

A study on the diversity and management of Pondicherry mangroves

FINAL
Project report

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Report Submitted to the
**Department of Science, Technology and Environment
Government of Pondicherry**
2005

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CITATION:

Saravanan, K.R. 2005. 'A study on the biodiversity and management of Pondicherry mangroves'. Report submitted to the Department of Science, Technology and Environment, Government of Pondicherry, India. 58pp.

ACKNOWLEDGMENTS

I duly acknowledge Prof. Anisa Basheer Khan, Department of Ecology and Environmental Sciences, Pondicherry Central University, Pondicherry, for her kind appreciation and supervision of this project report. Thanks are due to Department of Science, Technology and Environment, Government of Pondicherry, for the sanction of Grant-in-aid fund. I profoundly thank and kindly acknowledge the youth, key informants from the surrounding villages, all members of REEF and all other individuals who have contributed in various ways for the completion of this research project.

Principal Investigator

(K.R. SARAVANAN)

PROJECT SUMMARY

This one year project (2004-2005) is aimed to document the biological diversity of existing mangrove and to formulate strategic management plan for mangrove development in Pondicherry. 23 mangrove and mangrove associated vegetation and 80 diverse animals identified are: molluscs, crustaceans, pisces and aves at the study area. This study also acknowledge several observations made around this mangrove ecosystem during the study period. The detrimental and developmental activities engaged around this mangrove and their consequent impact on the well being of this mangrove ecosystem have been documented. To foster future development of Pondicherry mangrove ecosystem, a strategic management plan is formulated under three different management approaches. Emphasis on action oriented management in terms of nursery development, public / community participation, education, empowerment dissemination of information and project appraisal is discussed in detail.

FOREWORD

The 'unique' mangrove ecosystem, acclaimed both ecologically and economically important, bridging the land with the sea, involves very complex processes. These mangroves provide shelter grounds, breeding grounds, spawning grounds, nursery grounds for fish, shell fish, crabs and to a vast variety of organisms; grounds for stocking kernel; produce enormous amounts of detritus, protein rich food for organisms; are buffers against cyclonic winds, storm surge; minimizes flooding, deluge, erosion.....a bounty of valuable resources.

Regrettably, since a long time these natural assets faced cumulative negligence and arbitrary exploitation. However, behind the dark clouds of indiscriminate exploitation, the realization that this continued misuse damages not only the environment but also man - as has been recently witnessed during December, 2004 Tsunami- forms the silver lining.

French Institute, Pondicherry, contributed several publications on the wealth of mangroves, with Blasco (1975) reporting on Pondicherry mangroves in particular. This project report leads the way in projecting the ecological dynamics of the exclusive Pondicherry mangrove ecosystem in addition to the current biological diversity. It highlights the task of research, development, plantation, restoration, protection and integrated management through the knowledge systems of scientists, educationists, policy makers, NGOs, industries and the indigenous people who nurture decades of cultures evolved and shaped around the mangroves. Pondicherry mangrove ecosystem, one of the pristine mangrove forests in India has 23 species of mangrove and associated flora along with 80 diverse fauna as per this report, indicating a rich biological diversity.

Department of Science, Technology & Environment, Government of Pondicherry deserves commendation for encouraging a scientific study on the 'biodiversity and management of Pondicherry mangroves' through the funding this project. Pondicherry coast has withstood the impact of December, 2004 Tsunami, through the successful establishment of the planted mangrove seedlings, and we look forward to DSTE, Govt. Pondicherry, to make aware, to engage and to develop mangroves Pondicherry coastline.

Dr. Anisa Basheer Khan

INTRODUCTION

Much of the world's wealth of biodiversity is found in highly diverse coastal habitats. Coastal ecosystems such as estuaries, wetlands and mangrove forests contain significant diversity and are highly valuable for coastal communities. The coastal zone of India endowed with a very wide range of coastal ecosystems such as estuaries, lagoons, mangroves, backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs is characterized by unique biotic and abiotic properties and processes. Mangrove ecosystems command intensive attention among the coastal ecosystem due not only to their peculiar habitat characteristics but also due to their rich biodiversity. However the anthropogenic pressure often leading to neglect of the ecosystem and its surroundings culminate into a critical status of many coastal environments. Mangroves are the most threatened, more so throughout the tropical developing countries of the world.

Mangroves situated in tropics and the sub-tropics of the world consist of forest ecosystems growing under brackish water conditions the seashore. Mangroves interacting effectively with aquatic, inshore, upstream and terrestrial ecosystems support a diverse flora and fauna of marine, freshwater and terrestrial species. Interaction of mangroves with the physical environment is the basis for both species richness as well as the distribution of diverse animals in that ecosystem. These ecosystems are among the most productive ecosystems of the world, both floral and faunal. They constitute a nursery for many pelagic fish and crabs, that grow to maturity in the open sea. Biodiversity in mangrove is further enhanced as many species of fishes, crustaceans and birds either use or depend on this ecosystem during different stages in their life cycle.

Mangroves, situated at the confluence of the land and the open sea, mostly at river mouths and around lagoons with brackish water, protects the coastline against strong wave action, sand erosion and winds. But threats faced by the mangroves mainly by human activities being a continuous process, has resulted in annual mangrove loss globally to more than 1% annually. This destruction is a severe threat to the faunal and floral

biodiversity in these areas, eliminating sources of food and income for many local population. Recent natural disasters like Tsunami attenuate and as well attracts attention to the protective these environments which falling under the category of sensitive coastal area which protected many lives.

India has 2.66% of the world's mangroves and among them about 57% are found on the East Coast.. The east coast is endowed with the world's largest mangrove forest, the Gangetic Sunderbans in West Bengal which has 30 of 50 true mangrove species. Reports that freshwater reaching mangroves which are situated on the East Coast of India has considerably reduced, due to the diversion at the upstream areas are available. Similarly, total area of the mangrove wetlands, the amount and periodicity of freshwater flow, the tidal amplitude also show declination towards south from north and these extreme variations in environmental conditions is affecting the biological wealth. In Tamil Nadu coast, mangrove forests exists at Pichavaram and in Muthupet areas. Extensive scientific research covering all aspects has been carried out about these two mangrove ecosystems and published. However data available on the existence and importance of Pondicherry mangroves has been very much limited. Prioritizing assessment studies through this preliminary study on the existing biodiversity helps to understand the wealth and well being of Pondicherry mangroves.

OBJECTIVE OF THE STUDY

The present study aims to document two very important aspects on the existing Pondicherry mangrove ecosystem. The first is on the biodiversity and other is on management of mangroves at these study sites. Details of the objectives are:

- **Mangrove biodiversity**

Identification and documentation of the existing flora and macrofauna to prepare a biodiversity index for Pondicherry mangroves. The output is expected to supplement enough data for Regional or National Biodiversity Inventory related programs.

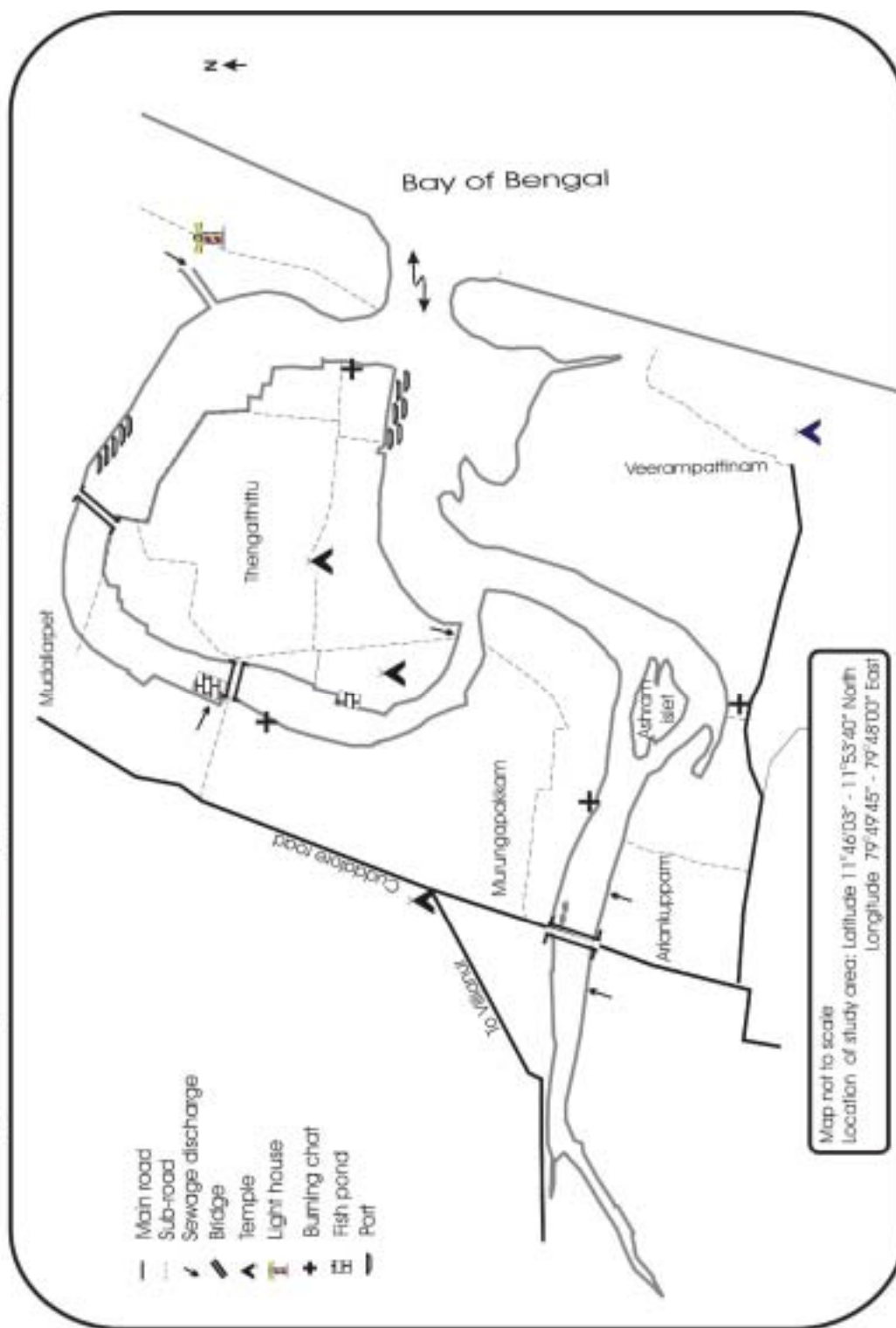
- **Mangrove management**

Documentation of the management activities undertaken so far in order to formulate a strategic management plan to foster future development and sustainability of Pondicherry mangroves.

STUDY AREA DESCRIPTION

Geographically the study area is lying within the boundaries of latitudes 11°46'03" to 11°53'40" North and longitudes 79°49'45" to 79°48'00" East. It is encircled by three villages viz. Ariankuppam, Murungapakkam, Veerampattinam and two islets namely Thengaithittu and Ashramthittu. The mangrove exists as a fringing vegetation distributed along the sides of Ariankuppam estuary / backwaters. Though the water way is a tributary of the river Gingee, for the last many years no freshwater reaches into this mangrove area except the municipal and agricultural discharges. This tide-dominated estuary opens into the Bay of Bengal on the Coromandal coast. The tidal amplitude averages to 20-70cm and differs accordingly to the lunar period, reaching its maximum during the northeast monsoon. The climate is sub-humid ranging with 65-75% relative humidity and with an average temperature of 28.8°C. The annual rainfall reaches to 1200mm with an average of 105mm. The soil salinity in this mangrove area ranges from 20-39g/kg. The villages nearby, ways to access into different mangrove locations and some legendary features of the study area has been provided in separate (Figure 1).

Figure 1. Map shows the villages, landmarks and accessibility to the study site.



METHODOLOGY

The areas where mangrove and mangrove associated vegetation is existing around Ariyankuppam backwater in Pondicherry region is first identified and documented. The area of the study interest is traced out with the help survey maps of the villages - Ariyankuppam, Thengaithittu and Murungapakkam - obtained from the Department of Survey and Land Records, Government of Pondicherry. By regular field visits the ways to access into different locations around the waterway was drawn. Several copies of this map was reproduced and used for the demarcation of inundated areas and coverage of mangrove and mangrove associated vegetation. The extent of tidal inundation, distribution of mangroves and mangrove associates at different localities were measured (approximately) and plotted in separate maps. In addition, the general geo-morphological, topographical and ecological features were also observed and recorded for preliminary assessment to attain basic knowledge about the habitat's environmental settings. All the recorded, plotted features were digitized and fed into computer to obtain a Cartographic map.

Biodiversity Assessment

For the assessment of present biodiversity status, the mangroves, mangrove associated vegetations, fishes, crabs, prawns, bivalves, gastropods and birds existing around the study area were considered for identification. The mangrove and mangrove associated vegetation were plucked during their flowering seasons for prompt identification. The fishes, prawns, crabs and mollusks were collected from the local fishermen who undertake regular fishing around the study area. Sampling the above mentioned fauna is made throughout the study period. Birds were observed using binocular (8X50). Identifications are made almost at the field itself and for confirmation, the specimens were brought to the lab for thorough screening. The identification manuals of Tomlinson (1986), Kathiresan (2000), FAO fish identification sheets (1994), Salim Ali (1972) were used for confirmation of collected specimens. All the specimen collected for identification are photographed and presented in separate plates.

Management Assessment

The assessment of management activities that had been so far undertaken like development, monitoring, protection etc were made by regular monitoring during the study period in addition to thorough literature survey. Research articles published and reports on the growth and development of Pondicherry mangroves were collected. The concerned departments, institutions and organizations, currently involved in developing mangrove were contacted and discussed about their proposed management activities.

Based on our observation and other documentations, different management activities so far undertaken for the development of this mangrove ecosystem and their subsequent result have been projected. Similarly, a strategic plan for future development of this mangrove ecosystem reinforcing different management activities was formulated and presented.

MANGROVE BIODIVERSITY

Richness in biological diversity of species and ecosystem functions in the coastal environment initiate for the production of resources and services essential to human communities. Conservation of biodiversity is therefore an important component in managing economically valuable living resources of these peculiar coastal ecosystems. According to the Biodiversity Convention Act, biodiversity is the basis for human survival and encompasses all life forms, ecosystems and ecological processes, acknowledging the hierarchy at genetic, taxonomic and ecosystem levels. At taxonomic level, the biodiversity of Pondicherry mangrove ecosystem includes both the diverse flora and fauna. The identified flora and macro fauna during the study period have been presented below in details:

FLORA

True mangroves

Seven true mangrove floral species belonging to 3 family were identified around the study area. A classified list of true mangrove vegetation identified is presented in Table 1 and in Plate 1. Among these seven species two viz. *Rhizophora apiculata* and *Rhizophora mucronata* were introduced to this ecosystem under social forestry scheme in 1995 by Department of Agriculture with the help of Center for advanced studies in Marine Biology, Annamalai University. The species *Avicennia marina*, is the dominant mangrove found in almost all the sites and is more dense at the entrance to Thengaithittu village. The next dominating species is *Bruguiera cylindrica* found distributed along Murungapakkam and Ariankuppam sites and limited to Thengaithittu and Veerampattinam villages. The other species *Bruguiera gymnorhiza* is only restricted to the small creek near the Ashram islet. *Acanthus ebracteatus* and *Acanthus illicifolius* are both found in Murungapakkam, Ariankuppam and Thengaithittu villages.

Mangrove Associates

About 16 mangrove associated floral species belonging to 12 families (Table 2, Plate 2) were identified along the inundated and the adjacent regions at the study area. The species such as *Aleuopus lagopodius*, *Clerodendrum inerme*, *Pongamia pinnata*, *Sesuvium portulacastrum*, *Suaeda maritima* and *Thespesia populnea* are present at all the sites where as the others are limited in their distribution to different sites.

Both the true mangrove and mangrove associate vegetation covers to nearly 30 ha (5.6%) of the total inundated area. The distribution of both the mangrove and mangrove associates at the study site was jointly presented (Figure 2.) as a picture of 'Green Cover'.

Figure 2. Map showing the distribution of both the mangroves and mangrove associates at the study site.

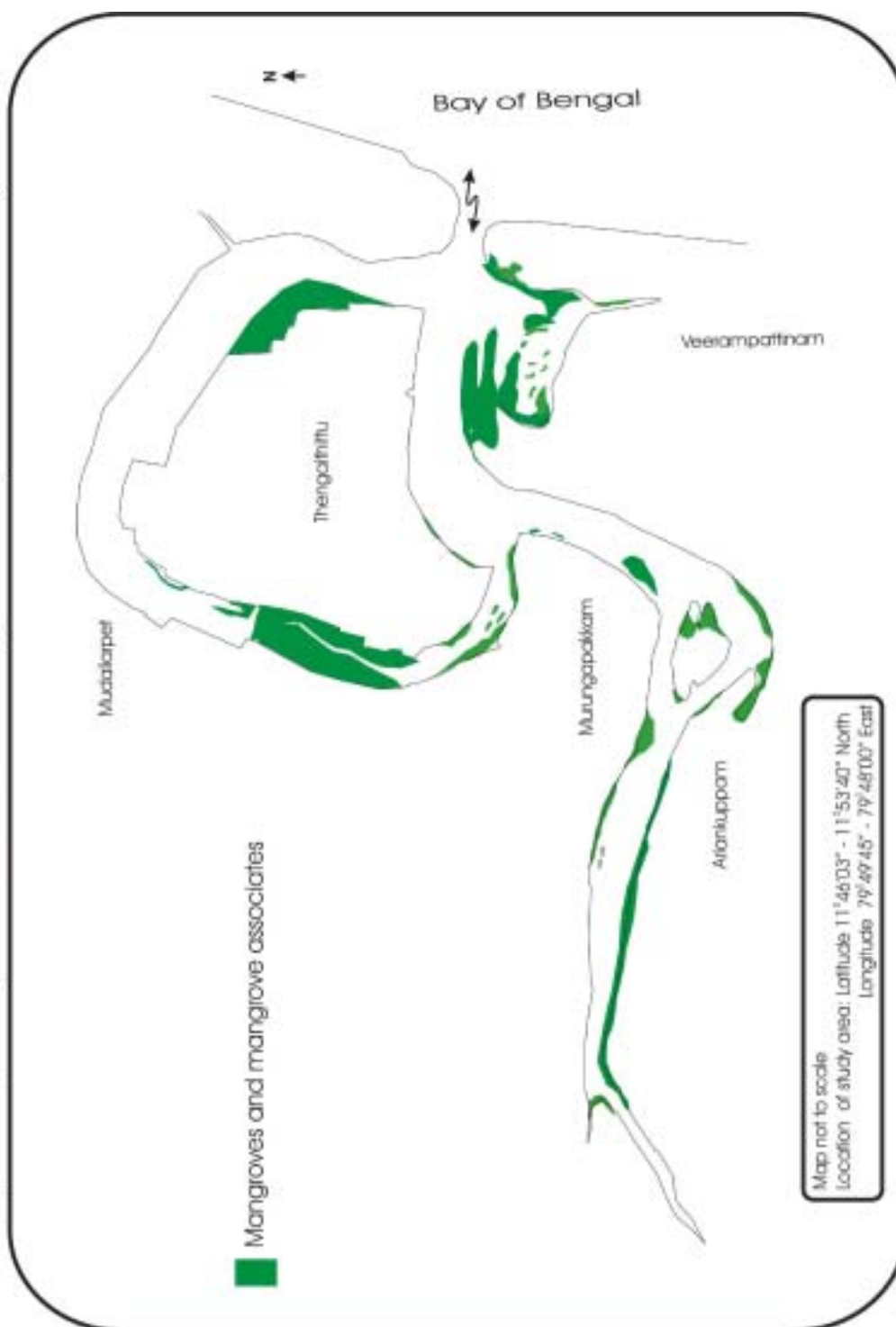


Table 1: True mangrove species identified in the mangroves of Pondicherry.

Class	Order	Family	Species
Dicotyledonae	Personales	Acanthaceae	<i>Acanthus ebracteatus</i> Vahl.
Dicotyledonae	Personales	Acanthaceae	<i>Acanthus illicifolius</i> L.
Dicotyledonae	Labiales	Avicenniaceae	<i>Avicennia marina</i> (Forsk.) Vierh
Dicotyledonae	Myrtales	Rhizophoraceae	<i>Bruguiera cylindrica</i> (L.) Bl.
Dicotyledonae	Myrtales	Rhizophoraceae	<i>Bruguiera gymnorrhiza</i> (L.) Lamk.
Dicotyledonae	Myrtales	Rhizophoraceae	<i>Rhizophora apiculata</i> Blume
Dicotyledonae	Myrtales	Rhizophoraceae	<i>Rhizophora mucronata</i> Poir

Plate 1. True mangroves of Pondicherry.



Acanthus illicifolius



Acanthus ebracteatus



Avicennia marina



Bruguiera cylindrica



Bruguiera gymnorrhiza



Rhizophora apiculata



Rhizophora mucronata

Table 2: Mangrove associate species identified in the mangroves of Pondicherry.

Class	Order	Family	Species
Monocotyledoneae	Graminales	Poaceae	<i>Aluoropus lagopoides</i> (L.) Trin
Dicotyledoneae	Theales	Clusiaceae	<i>Catophyllum inophyllum</i> L.
Dicotyledoneae	Leguminales	Caesalpinaceae	<i>Caesalpinia bonduc</i> (L.) Roxb.
Dicotyledoneae	Verbanales	Verbenaceae	<i>Clerodendrum inerme</i> Gaertn.
Dicotyledoneae	Leguminales	Fabaceae	<i>Derris scandens</i> Benth.
Dicotyledoneae	Leguminales	Fabaceae	<i>Deris trifoliata</i> Lour.
Dicotyledoneae	Solanales	Convolvulaceae	<i>Ipomoea pes-caprae</i> (L.) Sweet
Dicotyledoneae	Pandanales	Pandanaceae	<i>Pandanus tectoris</i> Kuntze
Dicotyledoneae	Leguminales	Leguminosae	<i>Pongamia pinnata</i> (L.) Pierre
Dicotyledoneae	Apocynales	Asclepiadaceae	<i>Sarcobolus carinatus</i> Wall.
Dicotyledoneae	Caryophyllales	Aizoaceae	<i>Sesuvium portulacastrum</i> L.
Dicotyledoneae	Chenopodiales	Chenopodiaceae	<i>Suaeda maritima</i> (L.) dumort.
Dicotyledoneae	Chenopodiales	Chenopodiaceae	<i>Suaeda monoica</i> Forsk. Ex. Gmel
Dicotyledoneae	Chenopodiales	Chenopodiaceae	<i>Suaeda nudiflora</i> (Willd.) Moq.
Dicotyledoneae	Malvales	Malvaceae	<i>Thespesia populnea</i> Solander ex Correa
Dicotyledoneae	Apocynales	Asclepiadaceae	<i>Wattakaka volbulis</i> Stapf.

Plate 2. Mangrove associates of Pondicherry.



Aleuropus lagopoides



Derris scandens



Calophyllum inophyllum



Derris trifoliata



Ceasalpenia bondoc



Ipomoea pes carpa



Clerodendrum inerme



Pandonus tectorius

Plate 2. Mangrove associates of Pondicherry (contd.)



Pongamia pinnata



Suaeda monoica



Sarcolobus carinatus



Suaeda nudiflora



Sesuvium portulacastrum



Thespesia populnea



Suaeda maritima



Wattakaka volbulis

Molluscs

Totally 15 species of mollusks were identified at the study site. Four of them belong to the class Bivalvia (Table 3 and Plate 3) and the rest 9 species belong to the class Gastropoda (Table 4 and Plate 4). *Crassostrea madrasensis* (Oyster) forms larger beds in Veerampattinam, Thengaithittu and in some location at Ariankuppam. *Meretrix casta* (Clam) and *Perna viridis* (Green mussel) were seen abundant at Veerampatiinam, especially near the mouth of the estuary. Other mollusks are found distributed at all the sites. The oyster green mussel and the clam are being collected as and when available in large quantity for their meat by the local population. Similarly, among gastropods, the *Vittina coromandaliana* are also been collected and marketed for making ornaments.

Crustaceans

15 species of decapod crustaceans are identified at the study area- 5 are penaeid prawns (Table 5 and Plate 5) and 9 are brachyuran crabs (Table 6 and Plate 6). All the prawns belongs to one family, Penaeidae, the crabs belongs to totally 5 family. All the prawns and some crabs such as *Scylla serrata*, *Portunus pelagicus* and *Portunus sanguinolentus* were considered as of fishery importance. During rainy season, the availability of prawn were abundant. The Tiger prawn (*Penaeus monodon*) were the target species caught during rainy season.

Pisces

39 species of fishes belonging to 24 family under 7 orders have been identified in the water ways at the study area. 77 percent of the fishes identified at the study area belong to the order Perciformes (Table 7 and Plate 7). *Gerrus filamentosus*, *Leiognathus bindus*, *L. brevisrostris*, *L. splendens*, *Mugil cephalus*, *Oreochromis mossambicus*, *Siganus canaliculatus*,

S. javus, *Sillago sihama*, *Terapon jarbua* and *Terapon puta* were observed in abundance throughout the study period. The presence of species like *Boleophthalmus boddarti*, *Lutjanus argentimaculatus* and *Scatophagus argus* is an indicator of the productive well being of mangrove ecosystem especially with *Lutjanus argentimaculatus* (Mangrove snapper) which occurs only in mangrove waters. Commercially important species such as *Ambassis commersoni*, *Atule mate*, *Chanos chanos*, *Etroplus suratensis*, *Johnius carutta*, *Kathala axilaris*, *Lutjanus russelli*, *Monodactylus argenteus*, *Nibea maculata* and *Sillago sihama* occur seasonally and are caught by fishermen in this mangrove waters.

Aves

Totally 14 species of birds have been observed and identified at this mangrove site during the study period. They belongs to 10 families under 4 orders (Table 8, Plate 8). Observation of species such as *Anastomus oscitans* (Open-billed stork), *Himantopus himantopus* (Black-winged stilt), *Nycticorax nycticorax* (Night heron), *Phalacrocorax niger* (Little cormorant) and *Podiceps ruficollis* (Little grebe) was rare and could be seen only for few days during the study period. Both the species of sand pipers are very common, especially *Tringa stagnatilis* observed often in larger flocks. The other species belonging to the family Ardeidae are found to roost on *Avicennia* and *Rhizophora* trees. As far as this mangrove ecosystem is concerned there is no poaching or shooting of these wetland birds but for some other anthropogenic disturbances.

The classified list of species and photographs of the diverse biological flora and macrofauna identified in the mangroves of Pondicherry during the study period have been presented below:

Table 3. Classified list of bivalves identified in Pondicherry mangroves.

Class	Order	Family	Species
Bivalvia	Arcoida	Arcidae	<i>Anadara rhombea</i> Born, 1780
Bivalvia	Ostreina	Ostreidae	<i>Crassostrea madrasensis</i> Preston, 1916
Bivalvia	Veneroida	Veneridae	<i>Meretrix casta</i> Chemnitz, 1782
Bivalvia	Mytiloida	Mytilidae	<i>Perna viridis</i> Linnaeus, 1758

Plate 3. Bivalves identified at Pondicherry mangroves.



Anadara rhombea



Crassostrea madrasensis



Meretrix casta



Perna viridis

Table 4. Classified list of gastropods identified in Pondicherry mangroves.

Class	Order	Family	Species
Gastropoda	Pulmonata	Ellobiidae	<i>Cassidula nucleus</i> Gmelin, 1791
Gastropoda	Caenogastropoda	Potomididae	<i>Cerithiidea cingulata</i> Gmelin, 1791
Gastropoda	Caenogastropoda	Potomididae	<i>Cerithiidea obtusa</i> Lamarek, 1822
Gastropoda	Pulmonata	Ellobidae	<i>Melampus cylonicus</i> Petit
Gastropoda	Caenogastropoda	Nassariidae	<i>Nassarius jacksonianus</i> Quoy and Gaimard, 1833
Gastropoda	Neritopsina	Neritidae	<i>Neritina violacea</i> Gmelin, 1791
Gastropoda	Caenogastropoda	Assiminidae	<i>Sphaerassiminea minuta</i>
Gastropoda	Caenogastropods	Potomididae	<i>Telescopium telescopium</i> Linnaeus, 1758
Gastropoda	Archaeogastropoda	Neritidae	<i>Vittina coromandeliana</i> Sowerby, 1832

Plate 4. Gastropods identified at Pondicherry mangroves.



Cassidula nucleus



Cerrithidea cingulata



Cerrithidea obtusa



Melampus cylonicus



Nassarius jacksonianus



Neritina violacea



Spaerassiminea minuta



Telescopium telescopium



Vittina coromandeliana

Table 5. Classified list of prawns identified in Pondicherry mangroves.

Class	Order	Family	Species
Crustaceae	Penaeoidea	Penaeidae	<i>Metapenaeus monoceros</i> Fabricius, 1798
Crustaceae	Penaeoidea	Penaeidae	<i>Penaeus indicus</i> Milne Edwards, 1837
Crustaceae	Penaeoidea	Penaeidae	<i>Penaeus semisulcatus</i> De Haan, 1844
Crustaceae	Penaeoidea	Penaeidae	<i>Penaeus monodon</i> Fabricius, 1798
Crustaceae	Penaeoidea	Penaeidae	<i>Penaeus merguensis</i> De Man, 1888

Plate 5. Prawns identified at Pondicherry mangroves.



Metapenaeus monoceros



Penaeus indicus



Penaeus semisulcatus



Penaeus monodon



Penaeus merguensis

Table 6. Classified list of crabs identified in Pondicherry mangroves.

Class	Order	Family	Species
Crustaceae	Decapoda	Gecarcinidae	<i>Cardisoma carnifex</i> Herbst, 1794
Crustaceae	Decapoda	Charybidae	<i>Charybdis lucifera</i> Fabricius, 1798
Crustaceae	Decapoda	Grapsidae	<i>Metapograpus maculatus</i> Milne Edwards, 1853
Crustaceae	Decapoda	Grapsidae	<i>Neopisesarma tetragonum</i> Fabricius, 1798
Crustaceae	Decapoda	Portunidae	<i>Portunus pelagicus</i> Linnaeus, 1758
Crustaceae	Decapoda	Portunidae	<i>Portunus sanguinolentus</i> Herbst, 1783
Crustaceae	Decapoda	Portunidae	<i>Scylla serrata</i> Forsskal, 1755
Crustaceae	Decapoda	Grapsidae	<i>Sesarma brockii</i> De Mann
Crustaceae	Decapoda	Ocypodidae	<i>Uca lactea annulepis</i> Milne Edwards, 1852

Plate 6. Crabs identified at Pondicherry mangroves.



Cardisoma carnifex



Charybdis lucifera



Metapograspus maculatus



Neoepisesarma tetragonum



Portunus pelagicus



Portunus sanguinolentus



Scylla serrata



Sesarma brockii



Uca lactea annulepis

Table 7. Classified list of fish species identified in Pondicherry mangroves.

Class	Order	Family	Species
Osteichthyes	Perciformes	Ambassidae	<i>Ambasis commersoni</i> (Cuvier, 1828)
Osteichthyes	Siluriformes	Ariidae	<i>Arius jella</i> (Day, 1877)
Osteichthyes	Perciformes	Carangidae	<i>Atule mate</i> (Cuvier, 1833)
Osteichthyes	Perciformes	Gobiidae	<i>Boleophthalmus boddarti</i> (Pallas, 1770)
Osteichthyes	Perciformes	Carangidae	<i>Carangoides chrysophrys</i> (Cuvier, 1833)
Osteichthyes	Gonorhynhiformes	Chanidae	<i>Chanos chanos</i> (Forsskal, 1775)
Osteichthyes	Perciformes	Serranidae	<i>Epinephelus tauvina</i> (Forsskal, 1775)
Osteichthyes	Perciformes	Cichilidae	<i>Etroplus suratensis</i> (Bloch, 1790)
Osteichthyes	Perciformes	Leiognathidae	<i>Gazza minuta</i> (Bloch, 1797)
Osteichthyes	Perciformes	Gerridae	<i>Gerrus filamentosus</i> (Cuvier, 1829)
Osteichthyes	Perciformes	Sciaenidae	<i>Johnius carutta</i> (Cuvier, 1830)
Osteichthyes	Perciformes	Sciaenidae	<i>Kathala axilaris</i> (Cuvier, 1830)
Osteichthyes	Perciformes	Leiognathidae	<i>Leiognathus bindus</i> (Valenciennes, 1835)
Osteichthyes	Perciformes	Leiognathidae	<i>Leiognathus brevirostris</i> (Valenciennes, 1831)
Osteichthyes	Perciformes	Leiognathidae	<i>Leiognathus splendens</i> (Cuvier, 1829)
Osteichthyes	Perciformes	Lutjanidae	<i>Lutjanus argentimaculatus</i> (Forsskal, 1775)
Osteichthyes	Perciformes	Lutjanidae	<i>Lutjanus madras</i> (Valenciennes, 1831)
Osteichthyes	Perciformes	Lutjanidae	<i>Lutjanus russelli</i> (Bleeker, 1849)
Osteichthyes	Perciformes	Monodactylidae	<i>Monodactylus argenteus</i> (Linnaeus, 1758)

Table 7. Classified list of fish species identified in Pondicherry mangroves (contd.)

Class	Order	Family	Species
Osteichthyes	Perciformes	Mugilidae	<i>Mugil cephalus</i> (Linnaeus, 1758)
Osteichthyes	Anguilliformes	Muraenesocidae	<i>Muraenesox bagio</i> (Hamilton-Buchanan, 1822)
Osteichthyes	Perciformes	Sciaenidae	<i>Nibea maculata</i> (Schneider, 1801)
Osteichthyes	Perciformes	Cichlidae	<i>Oreochromis mossambica</i> (Peters, 1852)
Osteichthyes	Scorpaeniformes	Platycephalidae	<i>Platycephalus indicus</i> (Linnaeus, 1758)
Osteichthyes	Perciformes	Haemulidae	<i>Plectorhinchus gibbosus</i> (Lacepede, 1802)
Osteichthyes	Perciformes	Haemulidae	<i>Plectorhinchus vittatus</i> (Linnaeus, 1758)
Osteichthyes	Perciformes	Scatophagidae	<i>Scatophagus argus</i> (Bloch, 1758)
Osteichthyes	Perciformes	Leiognathidae	<i>Secutor insidiator</i> (Bloch, 1797)
Osteichthyes	Perciformes	Siganidae	<i>Siganus canaliculatus</i> (Park, 1797)
Osteichthyes	Perciformes	Siganidae	<i>Siganus juvenis</i> (Linnaeus, 1766)
Osteichthyes	Perciformes	Siganidae	<i>Siganus lineatus</i> (Valenciennes, 1847)
Osteichthyes	Perciformes	Sillaginidae	<i>Sillago sihama</i> (Forsskal, 1775)
Osteichthyes	Clupeiformes	Engraulidae	<i>Stolephorus indicus</i> (van Hasselt, 1823)
Osteichthyes	Clupeiformes	Clupeidae	<i>Tenulosa toli</i> (Valenciennes, 1847)
Osteichthyes	Perciformes	Terapontidae	<i>Terapon jarbua</i> (Forsskal, 1775)
Osteichthyes	Perciformes	Terapontidae	<i>Terapon puta</i> (Cuvier, 1829)
Osteichthyes	Tetraodontiformes	Tetraodontidae	<i>Tetraodon nigroviridis</i> (Marion de Proce, 1822)
Osteichthyes	Clupeiformes	Engraulidae	<i>Thyrsa mystax</i> (Schneider, 1801)
Osteichthyes	Perciformes	Mullidae	<i>Upeneus vittatus</i> (Forsskal, 1775)

Plate 7. Mangrove fishes of Pondicherry.



Ambassis commersoni



Arius jella



Atule mate



Boleophthalmus boddarti



Carangoides chrysophrys



Chanos chanos



Epinephelus tauvina



Etroplus suratensis



Gazza minuta



Gerrus filamentosus

Plate 7. Mangrove fishes of Pondicherry (contd.).



Johnius carutta



Kathala axilaris



Leiognathus bindus



Leiognathus brevirostris



Leiognathus splendens



Lutjanus argentimaculatus



Lutjanus madras



Lutjanus russelli



Monodactylus argenteus



Mugil cephalus

Plate 7. Mangrove fishes of Pondicherry (contd.).



Muraenesox bagio



Nibea maculata



Oreochromis mossambicus



Platycephalus indicus



Plectorhinchus gibbosus



Plectorhinchus vittatus



Scatophagus argus



Secutor insidiator



Siganus canaliculatus



Siganus javus

Plate 7. Mangrove fishes of Pondicherry (contd.).



Siganus lineatus



Sillago sihama



Stolephorus indicus



Tenulosa toli



Terapon jarbua



Terapon puta



Tetradon nigroviridis



Thyrsa mystax



Upeneus vittatus

Table 8. Classified list of birds identified in Pondicherry mangroves.

Class	Order	Family	Species
Aves	Gruiformes	Rallidae	<i>Anaeronis phoenicurus</i>
Aves	Ciconiiformes	Ciconiidae	<i>Anastomus oscitans</i> Boddaert
Aves	Coraciiformes	Alcedinidae	<i>Alcedo atthis</i> Gmelin
Aves	Ciconiiformes	Ardeidae	<i>Ardea cinerea</i> Linnaeus
Aves	Ciconiiformes	Ardeidae	<i>Ardeola grayii</i> Sykes
Aves	Ciconiiformes	Ardeidae	<i>Egretta garzetta</i> Linnaeus
Aves	Ciconiiformes	Accipitridae	<i>Haliastur indus</i> Boddaert
Aves	Ciconiiformes	Recurvirostridae	<i>Himantopus himantopus</i> Linnaeus
Aves	Ciconiiformes	Ardeidae	<i>Nycticorax nycticorax</i> Linnaeus
Aves	Phalacrocoracidae	Phalacrocoracidae	<i>Phalacrocorax niger</i> Vieillot
Aves	Ciconiiformes	Podicipedidae	<i>Podiceps ruficollis</i> Salvadori
Aves	Charadriiformes	Charadriidae	<i>Vanellus indicus</i> Boddaert
Aves	Charadriiformes	Scolopacidae	<i>Tringa stagnatilis</i> Bechstein
Aves	Charadriiformes	Scolopacidae	<i>Tringa hypoleucos</i> Linnaeus

Plate 8. Birds identified at Pondicherry mangroves



Amaurionis phoenicurus



Anastomus oscitans



Alcedo atthis



Ardea cinerea



Ardeola grayii



Egretta garzetta



Haliastur indus



Nycticorax nycticorax



Himantopus himantopus



Phalacrocorax niger



Podiceps ruficollis



Vanellus indicus



Tring stagnatilis



Tringa hypoleucos

BIODIVERSITY RICHNESS

All together 23 species of flora and 80 species of macrofauna were identified from this pristine Pondicherry mangrove ecosystem. However the figure is too small when compared to that of the other nearby mangrove ecosystems like Pitchavaram, it is quite considerable as rich in biological diversity if Pondicherry is concerned. Previous records are of reports on fishes and true mangrove species and not on all the macrofauna of this mangrove ecosystem. About 72 finfish species were previously reported by Rajendiran and Kathiresan (2002), about 11 mangrove flora including its associates have been reported by Ramasamy (2003). Another report by NBSAP (2002) prevails the presence of 13 mangrove flora including mangrove associates around Pondicherry region. The present investigation and this project report form is the first kind recording all the diverse flora and fauna including existing macrofauna of Pondicherry mangrove ecosystem.

The presence of such a biologically diverse life-forms especially in this recently emerged ecosystem, indicates the productive well being of this pristine Pondicherry mangrove ecosystem. With only 7 true mangrove vegetation, it harbours / supports about 80 documented macrofauna indicates that this ecosystem as highly productive to nourish or / and provide shelter to a wide variety of organisms. However, this report lags behind in filling the species index of soil and water invertebrates. In addition to these, more biologically diverse micro-organisms present there are yet to be identified and documented.

THREAT TO BIODIVERSITY

Basically threat to the survival of the existing diverse flora and fauna of this mangrove ecosystem originates from various facets. The lack of awareness among fishermen community and intensive development activities undergoing at the mouth of the estuary since a very long time are the most prominent among them.

As mentioned before fishermen catch most of the commercially important fish species from this mangrove waterways because they fetch high price in the local markets. It is unavoidable that the juveniles and non-commercially important fish species also get

entangled in their nets while fishing. These juveniles and other species are killed immediately and thrown away instead of releasing them alive back into the water. If released and caught again in the net, these fishermen think in terms of their difficulty in sorting them out again from the net.. As for the molluscs, after removal of the meat, the shell of the oysters and the other molluscs are heaped outside the shallow water. This results in clearing the bed and reduces the opportunity for the settlement of the spat in bed. Only few shells are marketed for lime preparation. It is similar case with crab fishing, where they dig-out in near holes to reach out for the crabs. While digging the nearby mangrove roots and growing saplings get uprooted, which actually nourish quite a good mollusc population. All the observations were very frequently encountered throughout the study period. However these activities may not show a visible loss currently in biodiversity, but it is quite substantial, considering the small and pristine nature of this Pondicherry mangrove ecosystem.

Since the opening of mouth of the estuary in 1993, dredging is frequently engaged to allow large fishing boat for landing. It is intensified since 2000 once the site is marked to build a new fish landing port east of Thengaithittu. The mouth being narrow, experiences frequent sand accretion due to wave action and as such results in regular dredging at the mouth. The dredged sand is dumped near where the mangroves are, which over a period covers the area and almost destroys the plants and other organisms living within. In addition these dredging activities hinder those species which enter this mangrove during high tides. It was evidenced that nearly 45% of fish species were not been observed during this study period from the previously reported 72 species. Many of these species still persist in large near by mangrove-Pitchavaram. Pondicherry mangrove being small harbors less species with small population. There is often a high risk for their existence due to a change in habitat management or by natural disasters. It is anticipated that the loss in biodiversity by next year would be little higher due to the impact by the recent Tsunami (26th December 2004). The mangrove area at the southern Thengaithittu and eastern Murungapakkam is dredged and deeply excavated near the mangrove patches to drag out the damaged large boats which were carried away by the Tsunami waves. The excavation of this large area causing changes in hydrology in turn impact changes in soil quality at these sites. It may be beneficial or detrimental to the mangrove vegetation and its biological diversity can be witnessed in future.

Based on the current existing conditions at this Pondicherry mangrove ecosystem, its growth is not only visualized and also anticipated to attract more diverse species. The possibility is much higher if the formulated management activities are implemented in time before it get too late.

MANGROVE MANAGEMENT

Ecosystem management can be defined as activities dealing with development, research and protection measures towards an ecosystem to enhance the services they provide to mankind and for its own betterment as well. Overwhelmingly, all management activities towards an ecosystem are often engulfed with several events which have direct relationship with each other. Documentation of such activities so far held in and around Pondicherry mangrove ecosystem will clear the way to formulate appropriate management strategy. Thorough literature survey and observations made us to bring out such typical measures taken on and are given below:

DEVELOPMENTAL ACTIVITIES

Plantation of mangrove species is one of the well noticeable developmental activities continuously engaged since 1995-96. Plantation of mangrove vegetation was previously carried out by two Government departments and by one non-governmental organization.

Plantation by the Department of Agriculture:

The two important Red mangrove species viz. *Rhizophora apiculata* and *Rhizophora mucronata* were introduced very recently, in 1995-96 by Prof. Kathiresan of Center for Advanced Studies in Marine Biology, Annamalai University, Parangipettai. The plantation of these mangrove species was actually undertaken for a social forestry scheme funded by the Department of Agriculture, Government of Pondicherry. The plantation was made at both the sides of Murungapakkam bridge and fenced to protect (Plate 9A). Since 2001, both these species of *Rhizophora* are well established and species producing viable propagules.

Plate 9



A. *Rhizophora* planted near Murungapakkam bridge.



B. Mangrove area destroyed in Tsunami.



C. A mangrove nursery maintained by REEF.



D. One year old *Rhizophora* saplings raised in nursery.

Plantation by the Department of Forest and Wildlife:

In December 2003, the Department of Forest and Wildlife, Govt. of Pondicherry carried out plantation of the same *Rhizophora* species at Thengaithittu, just opposite to the Government fish farm. However, the planted seedlings dried out in a few months due to unfavorable soil conditions and frequent anthropogenic disturbances. The planted site was highly influenced by anthropogenic disturbance especially, during bait collection for fishing.

By the year 2004, Department of Forest and Wildlife, Govt. of Pondicherry sanctioned a project to Center for Advanced Studies in Marine Biology, Annamalai University to undertake plantation of mangrove species around Thengaithittu village. *Avicennia* and *Rhizophora* species were again planted at the eastern and southern part of Thengaithittu. From the growth and survival of the planted mangroves, it is clear that *Rhizophora* are better established than *Avicennia*. Our observations on the less survival of *Avicennia* at the planted sites reveals that the site was not suitable for these species of mangrove unless favourable changes have been initiated in the hydrology (by channelization). Unfortunately, even the well established *Rhizophora* seedlings have been destroyed due to the impact of Tsunami on 26th December, 2005 (Plate 9B).

Plantation by Non-Government Organization:

Since 2002, a Non Governmental Organization by name Regional Ecology and Environmental Federation (**REEF**) has been involved in developing Pondicherry mangrove ecosystem through intensive plantation at appropriate sites. This NGO is actually formed by research students and youth volunteers from the surrounding villages. Mangrove nurseries were set up (Plate 9C&D) by them at two ideal sites by introducing new techniques to raise mangrove seedlings that can adapt to stress during transplantation. By June 2003, they undertook plantation of the two *Rhizophora* species raised by them (in the nurseries) involving the school children and youth of Thengaithittu and Arianakupam villages and plantation was from Ashram islet to south of Thengaithittu village (Plate 10A&B). Continuous monitoring the growth and survival of the planted seedlings by them resulted in successful establishment of more than 75% of the mangrove planted. This achievement of

Plate 10



A. REEF members, youth and students of local village involved in mangrove plantation.



B. Well grown *Rhizophora* saplings planted near Ashram islet.



C. Planted mangrove saplings withstood the Tsunami effect.



D. Fishing vessel construction near mouth.

REEF was due to the site assessment made by trained research students of Pondicherry University under the guidance of supervising faculty Prof. Anisa B. Khan, of Department of Ecology and Environmental Sciences, Pondicherry University. By 2004, they could successfully extend mangrove plantation adjacent to the previously planted sites. Tsunami destroyed about 20% of the mangrove seedlings planted in November, 2004 by simple uprooting, but surprisingly one year old *Rhizophora* which were planted during 2003 withstood the effect (Plate 10C). Presently, the NGO has more than 10,000 mangrove seedlings ready for plantation which have been carefully raised in their nurseries. The **REEF** members are in high spirit with more than 75% of successful plantation that withstood Tsunami impact and are proud to get reported in newspapers. Since then they have intensified their efforts on mangrove plantation along Pondicherry coastline.

Other site development activities:

Very close to the plantation sites, building of harbour for fish landing besides the construction of a bridge are the two important works observed here. To allow larger fishing vessels to load down their fishery catch the mouth of the estuary is regularly dredged (Plate 10D). It is a continuous process and becomes more intensive if the mouth is blocked by sand accretion. As has been mentioned earlier this dredging activity leads to drive out many aquatic fauna from the site. Recently, with the proposal to construct a new bridge for prompt transportation west of Murungapakkam bridge, construction works have been started and to facilitate this work the well grown mangroves were clear felled. The disturbance and the subsequent loss to the existing mangrove and biological diversity is inevitable at least until the work gets completed.

RESEARCH ACTIVITIES

After plantation in 1995-96, the growth and survival of the planted mangroves were monitored by Center for Advanced Studies in Marine Biology, Annamalai University, and published a research article in 2002. Since 2000, this site was studied thoroughly for its ecological dynamics and current status for a Ph.D. program and a Thesis is submitted to Pondicherry University. Currently also the study area is regularly monitored by the NGO,

REEF for the growth of planted mangroves and in raising nurseries and planting the seedlings.

PROTECTION ACTIVITIES

As mentioned earlier, planted mangroves are protected by fencing around them. People are not aware of any legal ordinance to protect the existing mangrove since 2003. However, owners of agricultural lands have protected them since mangrove acts as fence for their crops. Only very recently a board insisting on the protection of mangrove was put up by the Department of Forests and Wildlife at the entrance to Thengaithittu, just opposite to the Government estuarine fish farm. The NGO taught the importance of the mangrove to the school children who disturb mangrove area while playing around the waterways, and who since then have stopped.

Formulation of strategic management plan to foster future development and sustainability of Pondicherry mangroves

Formulation of a strategic management plan with an approach to mangrove development and sustainability of the mangrove ecosystem is essential. The conservation of mangrove biodiversity and management plans may focus on several individual aspects such as historical ecology of the site, present environmental conditions and other development cum conservation activities. But the sustainability and well being of an ecosystem largely depends on management of three major factors such as Conservation, Resource and Research at the study area. Thus it is obvious here to elaborate and discuss the management activities under these three facets. Similarly management activities required for betterment of this ecosystem can also be considered under two typical approaches viz. management on scientific and social insight. Both these approaches are directly related to each other and will not work successful in isolation.

With all the observations made around Pondicherry mangrove ecosystem, and after analyzing the records and documents, several management plans under different managing actions were driven out to foster future development and sustainability of this mangrove ecosystem. Given below are some of the most important management plan to be undertaken for future development of the mangrove ecosystem under three different approaches:

CONSERVATION MANAGEMENT

The management approach on conservation of biological diversity largely depends on plantation of mangrove and protection given to them.

Habitat management

- o Habitat management can be achieved under two aspects such as habitat creation and habitat restoration. Basically habitat creation means the creation of a new habitat by developing new sites and linking remaining patches. Similarly, restoration refers to

modification of existing semi-natural habitat. As far as this mangrove concerned both these aspects would be quite applicable.

- o Communities that depend on these coastal resources face the long-term challenge for their sustenance and after natural disasters in terms of economic crisis. Belated responses in initiating remedial action after the damage becomes apparent seen almost in all developing countries. Unfortunately, inspite of very rich scientific information action is usually initiated only after irreversible destructive damage has occurred. In view of this critical situations, adoption of several preventive measures is essential to protect the coastal communities and for the conservation of these coastal ecosystems. Such defensive measures should cover all the activities of past, present and future, bearing in mind that the cumulative impact of these activities should not affect the existing biodiversity in any way. To achieve these goals best option is to set up nursery at the site itself.

Need for establishment of a nursery at or adjacent to the study site.

- o Raising the mangrove seeds for transplantation in a nursery established at the site or adjacent to it is ideal for successful mangrove establishment once planted. Especially since the two species viz. *R. apiculata* and *R. mucronata* have grown luxuriantly, restoring the habitat by planting these two species would result in better development in future. Introduction of other species belonging to the same family in between the spaces which have not yet been colonized will also result in better development.
- o Transplanting saplings grow well than inserted propagules straight into the soil. Several techniques became applicable while raising and planting mangroves in nursery. Raising the seeds in a nursery at or adjacent to the site selected for plantation reduces seedling mortality after transplantation. Soil from the selected site can be used for potting.

- o Planting native or already successfully established species would be much appreciable than introduction of a new species. Altering the site by the introduction of strange species newer to the site will be detrimental to the already established species. Thus, the species selection for plantation should be based on the existing environmental conditions at the site rather than trying to impose new species.

Involving public participation for mangrove plantation program.

- o Mangrove management plans often collapse especially because they fail to fulfill the very basic requirement like involvement and aspirations of local communities. Priority should be given to participation of local rural people in mangrove-based plantation activities. Emphasizing on education to encourage them to the level of self management, so that they involve themselves in protecting their own resources.
- o Involving local people reduces the information gap between local wisdom and knowledge systems available at different levels. Information about the coastal policies, coastal protection rules, laws and coastal acts can be taught to the inhabitants and to those involved in planting. Thus making local community literally well aware of coastal policies, leads to better management achievement.
- o Involving local people like the fishermen community, women self-help groups, youth clubs etc. motivates them to protect. Participants involved in plantation should be sufficiently cohesive, dedicated and have a common intention to plant and protect. Encouraging to plant mangroves in adjacent inundated areas initiates them to safeguard the mangrove with self intention.
- o To achieve best biodiversity conservation objectives, improved methodologies towards raising seedlings, maintaining and transplantation techniques should be practiced. Consequently, effective research projects and extension programs, which are critical and focusing public participation in conservation and management of these typical coastal ecosystem should be given highest priority.

RESEARCH MANAGEMENT

The management approach in the aspect of research encompasses different studies to be undertaken by the institution, departments and NGOs. An important early step in management is to understand the variation in the plant communities in relation to ecological and environmental factors with current and past developmental activities. Particularly understanding the aspects such as changes in hydrology, sedimentation, sewage input etc. are useful to design and implement different management activities that can support rich biodiversity in future. Prior to management design and implementation it is necessary to conduct a detailed survey to identify and document the following of the site.

Assessment on historical ecology of the study area.

- o Analyzing historical ecology of this coastal area in combination with past recorded documents and present field evidence are more useful to understand why the area has this type of ecology and what made it to support the present vegetation types. Reports on this aspect for Pondicherry are lacking except for a report published in 1987 revealing that entire coastal area starting from Marakkanam to Cuddalore was once had rich mangrove vegetation. Blasco (1975) also made observation of existence of *Avicennina marina* as patches especially at the present study site and Kathiresan (2000) mentioned this study site as of degraded mangrove area. Thus to have details, an intensive study is needed on both pedological and paleontological view to obtain the settlement of alluvial sediments and pollen. The study result will adds more details regarding the existence of similar forest types (if any) that have had extensively established and disappeared. This will provide enough information to decide maintain or alter the ecosystem for future development.
- o Assessment on this aspect not only throws light on the study area but also that of the adjacent coastal belt. It provides details on the past environmental setting and its ecology. The information retrieved is helpful to interpret with present settings and to prepare better site management activities.

Studies on geomorphologic and environmental features.

- Studies on geomorphologic features including general topography of the study area, elevation, directions of the waterway, creeks etc should be mapped and analysed for preparation of suitable management action. Detailed assessment on all the environmental physicochemical characters of both the soil and water should be undertaken on regular basis. Preparation of site specific map based on soil and water quality helps tremendously while undertaking site assessment for mangrove plantation. Details on temperature, seasonal rainfall, humidity etc supplement the management scheme as well.
- Soil and water quality management is of utmost importance for any biological conservation issues. Managing an estuarine or inter-tidal area requires clear understanding of its soil and water qualities. Changing or altering site for development without basic understanding of these factors is likely to result in unexpected variation at both within the site and around it.
- In addition to the agricultural run-off, the flowing surface water from adjacent lands, municipal sewage which carries domestic waste water and industrial effluents also contribute major terrestrial water source for this habitat, leading to either nutrient-deficient or enrichment. Pollution may result from increased levels of both P as phosphates from sewage or detergents, and N as nitrates from agricultural runoff. Since there is no exact freshwater source from any stream or river, pollutants can accumulate rapidly due to low flow-through rates and results in spoiled soil and water quality and reflects in loss of biological diversity.
- Preparation of a hydrological map in conjunction with a topography direction of all flowing water; sedimentation, areas of temporary and permanent water, anthropogenic features that influence the hydrology such as drainage, sewage; inflow, outflow, vegetation types that indicate wet or dry conditions of site will supplement the management activities. It is important to identify the pollution problem (if any) and source by analyzing environmental and biological samples. It is inevitable to locate the point source of pollution especially in flowing municipal sewage and agricultural run-off.

- o Educating local volunteers to monitor changes in water like sudden color change in water, dumping of industrial wastes, incidents of fish death and to report such events immediately to the concerned Department officials will minimize the detrimental loss of biodiversity.
- o Other than soil and water qualities, general geo-morphology of the study area, its temperature and rainfall fluctuations, the site humidity and irradiance are also important environmental factors that determine the health of this Pondicherry mangrove ecosystem. The cyclonic events during monsoon, flood due to unusual heavy rainfall and unexpected natural disasters like Tsunami also have direct or indirect impact on the biodiversity of these coastal ecosystems.

Studies on anatomy, morphology and phenology of the existing mangroves.

- o Anatomy, morphology and phenological studies of the mangrove and mangrove associates of the study site provide more details on mangrove physiology, seasonal flowering and fruit setting. The details in their physiological adaptation under stress condition are of important research interest to understand evolutionary process. Information on flowering and fruit setting can be helpful to give protection in addition to set time for propagule collection.

Assessment on Vegetation structure and biomass production.

- o Studies on vegetation structure such as pattern of distribution, canopy cover, basal area, canopy height and biomass production including aboveground and below ground biomass at present conditions are needed to design future management plans.

Biological diversity assessment including micro-invertebrates etc.

- o Many soil invertebrates need infuriatingly specialized requirements. A simple task like clearing away dead wood, dead oyster bed, soil excavation, cutting a patch of herbs or clearing a ditch can be detrimental for such species. Thus short-term changes in these aspects may not affect the vegetation at large but can drive out the invertebrate from sites. A complete biodiversity status of the study area is a need the time. It should includes soil infauna, benthic meiofauna, other micro-invertebrates and if possible microbes too.
- o A state level database on existing biodiversity resources should be prepared. The database should be interactive with complete description and importance of existing flora and fauna. This biodiversity index should be disseminated to all concerned departments at local, regional and national level for updating.

Land use pattern around the ecosystem on economical insight.

- o Documentation of the existing agricultural lands, crops cultivated, management activities applied for better harvest is important to have insight on land use pattern. It also determines the nutrient enrichment and in turn the productivity of mangrove ecosystem.

Site assessment for mangrove plantation.

- o As mentioned earlier, assessing the site is very important to test whether it supports the mangrove to be planted. All the physicochemical characteristics of both soil and inundated waters is required. The site can be even slightly altered to suit and support the growth of newer mangrove species if the environmental data are interpreted correctly.

Monitoring growth and survival of transplants.

- o After plantation of mangrove species at suitable sites, regular monitoring is needed to record growth and survival. This includes the shoot length, number of nodes , internodes, number of leaves, leaf area etc. These observations supplement basic information on the mangrove growth performance at different locations. Continuous monitoring is essential at least for three consecutive months after transplantation. Details obtained at the end of third month exactly reflects the survival rate and the specificity of sites in supporting planted mangroves.

Monitoring activities at mouth.

- o Worldwide there are several studies which exhibit the impacts of developmental activities such as harbour development, bridge construction etc., on mangrove ecosystems. Construction and repairing of damaged vessels at fish landing harbour is a continuous and regular process and is more intensive after Tsunami. The wash-out from the fishing vessel spoils the water with oil and scum spreads to the near mangroves. This would in due course directly damage the vegetation and ultimately leads to biodiversity loss.
- o However port building is an important event in terms of coastal economy, the measures taken to maintain the depth at the mouth is very crucial to the aquatic animals. Discussions with officials at port would help to regulate the dredging activities in a specific manner that do not disturb the marine organisms.
- o It is important to have a clear understanding of how the developmental activities undergoing at the mouth benefit conservation of this habitat. To have a clear idea, dialogues with the engineers of port department and with officials of the fishery department should be helpful. All the activities should be thoroughly followed and any consequent changes observed in relation to it should also be documented. Documenting this would aid management events to employ immediately to deal with changes.

Total environmental impact assessment with regards to the developmental activities.

- o Continuous dredging at mouth, repairing of damaged fishing vessels near mouth and proposed bridge construction at Murungapakkam will definitely have direct impact on the loss of biological diversity. A Long-term study is thus needed to document the consequences of these detrimental activities.

Dissemination of research output to the concerned departments.

- o The important aspect in the failure of most management plans is lack of information exchange between the government departments and institutions. In many instances development cum management schemes lag behind due to incomplete exchange of information and non-cooperative attitude. Distribution of research details to all the departments and institution involved in developing mangroves coast line will confront the problems if any.

Conducting meetings with all stakeholders.

- o Integrated conservation cum development action is more likely to be successful if it fully involves local people and to secure their support and co-operation for implementation. Conservation agendas can be prepared by conducting meeting with key interest groups, so that they can act as conservation facilitators or strategic managers.
- o Conducting seminars, meetings and group discussions gathering research students, official research managers, volunteer social welfare groups, NGO officials etc. will clarify problems in implementing any management plan. This will help to coordinate any activity carried out for successful ecosystem management.

- o Departments, institutions and NGOs should create options to promote campaign that includes education programs, distribution of brochures, posters and media publicity and the like.

RESOURCE MANAGEMENT

This approach includes various events such as resource utilization, exploitation and protection given to the mangrove ecosystem for sustainable harvest.

Economic valuation and documentation of the resource users at community level.

- o To understand the importance of biodiversity for human development, there is an urgent need to evaluate the products that can be used, in addition to the ecosystem services for human development. An accurate valuation of biodiversity needs to consider the direct use values and the indirect use values, and to combine consumptive and non-consumptive use. The direct and indirect services provided at present status are very crucial to determine how this mangrove ecosystem benefits its user. Economic valuation of the potential resource such as fishery, timber etc. is needed at community level i.e., those who are utilizing and harvesting from this mangrove ecosystem.

Assessment on potential resource utilization and exploitation.

- o Other than economic valuation, it is essential to determine what typical resources are being utilized and to what extent they have been exploited. This is in regard to different fishery resources and their habitat destruction by the users.
- o Habitat loss is identified to be the main direct cause of species loss. Degradation of habitats through unsustainable harvesting of plants and animals have been recorded. Physical alteration of the habitat by different means may be the other reasons. Similarly, overexploitation is major threat to many species, leading to extinction.

For example, fish populations are overexploited especially, many juvenile and non-commercial fish species are more likely to be caught, but being unutilized are thrown away. This leads directly to loss of such species from these habitats.

- Mangrove resources and biodiversity have traditionally been undervalued, putting its resources at a lower priority level. Unregulated use of resources, increased demand for the resources and rapidly expanding coastal development makes mangrove resources at risk. Mostly all deleterious impacts on coastal biodiversity stem from ignorance and lack of understanding of the importance and how it gets affected. Primarily, uncaring attitude towards the nature, lack of basic insight towards importance and economic value of the existing resources are the main reasons that leads to many negative impacts on biodiversity and its conservation.
- Resource management decisions should be ecologically-based, conservation-driven and risk-averse. Specific management objectives and determined measures for progress towards sustainable fisheries should be developed. Similarly, projects should be encouraged for identification and prioritizing habitat protection and restoration.

On perception towards the existence of mangrove ecosystem and its importance.

- The most important study to be carried out for better mangrove management is on perception towards existence and importance by the local people. This helps to understand the specificity of the ecosystem and what insight they can get on emergence and existence of mangroves.

Educating school children and volunteer youths around.

- School children and youth volunteers who working for societal welfare can be involved to implement mangrove management plans by providing first inputs on the educating importance of mangroves on coastal areas.

Public awareness creation to protect existing ecosystem.

- o Successful implementation of mangrove management also lies on the awareness among the local people. Creating awareness towards its importance will make them protect mangroves by forming community organizations.

Conducting public hearing programs.

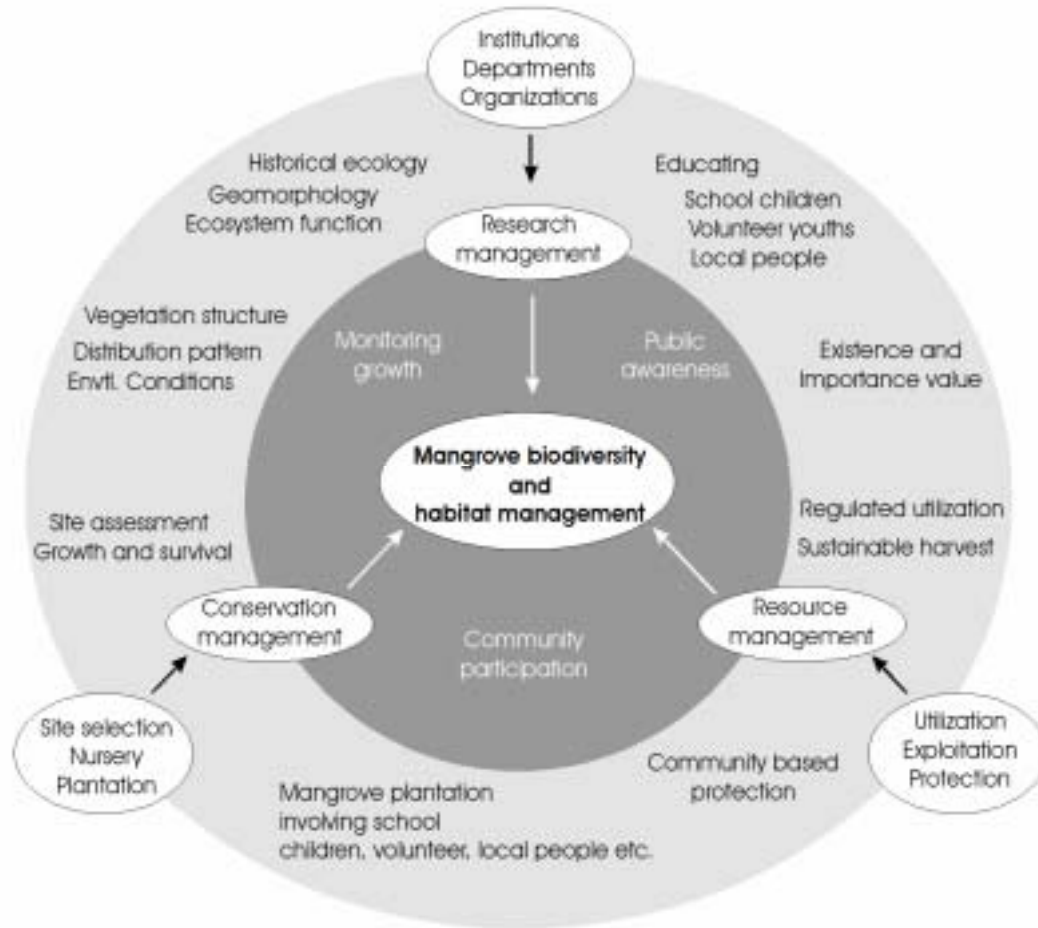
- o Celebrating events such as World Environment Day, World Forest Day by conducting competitions for school children and public, distribution of posters, brochures, pamphlets, stickers, labels etc. including in local language describing importance of mangrove helps to make the information reach to the maximum extent. Conducting audio-video shows in public also helps to disseminate the information as well. Wide publicity should be given through the distribution of booklets in local language. Resource persons should be invited to talk on various topics on conservation and biodiversity.

Integrating all management plans:

All the three management approaches are interrelated in a complex network. Good management practice is a culmination of many management actions. Integrating all the management options with the intention to implement and achieve specific goal for the betterment of this mangrove ecosystem will achieve highest biological diversity in near future.

However the central dogma is of management of biodiversity and mangrove habitat together, and it all depends on complex network of management actions. A network of events such as research, awareness, integration, dissemination etc. is presented in **Figure 3**.

Figure 3. Diagram illustrating network of actions involved for a better management of mangroves.



However the successful results of mangrove management are largely dependent on the natural processes like ecosystem adaptability and function. However, it is imperative here to consider as utmost than anything is the '**management of human factor**'. Because, human have long been a component of ecosystems and the interplay between biological processes. Human factors critically influence the outcomes of mangrove management projects. It is recognized that human involvement in causing degradation is as important as the natural determinants of the structure and function of the mangrove ecosystem in determining the success of a management project. For better management implementation and to have effective results, the human population must be viewed as an inherent part of the mangrove ecosystem. So the management practice should be more inclusive of local community participation and with each and every move of management plan benefiting them in someway for their sustenance as well.

To make realistic prognostication of the mangrove management in future, accuracy in the assessment of the present status is required. There is a clear need for much of the management to be experimental and certainly the need to document the consequences. Several research oriented studies are needed at this time to understand the current ecosystem functioning and integrity. For this is important to gain experience of the site prior to any management by studying thoroughly for at least a year.

From all above mentioned activities, management of this ecosystem can be best summarized as the following few guidelines below:

- By rapid assessment and documentation of the present status.
- By detailed study on physicochemical characteristic of the site.
- By the establishment of a field nursery and plantation involving community participation.
- By educating local people towards importance of existing ecosystem.
- By prioritizing the development cum management projects which involves community participation.

Sustainability of Pondicherry Mangrove Ecosystem, supporting a large number of biologically diverse flora and fauna is dependent on successful implementation on the network of management actions.

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