39	16.90	44.2	10.50	20.48
Tatapalli river	13.52	28.64	25.00	56.7	9.68	30.31
Bolghatti	3.30	39.03	29.30	70.5	17.43	33.00
Vypeen(mouth)	35.16	107.40	18.10	900.1	11.00	31.24
B.Neritic Zone						
Cochin Barmouth	27.90	31.20	13.30	159.0	12.00	71.90
Nayarambalam	41.02	61.05	21.98	671.1	8.12	72.16
Pallipuram (Barmouth Azheekodu)	14.66	26.56	17.50	21.8	12.84	57.31

The maximum suspended sediment concentration was observed in the bottom samples collected during the monsoon period, but this quantity decline progressively during the post-monsoon and pre-monsoon months. Short-term changes induced by the tidal currents are quite large and during the pre-monsoon and post-monsoon months the total material transported from sea into the backwater amounts to approximately 900 tonnes/day (Gopinathan and Qasim, 1971).

f. Nutrients

Nutrients, covering nitrates, nitrites, phosphates and Silicates of Cochin Backwaters and near shore environment were studied during 1998-99 and the results are presented as under:

i. Nitrate

Nitrate content in water varied from 0.80 to 7.86 μmol/l in monsoon, 0.92 to 19.16 μmol/l in post-monsoon and 5.25 to 11.8 μmol/l in pre-monsoon. The concentration of nitrate was high in estuarine zone compared to neritic environment due to freshwater input in the backwater region.

ii. Nitrite

The nitrite concentration ranged from 0.20 to 1.63 μmol/l in pre-monsoon, 0.07 to 0.4 μmol/l in post-monsoon and 0.14 to 1.27 μmol/l in monsoon season.

iii Phosphate

Phosphate content varied from 1.02 to 4.92 μmol/l in pre-monsoon, 0.44 to 3.29 μmol/l in post-monsoon and 1.84 to 17.7 μmol/l in monsoon season.

iv Silicate

Silicate content varied from 62.87 to 410.78 μmol/l in pre-monsoon, 5.7 – 51.0 μmol/l in post-monsoon and 139.6 to 717.4 μmol/l in monsoon period

The concentration of nitrate, nitrite, phosphate and silicate exhibited pronounced seasonal variation and also indicated large inputs from industrial units, sewage waste and agricultural run offs. On the northern parts of the estuary high nutrient values recorded during monsoon suggests the presence of an external input source.

g. Petroleum Hydrocarbons (PHC)

Petroleum hydrocarbons value (Table 8) recorded in the Cochin Backwaters ranged from 0.09 to 70.23 gm/l in monsoon and 6.65 to 17.9 gm/l in the post-monsoon season. The maximum values were recorded during monsoon at the barmouths of Cochin (42.92 gm/l) and Azheekodu region (70.23 gm/l). This is associated with shipping, fishing vessel operation, transportation, urban run-off and accidental spillage during tanker operations etc.

Table 8 - Petroleum Hydrocarbons in Cochin Backwaters (gm/l)

S.No.	Station	Monsoon	Post-monsoon
1	Vadakkarai	0.93	6.65
2	Bolghatti	2.83	12.9
3	Barmouth (Cochin)	42.92	17.9
4	Pallipuram (Bar mouth of Azheekodu)	70.23	1.75

h. Trace Metals

Many hazardous substances including heavy metals, discharged into the aquatic environment are known to accumulate in the estuarine sediment. In the present study, it was observed that Cu, Fe, Cd, Zn were high in Vadakkarai (near Periyar mouth) compared to other stations. The heavy metal values were Cu 4.75 mg/l, Fe 56.5 mg/l, Cd 7.5 mg/l and Zn 11.65 mg/l. Venugopal et al., (1982) reported that the level of Cu, Mn, Co, Ni and Zn were high in the northern part of Cochin Backwaters, which runs through an industrial belt.

i. Water Quality in Cochin Backwaters – a comparison

As per the Environmental (Protection) Act, 1985 (29 of 1986), the Cochin Backwaters have been classified under the "Ecologically Sensitive Zone. In the following table (Table - 9) the water quality of Cochin Backwaters is compared against the standards set for the SW-I waters by Ministry of Environment and Forests (MoEF, 1998).

Table 9 - Water Quality in Cochin Backwaters – a comparison

Sl. No	Hydrological Parameters	Standards set by MoEF	In Cochin Backwaters	Remarks
1.	PH Range	6.5 – 8.5	6.5 – 8.6	Within permissible limits
2.	Dissolved Oxygen	3.5 – 5.0 mg/l	3.44 to 5.59 mg/l	Within permissible limits
3.	Suspended Solids	None from sewage and industrial effluents	3.3 – 35.16 mg/l	High values observed due to Sedimentation, discharge of sewage and industrial effluents predominantly in the Cochin Barmouth area
4.	Lead	0.01 μg/l	0.008 μg/l	Very high values observed in the Cochin Harbour area
5.	Cadmium	0.01 μg/l	1.26 μg/l	Very high values observed in the Cochin Harbour area

The notification (1998) issued under Environment (Protection) Act 1985 (29 of 1986) envisages the Ecologically sensitive zone should be safe and relatively free from hazardous chemicals like pesticides, heavy metals and radionuclide concentration. However, high values of heavy metals concentration, sewage disposal and petroleum hydrocarbons have been recorded in the Cochin bar mouth areas. This high pollution level will affect the sustainable development of the resources in the Cochin Backwaters.

10. Biodiversity of Cochin Backwaters

Biodiversity – review of literature

Cochin Backwaters support diverse species of flora and fauna. Earlier studies on phytoplankton, zooplankton, benthos and fishes in Cochin Backwaters were reported by various authors as given in the Table-10.

Table 10 - Review of Literature on the Biodiversity of Cochin Backwaters

Sl. No.	Groups	Authors
1.	Phytoplankton	George, 1958 a,b; Devassy and Bhattathiri, 1974; Gopinathan, 1972 & 1975;Joseph and Pillai, 1975; Kumaran and Rao, 1975.
2.	Zooplankton	Abraham, 1970 a,b; Madhuprathap et. al., 1975; Menon et. al; 1972;Nair et.al., 1972; Pillai, 1970; Pillai et al., 1973; Silas and Pillai, 1975;Tranter et al., 1971; Wellershaus, 1974
3.	Foraminiferans	Antony, 1968 and 1980
4.	Cnidaria	Santhakumari and Vannucci, 1972; Vannucci et al., 1970
5.	Polychaetes	George, 1958a, Cherian, 1959
6.	Siphonophores	Rangarajan, 1974
7.	Bryozoans	Menon and Nair, 1971
8.	Chaetognaths	Nair, 1972; Srinivasan, 1972
9.	Benthos	Damodaran, 1973; Pillai, 1977;Sunilkumar, 1981
10.	Crustaceans	Rao, 1968, Cherian, 1977
11.	Molluscs	Kuriakose, 1980;Achary, 1987; Nair and Saraswathi, 1971;Mohan, 1979;Nair, 1994;Nair, 1985;Kripa, 1997
12.	Tunicates	Pillai and Pillai, 1973
13.	Fishes	Kurup and Samuel, 1985a, 1985b, 1987.Kurup et. Al, 1990c.

Totally 685 species of flora and fauna comprising 194 species of Phytoplankton, 135 species of zooplankton, 199 species of benthos, 150 species of fishes and 7 species of mangroves were recorded between 1958 and 1997 (Table –11).

Table 11 - Status of Biodiversity of Cochin Backwaters

Sl. No.	Group	No. of species recorded (1958-1997)
I.	**PHYTOPLANKTON** (Bacillariophyceae, Dinoflagellates, Cyanophyceae, Chlorophyceae, Filamentous algae)	194
II.	**ZOOPLANKTON**	
1.	Coelenterata	
	(i) Hydromedusae	32
	(ii) Scyphomedusae	1
	(iii) Ctenophora	1
	(iv) Siphonophora	5
2.	Cladocera	4
3.	Copepoda	47
4.	Ostracoda	7

Sl. No.	Group	No. of species recorded (1958-1997)
5.	Mysidacea	2
6.	Cumacea	2
7.	Tanaidacea	2
8.	Isopoda	1
9.	Amphipoda	7
10.	Decapoda	16
11.	Chaetognatha	5
12.	Tunicata	1
13.	Molluscan larvae	2
III.	**BENTHOS**	
1.	Foraminifera	52
2.	Coelenterata	6
3.	Polychaeta	64
4.	Crustacea	48
5.	Mollusca	29
IV.	**PISCES**	**150**
V.	**MANGROVES**	**7**
	TOTAL	**685**

(Source : Earlier reports as indicated in Table-10)

a. Phytoplankton

Cochin Backwaters is one of the most productive estuarine systems in the tropical environment with an estimated annual gross production of nearly 300 g c/m^2/day (Qasim and Gopinathan, 1969). In the present study maximum gross production observed was 53.6 g c/m^2/day during post-monsoon period. Kumaran and Rao (1975) listed 88 species of diatoms among which 20 species are common in the present study and have pronounced seasonal variation. Sreekumar and Joseph (1995a) estimated that a periphytic alga of the Cochin Backwaters comprises 66 species of Bacillariophyceae, 8 species of Chlorophyceae and two species of Cyanophyceae.

In the current study (1998-99), 123 species of phytoplankton were recorded, comprising 89 species of Bacillariophyceae, 31 species of Dinophyceae, 2 species of Chlorophyceae and one species of Cyanophyceae (Fig.11). The density of phytoplankton varied from 33 to 10275 cells/l in estuary and 34 to 395 cells/l in neritic zone. Sreekumar and Joseph (1995b) found that the average periphytic concentration was low during monsoon (14554 cells/m^3) and dominated by freshwater forms, while highest periphytic concentration was during post-monsoon (15, 332 cells/m^3). The abundance of species diversity of phytoplankton is varied in estuarine and neritic regions.The dominant species are *Asterionella japonica*, *Bacteriastum delicatalum, B.elongatum, B. hyalinum, Biddulphia mobiliensis, Pleurosigma sp, Thalassiosira sp, Chaetoceros, Coscinodiscus, Dinophysis, Fragilaria, Noctiluca, Oscillatoria, Pediastrum* and *Volvox*.

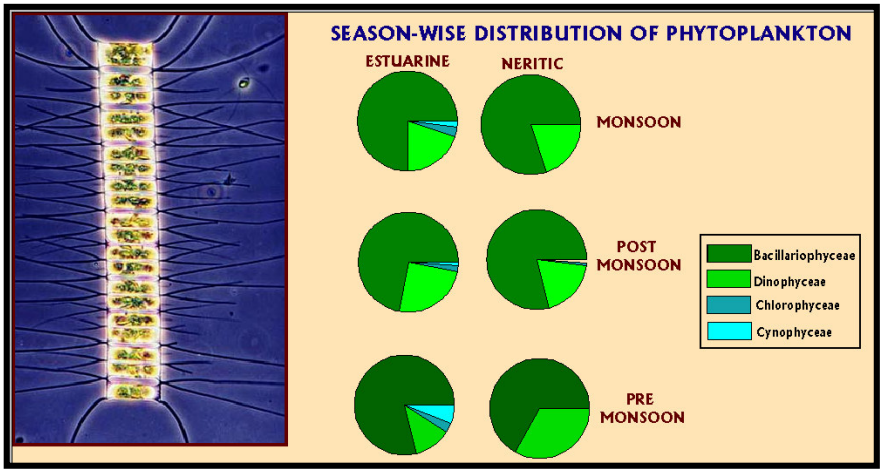

Fig. 11 - Distribution of phytoplankton in Cochin Backwaters

During pre-monsoon, the phytoplankton production in the estuary was high and fairly stable with the dominant diatoms being *Chaetoceros, Coscinodiscus, Skeletonema, Pleurosigma, Nitzschia* and *Dinoflagellates* of the genera *Peridinium, Noctiluca* and *Ceratium*. During monsoon the flora was mostly freshwater species of the genera *Pedorina, Volvox, Pediastrum* and *Desmedium*. During post-monsoon gradually the freshwater species disappear coinciding with the predominance of marine forms. Kumaran and Rao (1975) stated that most of the species recorded in the Cochin Backwaters were marine forms and the area near the barmouth was the most productive one and that the conditions immediately after or following a break in the monsoon are favourable for the sudden spurts in plankton abundance.

b. Zooplankton

In the present study (1998-99), 24 species of zooplankton were recorded, comprising 14 species of Calanoida, 2 species of Cladocera, 3 species of Cyclopoida, one species each of Amphipoda, Aphragmophora, Cydippida, Decapoda, and Myodocopina. The copepods constitute one of the dominant taxa of zooplankton (Fig.12).

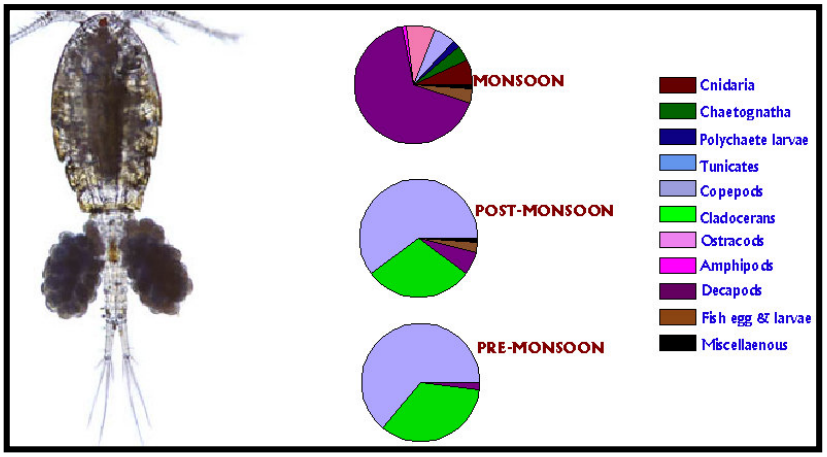

Fig. 12 - Seasonal quantitative distribution of Zooplankton in Cochin Backwaters

Both diversity and abundance of the zooplankton were high during pre-monsoon and post-monsoon season. Quantitative distribution of zooplankton (in %) is given in Table 12. The dominant species of copepods are *Sapphirna, Eucalanus, Acartia, Acrocalanus, Classocalanus, Oithona, Pseudodiaptomus, Paracalanus* and *Limura sp*. In the earlier studies , 49 species of copepods belonging to 22 genera were observed by Madhupratap (1977) in the Backwaters. According to Madhupratap and Rao(1979) salinity and tidal variations are important factors in deciding the distribution of Zooplankton in the Cochin Backwater.

Table 12 - Quantitative distribution of Zooplankton (in %)

Sl. No.	Groups	Pre-Monsoon	Monsoon	Post-Monsoon
1	Cnidaria	0.07	6.68	-
2	Chaetognatha	0.14	4.33	0.25
3	Polychaete larvae	0.02	1.57	0.02
4	Tunicates	0.006	-	-
5	Copepods	63.81	5.9	60.19
6	Cladocera	33.95	-	29.52
7	Ostracods	-	8.27	-
8	Amphipods	0.003	0.78	0.03
9	Decapods	1.65	67.38	6.08
10	Fish eggs & larvae	0.34	3.54	3.41
11	Miscellaenous	0.02	1.55	0.49

In the barmouth region, *Muggiacea* sp (Cnidaria), *Sagitta* (Chaetognatha) and *Doliolum* were the dominant groups observed during monsoon season, but in the estuary, *Pleurobranchia (Cnidaria), Saphirina, Eucalanus (Copepod)* and crab larvae were the most dominant groups in the monsoon season.

c. Benthos

In the present study (1998-99), 24 species of benthic organisms were recorded in estuarine and neritic zones of Cochin Backwaters. The qualitative distribution of macrobenthos is given in Table - 13.

Table 13 - Distribution of Benthic fauna in Cochin Backwaters

Groups	Pre-Monsoon		Monsoon		Post-Monsoon		Over all
	Estuarine	Neritic	Estuarine	Neritic	Estuarine	Neritic	
Crustacea	3	1	4	-	2	-	5
Polychaeta	9	10	9	9	7	5	16
Bivalves	1	2	-	1	-	-	2
Echinoidea	1	-	-	-	-	-	1

Macrobenthos distribution and composition, numerical abundance, species diversity, biomass and its relation to hydrography were studied in detail by Batcha (1984). He identified a total of 92 species, of which 33 were polychaetes, 28 crustaceans and 15 molluscs. The nature of substratum is another important factor in the distribution of macrofauna where clay bottom (organic matter (1.5-6%) supports poor fauna, whereas areas with sand, silt and clay in equal proportions support dense and diverse benthic populations (Batcha, 1984).

11. Fishery Resources

The icthyofauna of the Cochin Backwaters in comparison with those of other brackishwater lakes and estuaries of India is richer and more diversified.

Totally 150 species of fishes belonging to 100 genes under 56 families were identified from Cochin Backwater areas. The species, which inhabit the different zones of the estuary are oligohaline fishes (23 species) and truly estuarine fishes (38 species).

Kurup and Samuel (1987) observed 89 species of marine fishes, of which 41 species were euryhaline and 48 species were stenohaline, which regularly migrate from inshore areas of Arabian sea to the lake or vice versa depending on the conditions prevailing in the Backwaters . The regular occurrence of marine migratory fishes starts by the beginning of the post-monsoon period and the fishes flourish in the mouth and lower reaches of the estuary and constitutes a thriving fishery.

During the study period finfish and shellfish resources at various landing centres were noted during February - March 1999 (Table 14).

Table-14: Fishery Resources as recorded from the landing centres

(Catches in Kg)

Landing Centres	Group	February 1999	March 1999
Murikumpadam	Finfish	2682	3376
	Crustaceans (Shrimps & Crabs)	1042	6963
	Molluscs (Squid and Cuttle fish)	290	303
Munampam	Finfish	9803	10905
	Crustaceans (Shrimps & Crabs)	582	1342
	Molluscs (Squid and Cuttle fish))	1985	2152

a. Shrimp Resources

Fig. 13 - *Penaeus monodon*

Shrimps form a major constituent of the marine fish landing in India. Of this, a majority of penaeid shrimp is harvested from the Kerala coast. In the estuarine and backwaters of Kerala, *M.dobsoni* is the dominant species contributing to the capture as well as the traditional culture fisheries.

The following species of shrimps are common. They are *Metapenaeus dobsoni, M. affinis, M. monoceros, Penaeus indicus, P.semisulcatus, P.monodon* (Fig.13), *P. canaliculatus, Acetes indicus and A.erythraeus.*

b. Crab Resources

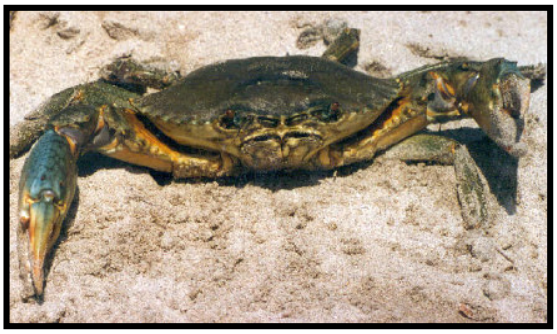

Fig. 14 - *Scylla serrata (mud crabs)*

Cochin Backwaters also support rich crab fisheries. The economically important species are *Scylla serrata (mud crabs*) (Fig.14), *Portunus pelagicus and P.sanguinolentus*, which constitute 4% of the exploited fishery resources of Cochin Backwaters yielding an annual production of 25.5, 22.01 and 10.5 tonnes, respectively. Crabs are obtained as by-catch in shore seines, boat seines, gill nets, cast nets, drag nets and stake nets used for finfishes.

c. Clam Fishery

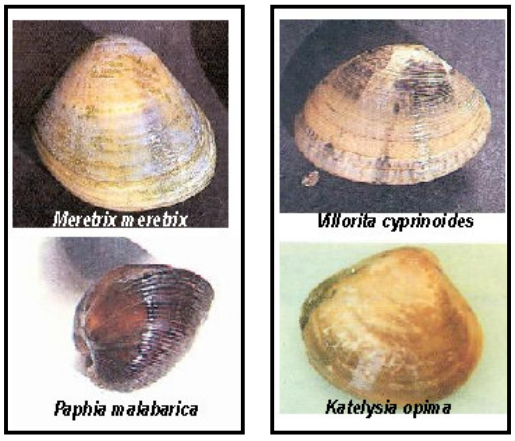

Fig. 15 - Clams of Cochin Backwater

The molluscan fishery of the Cochin Backwaters is exclusively sustained by the black-clam *Villorita cyprinoides* (Kurup et al, 1990c). The dominant species like *Villorita cyprinoides, V.cyprinoides var Cochinnensis, V.cyprinoides var delicatula, V.cornulopia, Meretrix meretrix, M.casta var ovum* and *Paphia malabarica* (Fig.15) are distributed

in the Cochin Backwaters. The peak clam landing is registered during the months of May and October. The exploited clam resources show a declining trend over the years; average annual live clam production decreased from 26,858 tonnes in 1968 (Rasalam and Sebastian, 1976) to 21.490 tonnes (Achary, 1987) and subsequently to a low value of 7203 tonnes in 1990 (Kurup et al, 1990c). This is attributed to the increased and indiscriminate fishing practices resulting in disturbances in spat settlement, mass removal of the undersized clams, and pollution hazards from coconut husk retting grounds and industrial pollutants.

12. Fishing Gear

Fishing in the Cochin Backwaters uses an incredibly complex array of fishing gears. Different terminologies are used for the same type of nets in different sectors of the lake. The operation of different types of gear starts from post-monsoon season and attains its peak during the pre-monsoon season. With the onset of monsoon, the fishing activity seems to be reduced due to the prolific spreading of *Salvennia auriculata* and *Eicchornia crassipes*.

Stake nets and dipnets (Fig.16) accounted for 73% of the total landings. The contribution from gill nets, seines, cast nets, line fishing and other indigenous fishing methods are 10%, 4% and 2%, respectively. Stake nets and dip nets are almost confined to the northern sector (Cochin estuary). The major part of the landings is obtained from gill nets (34%), seines (25%) and cast nets (19%).

Fig. 16 - Chinese dipnet

13. Mangroves

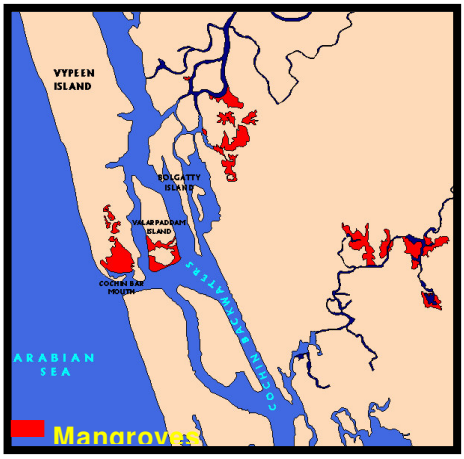

Fig. 17 - Mangroves distribution along Cochin Backwaters

Mangroves are found in Cochin, Vembanad, Quilon, Trivandrum, Cannanore, Kozhikode and Kottayam covering an area of 16 sq.km. (Banerjee & Ghosh, 1998), of which 6.9 sq.km is found in and around the Cochin Backwater region.

Mangrove species occur sparsely on the islands of Vypeen, Vallarpadam, Bolghatty and Thanthonnai (Fig.17). The dominant mangrove species in Cochin Backwaters are *Avicennia marina A.officinalis, Exoecaria agallocha, Clerodentron, Aegiceras corniculatum, Rhizopora appiculata* and *Acanthus ilicifolius*.

14. Major threats to Cochin Backwaters

Cochin Backwater has been experiencing high levels of anthropogenic pressure during the last five decades (Menon et al., 2000). Reclamation of land for harbour and urban development, intensive exploitation of resources, discharge of untreated or partially treated sewage and industrial effluents and siltation are major threats on this sensitive ecosystem.

a. Reclamation

Fig. 18 - Reclamation activities in Cochin Backwater

The Cochin Backwaters have been shrinking because of natural causes and human intervention. The human interventions are in the form of organised reclamation of low lands by filling and construction for varied uses (Fig.18).

b. Thannirmukham bund

A major human intervention was the construction of a 1.441 km long bund in 1976 at Thannirmukham (Fig.19) to prevent salt water intrusion in the cultivated lands of Kuttanad region. The southern region of the estuary which supported a good fin and shellfish resources has become devoid of these resources after the construction of Thannirmukham bund.

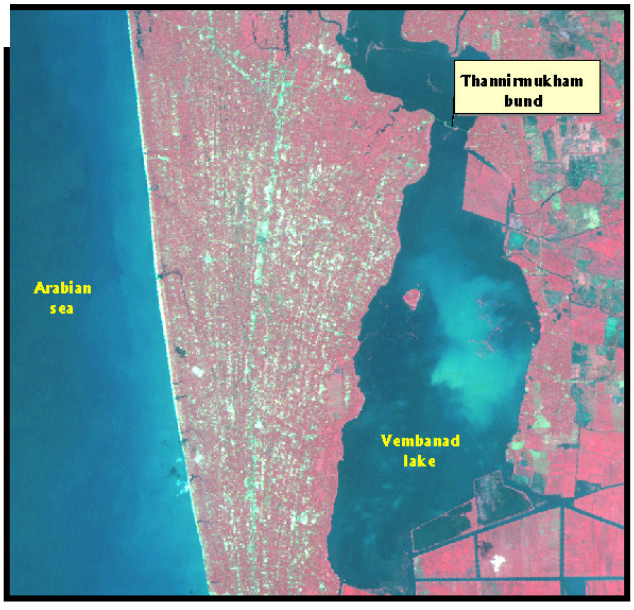

Fig. 19 - Thannirmukham bund

Siltation is a major factor contributing to the progressive shallowing of Backwaters. The process of siltation occuring as a result of river discharge and tidal inflow has been accelerated by man-made alterations such as deforestation, construction of dams, reservoirs and barriers.

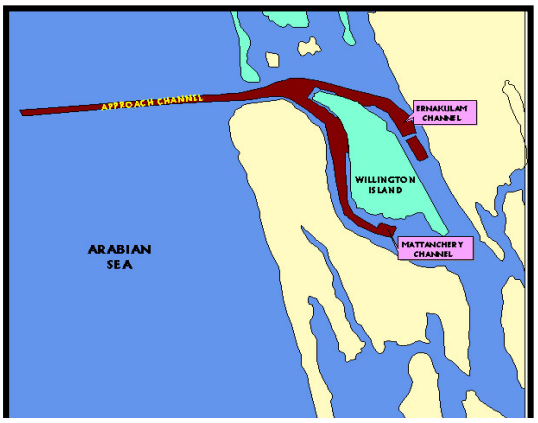

Fig. 20 - Channels in Cochin Backwaters

The magnitude of siltation in the Cochin Backwater is reflected in the removal of silt by dredging every year in order to maintain the shipping channel at Cochin harbour. The average amount of dredged materials removed from the Mattanchery and Ernakulam channels comes upto 3.61×10^6 m^3 (Rasheed 1997). Sediment accumulation rate in the estuarine and mangrove areas of the Cochin Backwater is 3-6 times higher than that in the adjacent inner-shelf area (Manjunatha et al, 1998). The rate of siltation is high during monsoon season and the bed of approach channel rises to 1.2 - 1.8 m every year.

d. Sewage Disposal

The population density in Cochin metropolitan area was 3281 persons per sq. km in 1991. The population explosion in and around Cochin contributes to the outflow of enormous amount of sewage effluents in to the Backwater. Total dissolved solids in the estuary are as high as 53750 mg/l during summer, but lowering drastically to 160 mg/l during the rainy season. Highest density of total coliforms and faecal coliforms was noted at the station near Cochin bar mouth region.

e. Pollution due to coconut husk retting activities

Retting of coconut husk is the basic process involved in the production of coir and coir based products, which is one of the most popular traditional occupations in the coastal areas of Kerala. Coconut husk retting is considered as one of the important sources of pollution in the Cochin Backwaters. As a result of retting, large quantities of organic substances including pectin, fat, tannin and also toxic polyphenols are liberated into the ambient water by the activity of bacteria and fungi.

f. Industrial Pollutants

The volume of industrial effluents produced in the Eloor-Kalamassery industrial belt is about 260 million litre per day much of which is directly discharged into the periyar river from where it enters the Backwaters. Major chemical pollutants present in these waters are acids, alkaline, suspended solids, fluorides, free ammonia, ammoniacal nitrogen, insecticides, dyes, chromium, Hg, Zn, other metals and unknown quantity of radio active materials (Thorium and Uranium) (Stephen, 1985). Ambalamugal, 16 km east of Cochin has also been developed into an industrial complex with establishment of a giant fertilizer plant and an oil refinery. The water and effluents from these factories are also dumped into the Periyar river at certain locations. Many hazardous substances including heavy metals discharged into the aquatic environment are known to accumulate in the estuarine sediments. It affects the productivity and larval resources of this environment. The impact of these industrial effluents is felt in the estuary in the form of mass mortality of fish *Ambassis gymnocephalus* as reported by Unnithan et al (1977).

g. Over-exploitation of Resources

- Increased and indiscriminate fishing practices resulting in disturbances of spat settlement of clams.
- Mass removal of the undersized clams. Near Bolgatty island large quantities of juvenile clams are collected and marketed. Fishing out the undersized clams is uneconomical and may be detrimental for the propagation of the species.
- Mass collection of shrimp seed for aquaculture practices, affects the sustainable shrimp fishery in these waters.

15. Recommendation for Resource Management

For conservation and management of the habitat and sustainable development of resources, the following are recommended :

1) Strict enforcement of the fisheries regulation to cover the seasonal and mesh size restrictions.

2) To regulate and monitor industrial pollution in Periyar river bed.

3) To ban the collection of natural shrimp seed and undersized clams.

4) Sea ranching of commercially threatened species like clams and shrimp for sustainable utilisation.

5) Conducting training and awareness programmes to coastal communities for community based resource management.

6) To update the fishery regulation from time to time based open precautionary and sustainability principals.

7) To control the reclamation and landuse activities as well as sewage disposal in and around the Backwater region.

8) To regulate and monitor coconut husk retting activities in the Cochin Backwater areas.

16. Conclusion

Studies showed that there is a decline in the Backwater area and floral and faunal diversity due to anthropogenic and increased human activities like construction of dams, barriers, reclamation etc. However, long term studies on shore line changes, bathymetry, biodiversity, etc., need to be carried out using effective standard methodology to supplement the basic information provided in the information system. This information system developed using Remote Sensing and GIS has demonstrated that these scientific tools could be effectively used for assessing the status of the critical habitats with respect to their ecology and biology and biodiversity monitoring and management of coastal resources of the Cochin Backwaters. The report forms a base line information to monitor the impact of developmental activities in the Cochin backwater.

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