ENVIRONMENT MANAGEMENT CAPACITY BUILDING

Coastal and Marine Area Management Component
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CRITICAL HABITAT INFORMATION SYSTEM USING GIS FOR PICHAVARAM MANGROVES SOUTH INDIA

Government of India
Department of Ocean Development

Integrated Coastal and Marine Area Management
Project Directorate, Chennai

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About the Activity

India has a long coastline of about 7500 km including its island territories, which consists of a variety of coastal habitats (areas) such as estuaries, mangroves, coral reefs, etc. These coastal areas and areas of endangered animals are considered as "critical habitats" as they are unique, fragile and exhibit high biodiversity supporting several coastal and marine plants and animals. By virtue of these habitats located in coastal areas, their high productivity and the services they offer, they are subjected to ecological pressure due to natural processes and human interventions.

The combined pressure of natural processes and human activities cause changes in these critical habitats leading to deterioration and/or loss of these areas over the years. The Agenda 21 adopted in United Nations Conference on Environment and Development (UNCED-1992) emphasises the need for protection of coastal and marine environment. The Department of Ocean Development (DOD) has been designated as the nodal department to deal with Chapter 17 of Agenda 21 covering the oceans, seas, semi-enclosed water bodies and estuaries.

There is a need to protect these productive areas ("critical habitats") from natural and human interventions while ensuring sustainable, rational utilisation of their resources and services. Therefore, the Department of Ocean Development decided to undertake capacity building exercises and formulated a programme namely, "Integrated Coastal and Marine Area Management (ICMAM)" with assistance from the World Bank. A Project Directorate was established in Chennai to carry out the ICMAM activities.

One of the activities identified for capacity building is "Development of Critical Habitat Information System (CHIS) using GIS" for 11 critical habitats along the Indian coast, comprising habitats such as mangroves, coral reefs, breeding habitats of endangered organisms, areas of high biodiversity, etc. The 11 sites chosen are Gulf of Kachchh and Gulf of Khambhat in Gujarat, Malvan in Maharashtra, 7 islands off Karwar in Karnataka, 3 islands of Cochin in Kerala, Kadamat island in Lakshadweep UT, Gulf of Mannar and Pitchavaram in Tamilnadu, Coringa in Andhra Pradesh, Gahirmatha in Orissa and Sunderbans in West Bengal.

This CHIS developed for Pichavaram comprises spatial data base derived from maps, satellite data and non-spatial database collected from various sources and field data. The CHIS is useful as a model for decision makers to plan the management actions. It also serves as a baseline database, which could be used for periodic monitoring of the mangrove

ecosystem. It can also be used as a training module for the students, researchers and administrators to explore the capability of recent techniques such as remote sensing and GIS.

The Mangroves

Mangroves are salt tolerant plants. They are found in tropical and subtropical coastal areas. Mangroves are of two dominant types, the riverine-type that fringes rivers (**Fig.1**) and tidal creeks and the open water type that is directly exposed to waves (Lugo and Snedaker, 1974). The former type is the most common. In India, mangroves at Pichavaram and Gulf of Mannar islands are examples of above types.

The word mangrove may be derived from Portuguese and English. 'Mangue' means tree, and 'grove' means group of trees. The vegetation in mangrove consists of many species. It may be a woody plant in the form of a tree or a shrub. The ability to live in brackish to seawater conditions varies with species.

Fig. 1 - A view of Pichavaram Mangrove

Distribution

Mangrove forests are distributed throughout the tropical and subtropical coasts of the world. They are able to grow well on shores that are sheltered from wave action. The mangroves may penetrate some distance upstream along the banks of rivers. They are particularly well developed in estuarine areas of the tropics, where they reach their greatest areal extent. Mangroves can also be present along the coral reefs and are protected from excessive wave attack by wave breaking on the fringing reefs.

Physical Conditions

Since mangroves can establish themselves only where there is no significant wave action, the first physical condition noted in the mangrove areas is that the water circulation is minimal. The lack of vigorous water circulation has significant effects. Slow water movement means that the fine sediment particles tend to settle and accumulate at the bottom. The result is an accumulation of mud, and hence, the substrate in mangroves is usually mud. Mangroves also have the ability to grow on many types of substrates, so it is not unusual to

see small islands of mangroves even on coral rock or sand. However, the extensive mangrove forests appear to flourish only on muds or fine-grained sediments.

Tide is another important physical factor. The tidal range and type of tide vary across the geographical range of the mangroves. Mangrove forests develop only in shallow water and intertidal areas and are thus strongly influenced by tides. Tidal action is important indirectly in a number of ways. Tidal action helps in excluding other competitively superior vascular plants permitting mangroves to exist and to penetrate inland. Tides transport nutrients into and export material out of mangrove forests and also aid in dispersing propagules. Finally, the action of the tides prevents soil salinities from reaching lethal levels in areas of high evaporation. Evaporation of water from soils makes them hypersaline. Hypersalinity tends to reduce the mangroves, creating barren lands. Perhaps these are the reasons as to why the mangrove communities reach their greatest development where there are large tidal fluctuations.

Full development of mangrove forests is thus found in areas of high rainfall or in areas where rivers furnish enough fresh water to preclude the development of hypersaline conditions. Tidal range is also an important factor. Wherever the tidal range is small, the intertidal zone is restricted, and formation of mangrove forests is also restricted. The most extensive forests are developed on shores that have a substantial vertical tidal range (Nybakken, 1988).

Importance

Mangroves act as a barrier against cyclonic storms, protecting the land behind. They also act as a buffer against floods, preventing soil erosion.

Mangroves trap fine sediments that are carried into the coastal zone by floodwaters, and there is a significant net export of nutrients from the mangroves into the coastal zone, which acts as a source of enrichment for the marine environment. Mangroves prevent inorganic nutrients being sunk in the sea through swift flowing terrestrial runoff and synthesise organic matter absorbing the inorganic nutrients. Hence various inorganic nutrients from the terrestrial runoff are recycled within the mangrove environment.

Leaf litter production by mangrove plants contributes largely to the organic matter available to the ecosystem. Thus the terrestrial and aquatic components of mangrove ecosystem contribute to each other enabling high productivity of the ecosystem. Due to their productive nature, they serve as nurseries for prawns, crabs, lobsters, and various fishes such

as mullet. Mangroves also shelter a number of endangered animals such as crocodile, turtle and pelican. Mangroves offer a variety of commercial utilities in the form of wood for timber and fuel, fodder for cattle and with substances of commercial value such as lignin, tannin, etc. It is scenic and an excellent place for pleasure boating.

Mangroves have been exploited by mankind for various uses, such as fishing, aquaculture and salt production, felling for timber and fuelwood, for substances of commercial importance, tourism, etc. These human interventions along with the natural forces such as waves, currents, tides, storms, rainfall, fresh water runoff, etc. have caused changes in mangrove areas worldover.

World-wide mangroves are disappearing at an alarming rate. In some developing countries about 80% of mangroves were lost in the last 20 years. The largest mangrove area occur in Indonesia (30%), Brazil (10%), Australia (8%) and Nigeria (7%), but in India only 3% of mangroves occur (Mastaller, 1996).

Mangroves in India

Mangroves occur in the coastal states and islands of India. As per 1987 data, the total mangrove area in India extended to 6740 sq.kms (Task-1). The largest extent of mangroves occur in West Bengal (Sundarbans) followed by Andaman and Nicobar Islands. Both natural forces and human interventions have caused the degradation of mangroves in India. Realising the importance of mangroves, the Government of India has taken up measures for conservation of mangrove in the country.

Conservation measures need be decided based on sound knowledge and data and information about the areas such as the coastal processes and human induced alterations, which might have caused changes over years. Conventional methods of storage and retrieval of data and information cannot be used by decision-makers to understand the various processes and factors that cause changes in the coastal areas. Therefore, a computer based Information System" capable of storing and visualising the governing processes of the coastal areas is imperative to draw up management plans.

Programmes for Integrated Management

The Department of Ocean Development, Govt. of India, has initiated a programme, namely, Integrated Coastal and Marine Area Management (ICMAM) as a capacity building exercise to make use of modern scientific tools and techniques for management of the coastal and marine environments of India. Realising the need for conservation of ecologically

sensitive critical habitats such as mangroves, coral reefs and habitats of endangered animals, a project namely "Development of GIS based Information System for Critical Habitats along Indian coast" was taken up as a part of the above programme. This information system named as "Critical Habitat Information System" aims at creation of a baseline database for the critical habitats to assess the present condition, to analyse changes over years and to suggest suitable management plans for conservation of the habitats based on the factors that cause changes.

CHIS For Pichavaram Mangrove

Pichavaram mangrove is one among the 11 sites chosen for development of Critical Habitat Information System (CHIS). Pichavaram is situated in the southeast coast of India in the Tamil Nadu State. It is located about 225 km south of Chennai, the Tamil Nadu state capital (**Fig.2**). It receives brackishwater from Vellar estuary in the north and Coleroon estuary in the south. It is connected to the Bay of Bengal on the east and receives fresh water from Uppanar river from the west (**Fig.3**).

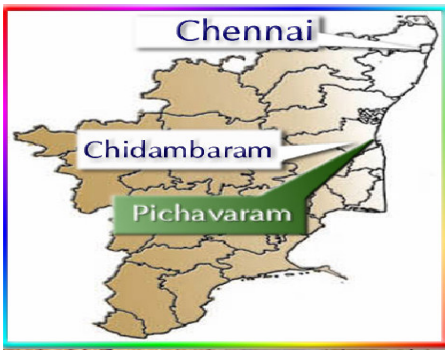


Fig. 2 - Location of Pichavaram

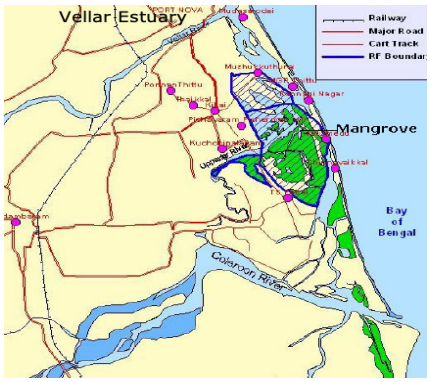


Fig. 3 - Area of Pichavaram

The Pichavaram mangrove forest was declared as Reserve Forest on 15.12.1987 with an area of about 1100 ha. The mangrove area consists of a number of small and large islets traversed by numerous creeks and canals. It is covered mostly by forest stands and the rest by mudflats, sandy areas and saline soils. Substratum is mostly muddy. Semidiurnal type of tides is characteristic in the mangrove area.

Need for CHIS for Pichavaram Mangrove

Pichavaram mangrove has been well studied for its ecology, flora, fauna, water quality, pollution, fishery resources, etc., from early 1970s. It is an ideal nursery ground for many commercially important fishes, prawns, molluscs, etc., and also attracts an appreciable number of migratory birds in seasons. It is of scenic importance attracting a number of tourists. However, over these years, degradation has occurred in many areas leading to loss

of forest area (and subsequent decline in fishery resources), due to natural and human impacts. In order to delineate the causes and areas of such degradation, to assess the present conditions of this ecosystem, and to suggest suitable management actions for conservation, this computer-based "Critical Habitat Information System (CHIS)" has been developed. This CHIS could be used by decision-makers to understand the factors that caused degradation and plan suitable management action. This CHIS will serve as a baseline data and could be updated and used for long term monitoring of Pichavaram mangrove forest cover.

The CHIS has been developed comprising spatial and nonspatial data of Pichavaram, using remote sensing, GIS and a database containing primary and secondary data. Due to synoptic and repetitive coverage, the satellite data provides information on spatial features. GIS provides capability to hold both spatial and nonspatial data from the database, as different themes or layers and enables analysis of combination of both spatial and nonspatial data and information.

Objectives

The objectives of development of CHIS for Pichavaram mangrove are:

(1) to provide a baseline data and information on the present conditions of mangrove area,
(2) to analyse changes that have occurred over the years, comparing the past data, and,
(3) to provide suitable measures including management actions for prevention of degradation, if any, based on the factors that might have caused the changes.

Methodology

Satellite data and data on various physico-chemical, biological, socio-economics were collected and analysed for the present study. Basemap was prepared for Pichavaram mangrove area using Survey of India Toposheet of 1970 (No.58 M/15) on 1:50,000 scale. The basemap was digitised using ARC/INFO and stored as a theme.

Satellite data of IRS-1D LISS III of 1998 and Landsat TM of 1987 were analysed for landuse/landcover studies using ERDAS image processing software. The False Colour Composite (FCC) of bands 3,2,1 of IRS-1D data was used to delineate the landuse/landcover features. Field checks were carried out for various features and the corrections were incorporated in the classification. Band ratioing technique was used to derive

landuse/landcover features from Landsat TM data. The landuse/landcover features derived from both the data were digitised on-screen.

The digitised landuse/landcover vector features were transferred to ARC/INFO GIS. The vector features were transformed to raster features using polygon formation and polygons were attached with polygon IDs and assigned labels such as mangrove, degraded, mudflat, etc. These raster features were brought into ArcView as landuse/landcover themes.

Data were collected on various physico-chemical and biological parameters using standard methodologies. Some of the environmental parameters studied were tidal amplitude, major water quality parameters such as salinity, pH, dissolved oxygen, nutrients, heavy metals, etc, and biological parameters such as qualitative and quantitative distribution of flora and fauna. Socio-economic data on population, literacy, dependence on fishery resources, fishing craft and gears, income, cattle population, etc., were also collected through Departmental Statistics and personal enquiries using standard procedures.

Institutions involved and their tasks

The following institutions were involved in the development of CHIS:

Institution	Task
Centre of Advanced Study in Marine Biology, Annamalai University	Collection of data on various physico-chemical, biological parameters for 3 seasons viz., June 1998, October 1998 and April 1999. Background information and data on socio-economic conditions.
Institute for Ocean Management, Anna University	Development of database incorporating the data collected. Preparation of basemap for Pichavaram using Survey of India toposheet. Development of Information System using GIS incorporating the spatial and non-spatial data.
ICMAM Project Directorate	Satellite data analysis. Analysis of data using GIS. Finalising CHIS under the management actions

Remote Sensing

Remote sensing data due to its synoptic, repetitive and multispectral nature provides a wide range of information even over inaccessible areas at frequent intervals. Remote sensing technology is an useful and cost-effective tool in coastal and marine area management. Based on remote sensing data, a variety of information such as

landuse/landcover, identification of plant communities, biomass estimation, shoreline changes, etc., could be derived and used for coastal zone monitoring and management.

The mangrove area can be well delineated through remote sensing data. It helps in monitoring the mangrove as and when required as it provides repetitive coverage of the area.

Geographic Information System

GIS is an excellent tool to store, manipulate, analyse, retrieve and to present the data in a geographical and spatial manner. It can hold both spatial and non-spatial data. GIS allows holding various information as separate themes. Overlay facility in GIS enables analysis of relationship and changes between different themes. This is a basic need to assess the extent of various landuse/landcover categories, such as mangroves, possible factors causing changes in these areas and predicting its future condition (**Fig. 4**).

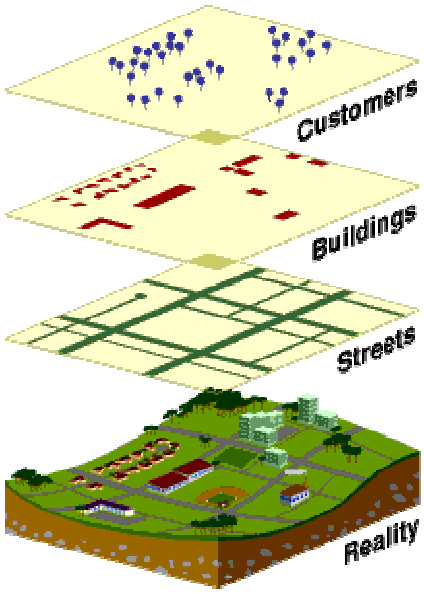


Fig. 4 - GIS as a tool showing layers

Therefore, to assess the status, to suggest suitable management plan for protection and rational utilisation of Pichavaram mangrove, a computer based information system called "Critical Habitat Information System (CHIS)" has been created using GIS and Remote Sensing.

Structure of CHIS for Pichavaram Mangrove

The CHIS for Pichavaram mangrove consists of the following information stored in GIS. The information are spatial (reference to geographic area) and non-spatial. In GIS, spatial data are referred as raster and non-spatial data as vector or point data. The structure of CHIS for Pichavaram mangrove is given in Table 1.

Table 1 - Structure of CHIS for Pichavaram Mangrove

No.	Parameters	Period	Type
Spatial Data			
1.	Basemap from toposheet	1970	Vector/Raster
2.	Satellite data of Landsat TM	1987	Raster
3.	Satellite data of IRS 1D	1998	Raster
4.	Landuse/landcover map	1987	Raster
5.	Landuse/landcover map	1998	Raster
Non-Spatial Data			
6.	Environmental Parameters (physico-chemical, biological)	1998-99 (3 seasons)	Point
7.	Socio-economics	1999	Point

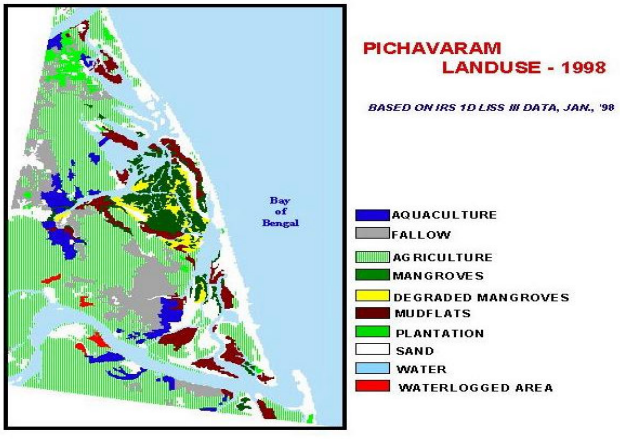
Landuse/ Landcover in Pichavaram

Landuse/ landcover of Pichavaram mangrove and surrounding area might play an important role in causing impact on the mangroves. These aspects were analysed using IRS-1D January 1998 satellite data coupled with ground check. The dark red colour indicates healthy mangroves. Degraded areas can be seen within mangroves and in the periphery (**Fig. 5**).

The analysis of IRS 1D satellite data revealed various landuse/ landcover categories such as mangroves, degraded mangroves, mudflats, fallow land, sandy areas, agriculture areas, aquaculture ponds, etc. It is observed that agriculture is a major practice in the mainland near mangrove area. Aquaculture areas are also seen, but are located little away from mangroves. The deep red colour in Satellite image and green colour in GIS indicated healthy mangroves (**Fig. 6**).

IRS 1D image 1998

Fig. 5 - Satellite imagery of Pichavaram



Landuse map 1998

Fig. 6 - Landuse derived from satellite data displayed in GIS

Field photographs show well-developed mangroves (**Fig. 7**) and degraded areas (**Fig. 8**).

Fig. 7 - Well developed mangrove

Fig. 8 - Degraded mangrove area

Application of GIS

GIS in association with Remote Sensing and field data helps in analysis of the areal extent of mangrove forests over the years. It helps in calculating the areas of various landcover features such as dense mangroves, degraded / rejuvenated, etc. A comparison of status of mangroves over the years has been demonstrated using GIS.

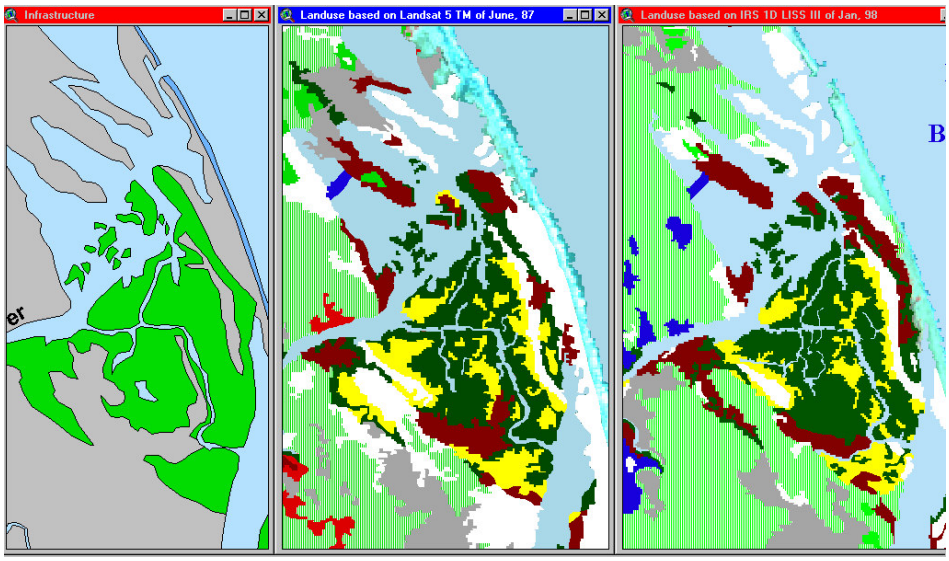


Fig. 9 - Comparison of distribution of mangroves during 1970,1987 and 1998

The 1970 toposheet of the Pichavaram mangrove area and landuse/landcover maps derived from satellite data of 1987 and 1998 were compared to analyse changes that have occurred. Changes in the various landuse/landcover categories such as mangrove, degraded mangrove, mudflats, agricultural area, aquaculture farms, etc., have been observed in the mangrove and surrounding areas (**Fig. 9**).

Using the GIS, areas of healthy mangrove during 1987 and 1998 have been estimated as 398 and 411 ha respectively (**Fig. 10**). GIS allows overlay of maps and estimate the changes that have occurred among the various landuse/landcover categories. Overlay of 1987 and 1998 landuse/landcover maps revealed changes in landcover over 10 years (**Fig. 11**). Details of conversion are discussed below.

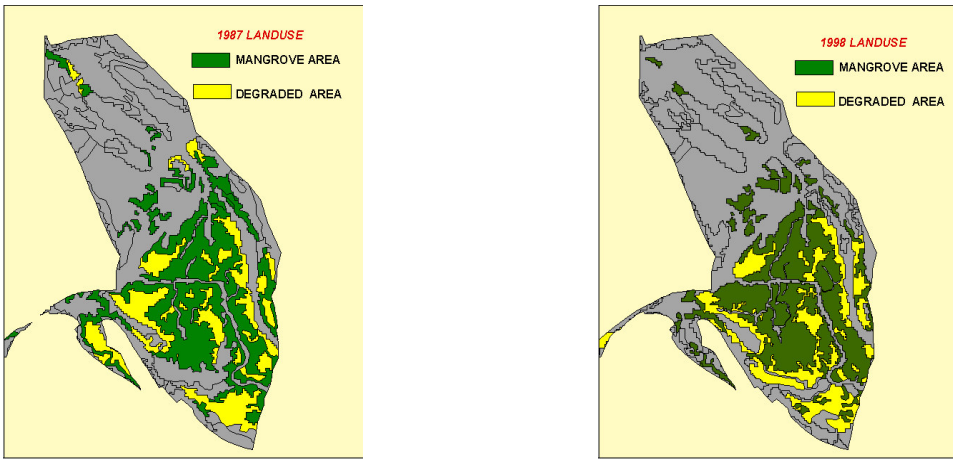


Fig. 10 - Healthy and Degraded Mangrove area during 1987 and 1998

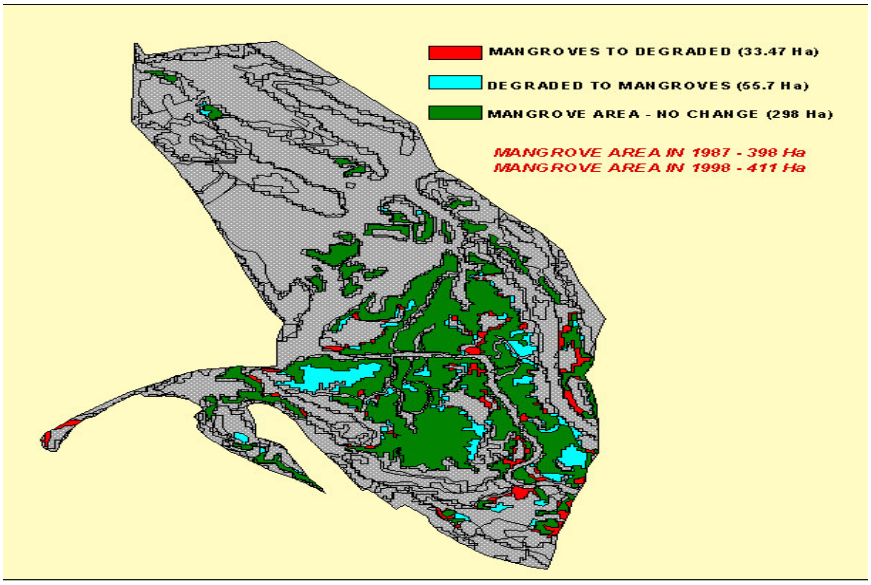


Fig. 11 - Overlay of mangrove area during 1987 and 1998

Comparison of 1987 and 1998 landuse cover maps reveal that changes have occurred in both ways viz., (1) healthy mangroves to degraded and mudflats, and (2) degraded and mudflats to healthy mangroves. This means that both degradation and rejuvenation have taken place during these years. Marginal changes have been observed in the mudflat, degraded and mangrove areas. Degraded mangrove areas are less in 1998 than in 1987 indicating increase in mangrove area. However a marginal gain in mangrove area is observed over a 10-year period between 1987 and 1998.

Some of the major changes that have occurred are listed below.

MANGROVE	[1987)	TO DEGRADED [1998]	-	33 ha
DEGRADED	[1987)	TO MANGROVE [1998)	-	58 ha
MANGROVE	[1987]	TO MUDFLAT [1998]	-	29 ha
MUDFLAT	[1987]	TO MANGROVE [1998]	-	24 ha

The gain in mangroves is due to afforestation measures and degradation is due to other factors which are discussed in the later part of this report.

Status of Biodiversity

Biodiversity is 'the variability among living organisms from all sources including *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species and between species. Though the term 'biodiversity' refers to calculate the number of species and their abundance as an 'index', this terminology is used in general to indicate the number of species of plants and animals that have been observed in the environment.

In Pichavaram mangrove environment, data on qualitative and quantitative distribution of flora and fauna were collected for 3 seasons during 1998-1999. **Fig.12** Indicate percentage of each group. Previous studies have revealed occurrence of more number of organisms as recorded from this mangrove region. The number of species observed in each group is given below.

Group	No. of species
Phytoplankton	109
Zooplankton	68
Seagrasses	3
Seaweeds	9
Mangroves	14
Benthos	114
Fishes	15
Birds	57

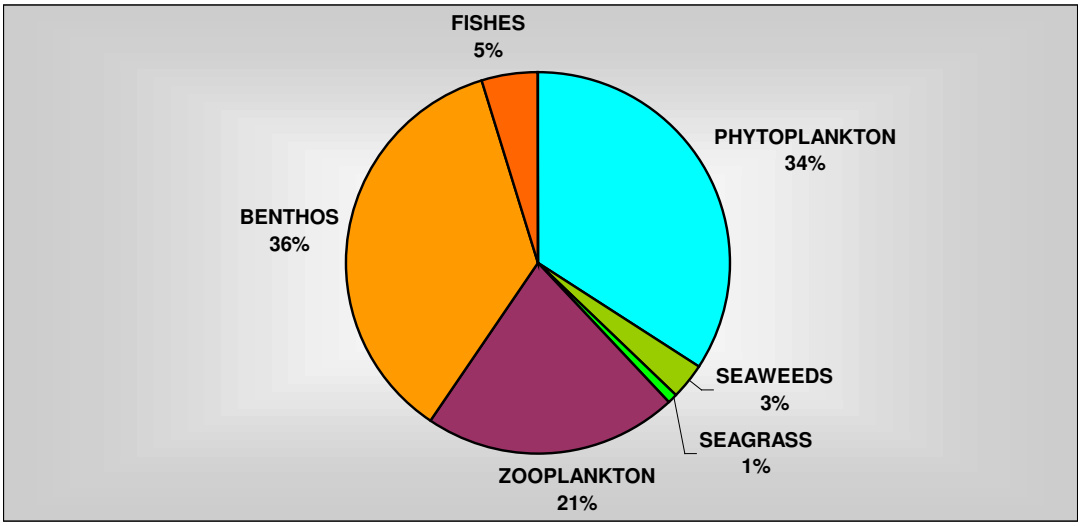


Fig. 12 - Percentage of species occurrence of aquatic flora and fauna in Pichavaram mangrove during 1998-1999

Phytoplankton

Phytoplankton as the primary producers form a vital source of energy. They are the basis of life as they initiate the food chain. Species composition and community structure of phytoplankton are very important from the ecological point of view. A total number of 109 species of phytoplankton were recorded. 93 species were observed in mangrove zone, while 64 species only were observed in neritic zone.

Group	June '98	October '98	April '99
Bacillariophyceae	36	64	31
Cyanophyceae	3	4	4
Dinophyceae	4	11	5
Chlorophyceae	0	0	6
Total	**43**	**79**	**46**

Zooplankton

Zooplankton is a vital link in the food chain, as it forms food for the secondary consumers in the pelagic food chain. A total number of 68 species of zooplankton were recorded. Copepods formed the dominant group followed by rotifers, cyclopoids, tintinnids, etc. 65 species were recorded in mangrove zone while 60 species were recorded in neritic zone.

Group	June '98	October '98	April '99
Species	48	31	30
Larvae	4	8	4
Total	**52**	**39**	**34**

Benthic Animals

Benthic organisms play a vital role in food chain by feeding on detritus or filter feeding or by preying upon other organisms. The benthic organisms belonging to the following major groups were represented in the samples. They are nematodes, polychaetes, crustaceans and molluscs. A total of 114 species of benthic organisms were observed of which 95 species were recorded from mangrove zone, while only 80 species were recorded from the neritic zone.

Group	June '98	October '98	April '99
Annelids	17	18	11
Arthropods	30	37	14
Molluscs	20	11	9
Nematodes	14	9	5
Total	**81**	**75**	**39**

The distribution of phytoplankton, zooplankton and benthic organisms was studied in relation to the different zones where they were recorded. The zones were delineated as freshwater zone, mangrove zone and neritic zone based on the sampling locations. The results show that more number of species was observed in mangrove zone than the other zones.

Zones (Sampling points)	Phytoplankton	Zooplankton	Benthos
Freshwater zone	78	59	80
Mangrove zone	93	65	95
Neritic zone	64	60	80
Total	**109**	**68**	**114**

Seaweeds / Seagrasses

Marine macroalgae or seaweeds are found to grow in intertidal and subtidal regions of the seacoast. Some seaweeds are edible and some are used as manure. Algin, agar-agar and fine chemicals are extracted from seaweeds. Seaweeds and seagrasses are ideal nursery grounds for young ones of various organisms. They serve as sediment traps besides stabilising bottom sediments and improving water clarity by acting as a filter system. Seven species of seaweeds belonging to Chlorophyta (5 species) and Rhodophyta (2 species) were recorded. Three seagrass species of *Halophila* (2 species) and *Halodule* were observed.

Fishes

Mangroves are considered as important habitats for fishes since they offer shelter, food and protection from predators. 15 species of fishes were observed. Mullet is the dominant species among fishes.

Mangrove Plants

10 species of mangroves representing 6 families and 4 species of salt marshes belonging to a single family were recorded during the present study. According to IUCN categorisation, out of 14 species, 10 are endangered, 3 are vulnerable (*E. agallocha, R. mucronata, A. indicum*) and 1 is at lower risk near threatened (*S. brachiata*). The list of species in the order of relative dominance and the IUCN status is given below.

No.	Species	IUCN Status (Nationally)
1.	*Avicennia marina*	Endangered
2.	*Suaeda maritima*	Endangered
3.	*Avicennia officinalis*	Endangered
4.	*Suaeda monoica*	Endangered
5.	*Rhizophora mucronata*	Vulnerable
6.	*Rhizophora apiculata*	Endangered
7.	*Excoecaria agallocha*	Vulnerable
8.	*Bruguiera cylindrica*	Endangered
9.	*Ceriops decandra*	Endangered
10.	*Aegiceras corniculatum*	Endangered
11.	*Acanthus ilicifolius*	Endangered
12.	*Arthrocnemum indicum*	Vulnerable
13.	*Lumnitzera racemosa*	Endangered
14.	*Salicornia brachiata*	Lower risk-Near Threatened

Rhizophora species are taller than other species. Salt marsh species (*Arthrocnemum indicum, Salicornia brachiata, Suaeda maritima* and *Suaeda monoica*) are present in core mangroves, indicating nature of soil as hypersaline.

Extinct and Rare Species

Kandelia candel and *Bruguiera gymnorrhiza* reported from this mangrove in 19th century have become extinct. *Xylocarpus granatum* has also become extinct now. *Sonneratia apetala*, which was once abundant (Caratini et al., 1973) and *Rhizophora lamarckii* (now known as *Rhizophora annamalayana* Kathiresan), a rare species, are reported to be near extinction (Kannupandi and Kannan, 1998).

New Species

Rhizophora annamalayana, a new species has been described as a hybrid between *R. apiculata* and *R. mucronata* (Kathiresan, 1995a). Previously this species was called as *R. lamarckii*, a hybrid between *R. stylosa* and *R. apiculata* (Muniyandi and Natarajan, 1985). But *R. stylosa* is not recorded in Pichavaram (Kathiresan, 1995b).

Birds

Pichavaram mangrove ecosystem attracts a number of true migratory and local migratory birds. Favourable season for the visit of birds is from September to April every year and the peak population could be observed between November and January. Shallow water area with high density of macrobenthos serve as excellent feeding grounds for the birds. Macrobenthos form staple diet for shore birds. Common occurrence of piscivorous birds (members of Ardeidae and Laridae) is due to occurrence of many species of fishes in plenty which form their diet. In the food web, egrets, herons, storks, gulls, terns and raptors hold top position owing to their habit of feeding on fishes. As many as 57 species of birds were recorded during the present study.

Significance of Pichavaram

The health of the ecosystem is indicated by its biodiversity. The increased number of species of phytoplankton, zooplankton and benthic animals observed in the mangrove zone rather than neritic zone, indicates that mangrove zone is more productive.

Considering the rich biodiversity observed in Pichavaram mangrove area, observing the extinction of few mangrove species, and that Pichavaram mangroves serving as nursery, feeding, breeding and nesting habitat for many species of fishes, shrimps, birds, etc, it is imperative that there is a need for conservation of mangrove. Causes of changes in or degradation of mangroves must be known for effective conservation plan.

Activities in Pichavaram Mangrove

The villages surrounding the Pichavaram Mangroves and the employment status and income level of the population are given below:

Village	Fishing (Person(s))	Unemploy-ment	Income (Upto Rs.3000) (Person(s))	Income (Upto Rs.3001 – 6000) (Person(s))	Income (Upto Rs.6001 - 12000) (Person(s))
Mudasalodai	98	243	37	29	30
T.V.S.Pettai	292	Nil	342	Nil	Nil
Nadu Mudasal Oodai	45	118	22	5	19
M.G.R. Nagar	279	183	239	40	Nil
Muzhukkuthurai	105	324	126	5	Nil
Pillumedu	18	33	1	15	6
Killai	407	1063	179	283	91
Kannagi Nagar	21	29	8	10	3
Chinnavaikkal	58	117	12	42	31
Kalaignar Nagar	168	94	110	50	51
M.G.R.Thittu	164	411	122	42	Nil
Koolaiyar	73	186	53	20	6
North Mudasal	139	356	50	47	57

The personnel engaged in other categories mostly include those in fresh fish trade. This clearly indicates that the villagers are depending upon the backwaters and mangroves to meet their livelihood. The details of fishing and tourism activities are given below:

Fishing

About 147 species of fishes are recorded from the Pichavaram area. Of this, 74 species are marine forms and 64 species are brackish water forms. Total catch of fish is around 200 tonnes/year. Mullets are the dominant fishes captured. *Metapenaeus monoceros, M. dobsoni, Penaeus indicus* and *P. monodon* are the dominant species among shrimp. Crafts such as catamaran and dugout canoes and gears such as small seine net, push net, scoop net, cast net, crab traps, etc, are used for fishing. Local fishermen report that fish and shrimp catch has been declining since the past few years.

Tourism

In late 1970s, the scenic beauty of Pichavaram mangroves has attracted movie makers to shoot their films in the shallow waterways. Through the movies, Pichavaram has become a tourist place. With the advent of tourist flow, the Tamilnadu Tourism Development Corporation (TTDC) has also announced this place as a tourist spot and listed it in state's tourist map from 1985 onwards. TTDC is maintaining cottages, dormitory and restaurant for tourists. About 500-1000 tourists visit Pichavaram every day.

Aquaculture

Aquaculture of shrimps is carried out in about 40 ha area, around Pichavaram. Traditional and semi-intensive type of aquaculture is practised. Species of *Penaeus* are cultured in aquafarms. No mangrove area has been converted for aquaculture.

Causes of degradation / changes

Now knowing that areal extent of mangroves has changed over years and that various human activities are going on in the Pichavaram mangrove environment, analyse of changes have been made using GIS. Chapter 8 gives details of degradation / changes that have occurred in Pichavaram mangrove. The possible causes of changes are discussed below:

Aquaculture

Even though area under aquaculture increased significantly in 1998 compared to 1987, the aquaculture areas are far away from the mangroves. It is also noted that no mangrove area has been converted for Aquaculture (**Fig.13**). Further the discharges from the aqua farms did not contain biodegrading substance, which affect the water quality of the area.

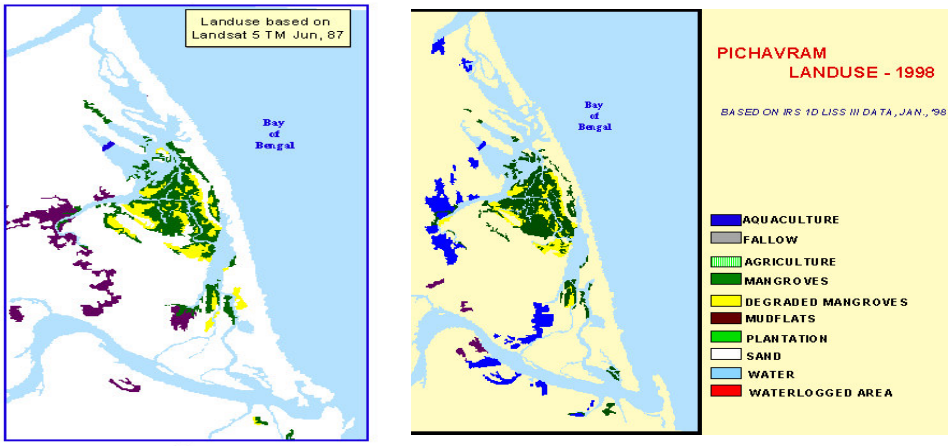


Fig. 13 - Areas of aquaculture around the mangrove

Water Quality

Important water quality parameters such as salinity, dissolved oxygen, pH, nutrients and heavy metals monitored for 3 seasons were well within the normal limits and do not play significant role in causing degradation. Water quality data also do not indicate any significant contamination due to release of wastewater from aquafarms and other land-based sources.

Thus, neither water quality nor recent development of aquaculture farms around mangrove seem to have caused mangrove degradation. Use of mangrove for fuelwood and fodder seems to be an important factor causing degradation. Another important factor observed was insufficient tidal flushing to interior / elevated areas, where soils have become hypersaline and devoid of vegetation.

Role of Socio-economics

Decrease in mangrove area could be attributed to large scale felling by human activity and grazing of cattle. Mangrove vegetation is traditionally known for fodder for the cattle and the trees as timber and fuel for households. Discussion with local people and officials revealed that usage of mangrove for fuel has been greatly reduced. Though large scale felling has been reduced to a great extent, illicit felling is still continuing on a miniscule level in the dense interior areas (**Fig.14**). Data on population of cattle in villages around Pichavaram mangrove indicate that cattle grazing may be a possible factor for mangrove degradation (**Fig.15**). Field visits confirmed that grazing by cattle is going on in the peripheral areas of mangroves.

Fig. 14 - Tree felling in Pichavaram

Fig. 15 - Cattle grazing mangrove areas

Integrated Management actions with GIS

Increase in mangrove area between 1987 and 1998 could be due to the efforts taken by Tamil Nadu Forest Department (**Fig.16**). Trenches were made by Tamil Nadu Forest Department, which enhance flushing of tidal waters to some extent into the interior areas. The Department also took up afforestation measures. Water exchange is required for the growth of mangroves.

Fig. 16 - Afforestation

Fig. 17 - Manmade canals as a part of afforestation measure

Water circulation in the mangrove creeks and swamps is an essential factor for growth of mangroves as well as dispersal of mangrove seeds and larvae of fishes and shrimps and transport of nutrients from mangrove to coastal waters. Therefore, reduced tidal flushing along with gradual siltation of interior mangrove areas may be a causative factor for degradation / further propagation of mangrove areas. Field studies on water circulation in mangrove fringed tidal creeks showed that peak velocities in the creek can exceed 1m/s, while in the mangrove forest the speed rarely reaches 0.07 m/s (Wolanski et al, 2000). The complex currents are steered by topography of mangrove and vary spatially and temporally. The mangrove swamp is inundated only in the highest tides. There is also a large vertical shear of the currents that is due to bottom friction preferentially slowing down the bottom waters. These gradients can be different in the mangroves and in the creek especially at ebb tide when strong currents can prevail in the creek while the swamp water is nearly stagnant. The lateral trapping phenomenon controls the flushing of mangrove-fringed tidal creeks. During the dry season and in the absence of surface or ground water fresh water inflow and due to evaporation and evapotranspiration, most mangrove creeks become hypersaline. Hypersaline soils lead to stunted growth of the mangrove plants and create bare saline soil areas.

Discussion with the fishermen also revealed that the tidal inundation in the mangroves has been decreasing due to frequent bar mouth closure at Chinnavaikkal point (northeast of mangrove connecting to Bay of Bengal) and that there is a decline in fish catch in the recent years.

As stated earlier, to contain degradation of mangroves in Pichavaram, Tamilnadu Forest Department and M.S.Swaminathan Research Foundation (a Non Governmental Organisation) have made trenches in some areas to enhance flushing of tidal water. However, to increase water spread area (enhance tidal flushing) detailed hydrodynamic study in the mangroves is required particularly to know the areas having suitable substratum, which do not receive adequate sea/estuarine water. Development of hydrodynamic model based on accurate scientific data such as bathymetry, currents and tides, along with field surveys for elevation are required to be done to identify the areas, that need dredging to increase water flow and trenching to increase access. Such a model when integrated with GIS will provide accurate information on possible extent of water penetration in each area in the mangroves which help in determining exact locations for dredging.

Conclusion

GIS helped in analysis of changes in the Pichavaram mangrove over theyears. The CHIS serves as a baseline database for spatial and non spatial data and information, which could be updated. This Information system can be useful as a tool for decision-makers to monitor the changes in future and take appropriate management actions, taking into consideration the rational utilisation of the resources.

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